THE VISIBILITY OF RESEARCH

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The Visibility of Research

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Editors
Chris Jarrett | Kyoung-Hee Kim | Nick Senske

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INTRODUCTION

ARCC 2013: The Visibility of Research

The ARCC Architectural Research Conference provides an important venue for the exchange of ideas in architecture. ARCC brings disciplinary discussions into focus while making visible a wide range of research methods, modes of inquiry and insights for the architectural community. Globalization, rapid urbanization, sustainability and climate change, material and construction innovations, new digital media and visualization capability, cultural and social networking are but some of the issues motivating contemporary architectural research and thus the subjects of this conference.

The premise or provocation of ARCC 2013 is that architects are recognized more so for their role in the design of buildings and environments, and less so for their role in the production of knowledge. Yet we know the wide body of research that takes place in the discipline and profession advances the field through numerous means: by introducing new ideas, testing questions, defining methodology, developing technology and promoting critical discourse. How exactly research shapes design and the built environment, however, is not always clear. For many, its contributions remain all but invisible.

The theme of ARCC 2013 is visibility, in all its possible connotations. The goal of this year's conference is to interrogate the idea of visibility from a variety of perspectives to bring research itself into sharper focus. The Proceedings of ARCC 2013 presents a wide range of ideas and investigations. Inside are eighty-eight papers and twenty-seven poster abstracts. The original call for submissions was divided into seven categories, plus an open category. The intention is to bring visibility to the pertinent research subjects shaping the discipline of architecture today.

CONSTRUCTION - Innovations in materials and construction visualization. The proliferation of new technologies has enabled a plethora of new and hybrid materials to meet 21st century economic, programmatic, and environmental demands. Whether something newly found in nature or made in the lab, a growing body of research engages our material culture in creative and profound ways. What is the genesis and promise of these new materials? What is their purpose and what problems do they solve? How have computation and parametric modeling enabled the visibility of new forms of constructional possibilities and material conditions?

CULTURE - Making visible: new ideas, minor voices, and topics on the margins. Architecture has the capacity to record culture through a specific ordering of space, program and materials in a particular place and time. Dominant cultural paradigms are all around us. They make themselves visible, from civic institutions to the everyday spaces we occupy and live in. But what about the places and people we know little about? How does culture in the margins find place and meaning in our lives? What are the possibilities of giving voice to those who have less means to express themselves? Why are some cultures made more visible than others?

HISTORY - Maps, media, and models in architectural history. Arguably, the past is key to understanding the present. History has the capacity to affect us in wide-ranging ways. The expansion of new research methods and tools has uncovered new ways of understanding the world around us. What new forms of archival research are at work today? How has new media and mapping techniques constructed new histories never yet seen? What new or alternative models of history are being made visible and through what new research methodologies and technologies of inquiry? What is the role and value of history in a constantly changing, mediated environment?

PEDAGOGY - New Visions and Revisions in Architectural Education. The rapid technological changes of the past two decades have presented complex challenges to architectural education. A new generation of teachers has emerged who are schooled in the creative use of advanced technologies. How has the speed of information exchange, accelerated by digital technology, changed architectural education? What forms of interdisciplinary engagement are explored in schools of architecture? How have global urbanization, economic instability and climate change spurred a rethinking of design methodologies and the potential for expanded cross-disciplinary collaboration?

POLICY - Educating policymakers, practitioners, and the public. The dissemination of research beyond the boundaries of our discipline is central to making real and measurable impact in the lives of those who occupy our built environments. How does research visibly affect policy change? Who is our audience and how well do they understand what we do? What new strategies are at work to better educate the constituencies subject to our research? What new methods are employed to produce effective policy change? How well do we communicate with our audience, and how well do they understand, let alone support, the architectural research we undertake?

SUSTAINABILITY - Visualizing sustainability and performance in buildings. A range of concepts of sustainability have emerged over the past two decades. These concepts have powerfully reshaped the discourse of architecture, affecting pedagogy, curriculum, and research trajectories. How does visibility contribute to the understanding of sustainability? What innovative research methods are addressing the profession's ambitious carbon reduction goals? How have new computational tools and design methods influenced the discourse on sustainability? What types of building performance are being measured and how do such metrics influence architectural design?

URBANISM - Technology, connectedness, and the urban environment. Urban performance depends not only on the city's infrastructure but also on the availability and quality of knowledge communication and social infrastructure. How can new technologies be leveraged to improve the urban environment? What new types of public/private collaborations can empower cities and their communities through meaningful technology experiences that link education, urban development and community building? How does the growing importance of information and communication technologies shape the experience of the city?

These subjects are richly explored in numerous and unexpected ways by the authors in these proceedings. They help us reflect on various contemporary issues and dilemmas, from the social and environmental to the political and formal. What is the impact of this good work? What questions does it raise? What influence will it have at our home institutions? What affect will it have on future architectural research? Time will tell.

ARCC 2013 would not have been possible without the support and confidence of the ARCC Board of Directors, led by President Keith Diaz Moore. Special thanks are extended to Philip Plowright and Hazem Rashed-Ali for their early guidance and supporting documents. We'd like to also thank Ken Lambla, Dean of the College of Arts + Architecture at UNC Charlotte for his encouragement and unwavering support, as well as the faculty in the School of Architecture. Sheri Rice, Business Services Coordinator in the School of Architecture, provided extensive organizational and bookkeeping support, without which we would have found ourselves up all night trying to make the numbers work. Michele Wallace and Rachael Murdock provided unmatched administrative assistance.

This conference drew much interest, reaching nearly 300 abstract submissions. We are especially thankful to our Review Committee Members – all 100 of them! Behind the scenes, none of this would have been possible without the commitment of graduate student Emily Boone, who worked nearly daily on this project. Joshua Gerloff came to the rescue half-way through the process. Without their dogged data crunching and daily dose of young energy, we would have failed to meet the finish line. Finally, none of this would have been possible without the authors who made this happen. Their interest, energy, expertise, time and presence are gratefully appreciated.

Conferences provide the opportunity to share ideas, debate differences, meet new people, and learn from others. Bringing people together to exchange ideas is what it's all about. It's been our privilege to host ARCC 2013. If, collectively, as a group of scholars, designers and practitioners, we've been able to shed some new visibility on the subject of architectural research, both our own and others, then we've met our challenge.

Chris Jarrett, Chair
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CONSTRUCTION

Innovations in Materials and Construction

Perception is Reality:
Visibility in Architectural Lighting Research

Mary Ben Bonham

Miami University, Oxford, Ohio

ABSTRACT: How architects measure light is changing. Human perception of light is ostensibly the reason why spaces are illuminated, yet primary lighting guidelines used by architects measure how much light is falling on a surface, not the distribution of light to the human eye (Cuttle 2011). Recent lighting research related to human visual perception introduces new ideas that, while they challenge the status quo of lighting practice, build on decades of respected prior research. In this paper's case in point, researchers are developing new methodologies and tools to study luminance distribution in built environments (Inanici & Navvab 2006). The concept of studying luminance, or perceived light, instead of only illuminance has long been established in texts by leading lighting designers and researchers (Lam 1977, Boyce 2003, Steffy 2008). This paper aims to provide information on luminance distribution as a factor of emerging importance in the design of quality illuminated environments. To this end, it reviews the use of illuminance and luminance metrics in contemporary architectural lighting practice and research contexts, exposing the objective and subjective aspects of light that these terms measure. It finds that new tools that analyze luminance data from high dynamic range photography and digital simulation models are joined by new lighting knowledge dissemination platforms, together breaking down barriers that prevent architects from designing with luminance concepts. Examination of these research and knowledge tools reveals a shift to a cross-disciplinary, user-centered approach to architectural lighting where realities of human visual perception and surrounding physical contexts enjoy renewed attention.

KEYWORDS: Lighting, perception, practice, luminance, education

INTRODUCTION

Considering architectural lighting research, *visibility* has two concurrent connotations relevant to architectural practice. First, the Illuminating Engineering Society of North America (IESNA) defines visibility as "the quality or state of being perceivable by the eye (IESNA 2003, 192)." Human perception of light is ostensibly the reason why spaces are illuminated, yet primary lighting guidelines used by architects measure how much light is falling on a surface, not the distribution of light to the human eye (Cuttle 2011). Second, visibility in the sense of access to information is a desirable characteristic for the technical knowledge generated by lighting researchers about visibility, perception and related human factors. Many important findings about lighting are isolated in discipline-specific journals that are rarely referenced by architects. At the intersection of these visibility issues is the question of how research about human visual perception is causing innovation across all facets of the lighting design industry and subsequent reform to architectural practices related to lighting. The following discussion aims to emphasize the importance of lighting proficiency for architects, and to begin to explain the underlying split nature of lighting design research as it synthesizes objective and subjective components of light.

1.0 HOW MUCH LIGHT?

> The standards and recommendations that guide general lighting practice bear no sensible relationship to providing for human satisfaction (Cuttle 2011).

1.1 Dual approaches

The simple question architects may have about visibility and perception, "How much light?" begs a complex answer. A status quo or typical architect's response would likely be given objectively in terms of *illuminance* (measured in lux) to accommodate anticipated uses or perhaps in terms of *lighting power density* (watts per square meter), a metric that rectifies minimum illuminance levels with mandates for maximum energy consumption. A change to this line of thinking is afoot, however. Using both books and blogs to transmit the message, author and academic Kit Cuttle addresses a lighting profession that is in transition to a new way of thinking about lighting. The concepts of visibility and perception, so unified in the IESNA definition of visibility in the Introduction are divided when it comes to how different lighting professionals approach lighting design.

Cuttle categorizes two distinct approaches for determining light quantity and distribution as ‘best practices’ and ‘architectural’; he has taught both methods and clearly favors the latter as the way of the future.

The best practices approach sees task visibility as the purpose of lighting. This illuminating engineering method employs the illuminance unit of measurement to quantify the amount of light falling on a workplane. In 1979, IESNA refined the illuminance selection process to respond more to human factors such as knowledge of the space and occupant characteristics when determining target light levels. The Tenth Edition of the Lighting Design Handbook furthered refined the process to have more categories with finer steps while maintaining the emphasis on task visibility (DiLaura et al 2011). This method is most familiar to architects because it is codified in IESNA illuminance guidelines and the metrics of energy codes such as the International Energy Conservation Code (IECC).

The architectural approach focuses on appearance as the purpose of lighting, recognizing the role of human visual perception and room finishes in measuring whether lighting is adequate. It should be noted that many lighting designers follow both code-driven task visibility and individualized architectural methods in an iterative process. But codes and established metrics alone dominate the methods of many lighting decision-makers. Understanding this, Cuttle proposes perceived adequacy of illumination (PAI) as a new criterion, and mean room surface exitance (MRSE) as a metric for evaluating quantities of perceived light. MSRE is the average luminous flux density (lm/m2) from surrounding room surfaces; in other words, it measures how much light reflected from room surfaces is available to the eye. More research using human subjects is needed to validate use of PAI and calibrate the MRSE metric (Cuttle 2012).

The divide in approaches can be further characterized as rational versus phenomenological, or objective versus subjective, keeping in mind that in either methodology it is desirable for light and its perception to be quantifiable and measurable.

Figure 1: An interior where appearance of light has been considered along with the delivery of adequate light to perform a variety of visual tasks. Victoria and Albert Museum, London. Source: (J. Elliot 2009)

1.2 Dual Measures

To achieve well-tempered environments (Banham 1984) architects are required to synthesize quantifiable requirements with qualitative goals for the character and function of a space. *Illuminance* (E) and its partner concept *luminance* (L, measured in candela per square meter) provide the means to quantify light so that guidelines can be set for qualitative goals. The difference between what these interrelated terms measure – simply put, how much light falls on a surface for illuminance and how much light is reflected to the human eye for luminance (IESNA 2009) – hints at lighting’s concurrent objective and subjective realities. On one hand, figuring light distribution on a workplane is a relatively simple, objective task. On the other hand, determining how occupants perceive that light is an affair that requires synthesis of knowledge about subjective and objective properties of light, materials, space, and humans.

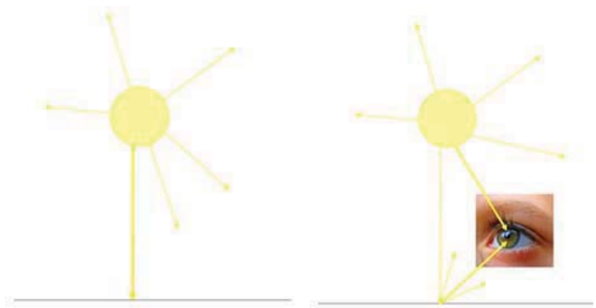

Figure 2: Illuminance (left), the density of luminouse flux received by a surface, relates to a light source's intensity. Luminance (right) is the intensity of light that is received by the eye of an observer. Luminance is dependent on direction, and takes into account the degree to which material surfaces reflect or transmit light in a space. Source: (Sarawgi 2013)

Calculation and measurement methods for illuminance are accessible to architects, and photometric meters are relatively inexpensive tools for analog measurement of illuminance in built spaces. Calculating luminance requires additional information about material surface reflectance and room interior layout, and is dependant on shifts in viewpoints. Luminance meters have historically been more expensive and less widely used tools. The next section focuses on recent research advancing affordable and accessible tools for measuring luminance distribution in digital and analog settings. But for now, in order to contextualize that research, it is important to provide general information about who is creating and using lighting research, and how lighting research is performed and knowledge disseminated.

2.0 LIGHTING CONTEXTS

2.1 Practice

Lighting practitioners defy simple categorization of their education, training backgrounds and paths of entry into the lighting field. Education may emphasize the roots of the architectural lighting profession in the science and art of theatre lighting, it may present an engineering basis of design, or both aspects may be synthesized. Many start in the lighting field with apprenticeship rather than specialized higher education. Examinations determine professional credentials at a variety of experience levels. Architectural lighting is first and foremost the domain of professional lighting designers. However, because quality lighting is achieved through careful coordination of spaces, materials, electrical systems, budgets and more, responsibility for the achievement of quality lighting regularly falls within the purview of architects, electrical engineers, interior designers and other members of the project team. The architect in the role of coordinator between disciplines and prime communicator with the client regarding project objectives must have sufficient capacity to make and manage lighting decisions. At times when no lighting design consultant is engaged on a project, or when a project uses integrated project delivery model, the need for architects to be knowledgeable about lighting is intensified.

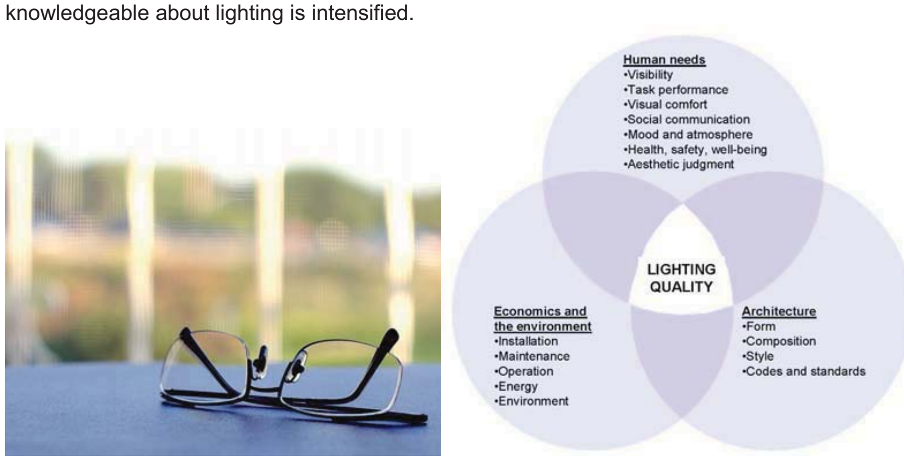

Figure 3: Quality lighting balances human needs with economic, environmental and architectural concerns. Source: (Left: Dori 2006; Right: IES lighting quality diagram by Ardra Zinkon, 2011)

2.2 Research

Lighting researchers fall into as many categories as the practitioners described above; add to these researchers having a non-construction human or natural sciences background. Lighting researchers are expanding and refining knowledge on nearly every aspect of lighting, from creating new lamp technologies to studying human circadian system response to light. Architects that perform lighting research in university research settings are specially positioned to introduce new ideas, develop technology and question current practices in ways that are relevant and accessible to other architects. Researchers with architectural training can be found in university research centers, government research laboratories, private research consortiums, manufacturing industries, and lighting design or architectural/engineering (A/E) consulting firms. Cooperative efforts between these groups are common.

2.3 Knowledge

How is lighting knowledge disseminated? Lighting design research journals such as *Leukos*, the journal of the Illuminating Engineering Society and *Lighting Research and Technology*, a Sage publications journal, have a diverse but limited readership of individuals including practitioners, researchers and manufacturers. Trade publications with a focus on lighting applications (*e.g. Lighting Design and Application* and *Architectural Record Lighting*) spread research findings to a large audience, but do so in a selective manner in less technical detail. Many important findings about lighting are isolated in discipline-specific journals that are rarely referenced by the many disciplines involved in lighting.

Books that encapsulate practical application of the lighting field's most influential research form a basis from which to observe established lighting design practices. This paper references the following texts aimed at an architectural audience: *Perception and Lighting as Formgivers for Architecture* (Lam, 1977) and *Architectural Lighting Design* (Gary Steffy 2001, 2008). Additional seminal and influential texts are too numerous to mention in this study.

How lighting knowledge is transmitted to an architect has great variation. A National Architectural Accreditation Board (NAAB) required building systems course in an architectural degree program might address lighting for only a few weeks or for an entire semester. An advanced course in lighting may or may not be offered. Lighting courses may or may not emphasize specific lighting facets such as physical properties of light, calculation methods, integration of daylighting with electrical lighting, controls, energy conservation, codes, human factors, integration with material and furniture layouts, etc. With such a vast range of topics to be addressed, some aspects are sure to be omitted. Naturally, architects will gain more comprehensive knowledge in architectural lighting in the field through ongoing project experiences. But it may not be sufficient any longer to rely on incremental, empirical knowledge to achieve 'good enough' lighting. There is increasing demand for environments to deliver higher levels of energy conservation, visual comfort and health for occupants, on time and on budget. It is time for architects as project team leaders to have capability to confidently participate in both objective and subjective aspects of architectural lighting.

2.4 Process changes

Over thirty years ago, lighting design principal and author William M.C. Lam articulated the need for an "all in" team approach to achieve lighting excellence:

> A closer cooperation will be required among all the members of the design team at all stages of the design process, with more emphasis on the formulation and achievement of perceptual rather than numerical objectives (Lam 1977, 83).

Fortunately for the task of quality lighting, projects increasingly employ integrated project design and delivery (IPDD) process models.

> The integrated design process is a method of intervention in early stages of the design process that supports the development and design team to avoid sub-optimal design solutions (Larsson 2009).

IPPD has advanced in use in part due to its role in helping projects to achieve higher performance in sustainable and energy-efficient design, efforts that require close coordination between disciplines. The process can also help deliver higher performing illuminated environments by facilitating teams to establish and meet shared objectives through cross-disciplinary planning.

Professional lighting design methodologies clearly distinguish between objective, rational properties of light and subjective, experiential qualities of illuminated environments, yet synthesize these aspects into working paradigms. This is in contrast to everyday lighting practices of other professionals such as architects or electrical engineers who respond directly to numerical code requirements in a way that is disconnected from or contradictory to strategies they may employ to achieve desired experiential qualities in a space. To work together effectively, professionals will need to at a minimum understand the mindset and work processes of their collaborating team members. Teams would be even more effective if shared methodologies could be established such as the human-centered design criteria promoted by Cuttle. Recent lighting research related to visual perception is being driven by this slow but sure sea change in attitudes.

3.0 RESEARCH ADVANCING THE LUMINANCE CONCEPT

> In an interior space, the visible surfaces and the way in which they are illuminated are the design. They define space and its perceived meaning (Lam 1977).

3.1 Evolving methods

Lighting researchers are introducing new ideas that, while they challenge the status quo of lighting practice, build on decades of respected prior research. In this paper's case in point, researchers are developing new methodologies and tools to study luminance distribution in built environments. The concept of studying *luminance*, or perceived light, instead of only *illuminance* is itself preceded in texts by leading lighting designers and researchers.

Luminance, or measured brightness as it used to be called, is a powerful metric for human-centered lighting design. Being the product of illuminance and surface reflectance or transmittance, it captures the intensity and formal characteristics of a light source as it is experienced in an applied context. Building on the ideas of Lam and others, lighting designer and educator Gary Steffy has articulated a cogent understanding of luminance and procedures for the use of the luminance metric. While full exploration of Steffy's recommendations for lighting designers is outside the scope of this study, several of the book's sections related to human psychological and physiological factors serve to illustrate why designing with luminances is advantageous.

"Lighting is all about planning and maintaining luminances (Steffy 2008, 107)." Alone, for a given point in space, a luminance value is discrete and quantifiable. It does little to describe the quality of the light, or how it is perceived. In combination however, multiple luminance values describe the qualities of light in a space. Steffy articulates how luminances can be distributed to create visual hierarchy and visual attraction (focal centers). Two adjacent areas of luminance, such as a focal object and its background, can be quantified with a luminance contrast ratio. Drawing from John E. Flynn's work on the psychology of lighting (Flynn, 1973, 1979), Steffy ranks luminance contrasts in terms of their 'attraction power'. For example, a 2:1 focal-to-background ratio is considered to have 'negligible' attraction power, with the effect of providing a 'barely recognizable focal' whereas a 10:1 ratio would have 'marginal' attraction power setting a 'minimum meaningful focal.' Creation of a 'strong significant centerpiece' effect, the contrast between the focal luminance and its background could approach 100:1. In addition to varying the intensities of the luminances as described above, chromatic contrast through manipulation of light source color and receiving surface material color can establish visual hierarchy and attraction (Steffy 2008).

Variations in luminance uniformity, location, and intensity also influence how occupants feel about a space. Again drawing from the research of Flynn and others, Steffy categorizes five impressions of space: visual clarity, spaciousness, preference, relaxation, and privacy (Steffy 2008).

Steffy also recommends studying luminance values for the role they play in "how we see, react to, and accomplish tasks (Steffy 2008, 130)." In general, luminance values on tasks should be high enough for tasks to be performed accurately, yet low enough for visual comfort issues such as avoiding glare. How high or low depends on the surrounding context. Steffy explains why the 'three lighting layers' of ambient, task, and accent or architectural are important: Ambient lighting levels affect overall subjective impressions of a space; accent lighting draws attention to special architectural elements or artwork; task lighting is localized specific to light task areas (Steffy 2008).

The ideas of Steffy and Cuttle are presented as indicators that the luminance concept is gaining renewed importance in the design of quality illuminated environments. The importance revolves around the fact that luminance concepts discussed here - luminance distribution, luminance contrast ratios, and mean room surface exitance – all take human visual perception and surrounding physical contexts into account. The emergence of this lighting trend is not isolated, however, for the synthesis of lighting with building envelope and interior room finish design can lead to optimization of those building components in ways that serve a number of sustainability objectives. Lighting joins with daylighting harvesting, balancing of thermal inertia, solar control, acoustics, and desirable views to create successful high performance 'whole buildings'.

3.2 Evolving tools

Researchers are seeking ways to support the needs of lighting designers and other professionals through developments in lighting simulation technology. This work can help merge subjective and objective analysis within a rigorous design process. Lighting researcher Mehlika Inanici and collaborators have developed new visual perception-based lighting analysis methods and tools in a project for Lawrence Berkeley National Laboratory (LBNL) titled “Lighting Measurement, Simulation, and Analysis Toolbox” (Inanici 2005).

> The project demonstrates several techniques for analyzing luminance distribution patterns, luminance ratios, adaptation luminance, and glare assessment. The techniques are the synthesis of current practices in lighting design and the unique practices that can be done with per-pixel availability. Demonstrated analysis techniques are applicable to both computer-generated and digitally-captured images (physically-based rendering and High Dynamic Range photographs) (Inanici 2005, 2).

Per-pixel luminance data analysis uses photography and digital modeling with post-processing. The RGB data in each high dynamic range (HDR) image is converted into CIE (International Commission on Illumination) XYZ data using the CIE 1931 Standard Colorimetric Observer Functions (Inanci and Galvin, 2004; Inanici and Navvab 2006). HDR imagery captures a scene in high resolution, covering the total human vision range from starlight to sunlight within a large visual field of view mimicking human vision capabilities. Inanici’s team developed the Virtual Lighting Laboratory™ (VLL). Through this computational methodology and tool, any HDR photograph originating from either digital camera photograph of a physical scene or an image produce by a lighting software program like Radiance™ can be imported and analyzed in fine, per-pixel detail (Inanici 2005).

Digital HDR photography is a relatively low cost and accessible solution for capturing luminance values. Web-based software has potential to demonstrate light distribution phenomena without mastery of programs like Radiance. The Radiance Image Database pilot developed by Inanici and other LBNL researchers allows users to select images from an image bank, change design and context parameters, and view the corresponding changes in luminous performance data (Inanici 2005). Sample images from the Radiance Image Database in Figure 4 use per-pixel data to reveal luminous distribution in a number of display modes:

> Each image is available in four display modes: camera exposure, based on average luminance (top left), camera exposure with superimposed iso-contour lines of luminance or illuminance (top right), human exposure, based on the sensitivity and adaptation of the human eye (bottom left), and false color mode, showing magnitude of luminance or illuminance (bottom right) (LBNL 2002, 3)

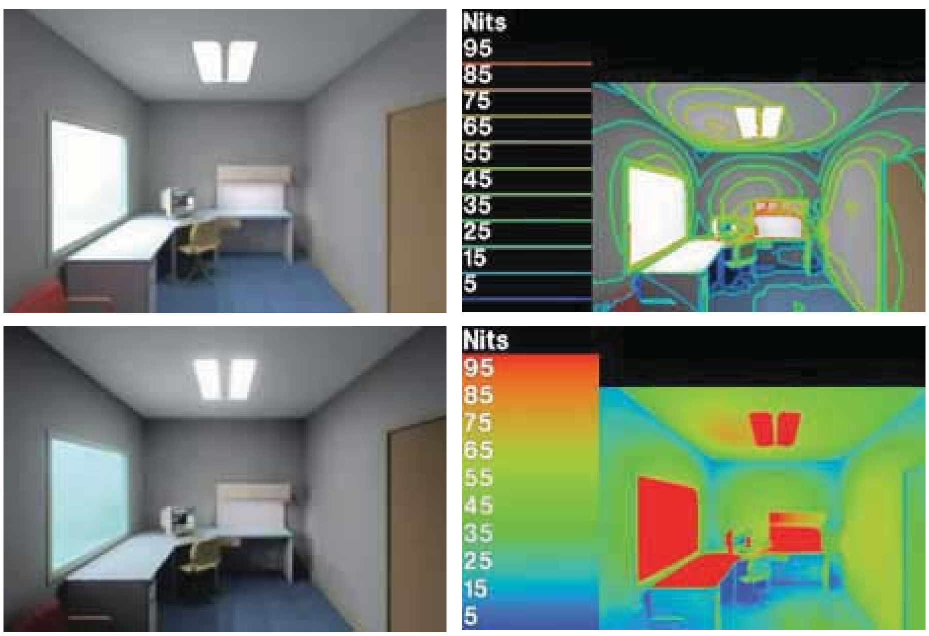

Figure 4. Images from the Radiance Image Database reveal luminous distribution. Source: (Lawrence Berkeley Laboratory Environmental Energy Technologies Division News 2002)

3.3 Barriers to use of luminance concepts

Barriers to architects’ use of luminance and other lighting concepts have persisted for some time, signifying a weakening of architects’ capacity to manage and achieve lighting goals. These include lack of familiarity with the meaning of lighting terminology, for example the difference between illuminance and luminance. Luminance is always defined and discussed in lighting texts aimed at architects, but educational courses will rarely actively calculate or promote use of luminance-based metrics. Energy codes and the IESNA guidelines most commonly used by architects refer to illuminance rather than luminance, leaving only a sector of lighting designers to employ luminance as part of their individualized design processes. Certainly, the lack of readily available tools to measure luminance has played a part in its marginalization. HDR technology has great potential to erase process barriers. Still, educational and knowledge transmission barriers must be addressed.

3.4 Shifts in education and dissemination of knowledge

Advances in lighting design practice are generally revealed to architects indirectly through updates to building industry codes, standards, and guidelines. Publications featuring cutting-edge lighting research are generally written for a readership of lighting or engineering professionals. A preferable situation would find knowledge about lighting best practices being transmitted directly to architects. This points to the need for enhanced education and cross-disciplinary discourse on the topic of lighting. Fortunately, lighting knowledge is becoming easier to access through Internet and digital technologies as evidenced through the Radiance Image Database described above.

Several websites have been developed through government and private sponsorship that aim to broadly educate architects and other professionals on lighting topics. The New Buildings Institute (NBI), a non-profit organization, is the developer of the Advanced Buildings suite of web-based tools including the Advanced Building's Core Performance Guide in use since 2007 followed by the 2010 Lighting and 2011 Daylighting Pattern Guides (NBI 2013). NBI's Advanced Lighting Guidelines is platform through which accepted new best practices can be broadly and effectively transmitted. The National Institute of Building Sciences (NIBS), another non-profit organization, is developer of the Whole Building Design Guide (WBDG 2013) which addresses lighting best practices in the whole building context. The US Department of Energy's Energy Efficiency and Renewable Energy division High Performance Buildings Database (US DOE 2013) is another resource for lighting best practices.

In the education sector, several interactive websites have been created that seek to spread lighting knowledge to broader audiences. The website created by educator Tina Sarawgi of the University of North Carolina, Greensboro, has been in use since 2009:

> E-light is an interactive exploratory interface designed to enable one to draw connections between lighting design software programs and lighting design concepts (E-light 2013).

The site links concepts and metrics of lighting, including luminance, with software design and visualization techniques. By connecting inherently quantitative software back to lighting concepts, students or professionals using the site can better bridge the gap between lighting's objective and subjective characteristics. For example, daylight or electric light sources in a three-dimensional model can be simulated in terms of illuminance or luminance spatial distribution with a simple command.

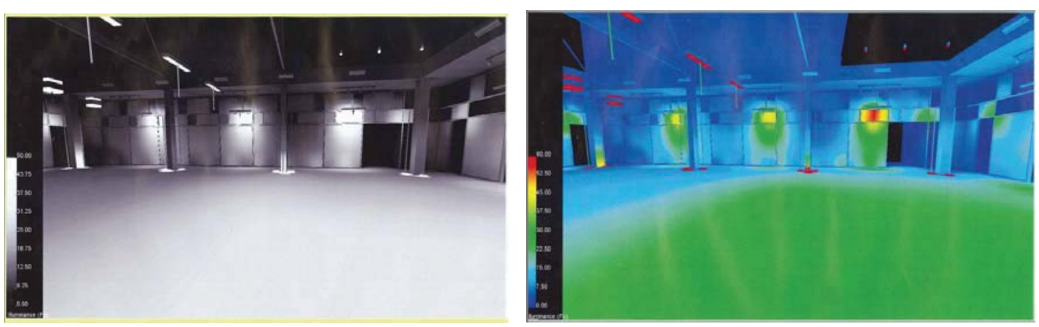

Figure 5: Lighting software can visualize illuminance distribution (left, using grayscale visualization) or luminance distribution (right, using pseudocolor visualization) within a space. Source: (Author and Elizabeth Nahrup 2012)

The author is a contributor to another web resource initiated by educator Katherine Ankerson of Kansas State University:

> The idea underpinning "Lighting Across the [Design] Curriculum" is that lighting is so critical to all aspects of design, that the conversation must be initiated early in a student's design education and carried throughout the design educational process with multiple topics. Comprised of seven interactive modules (and applicable to architecture, interior design, and landscape architecture as well as to architectural engineering), content, examples, definitions, and educator resources are provided, supplemented with animations, audio, and other interactive features (Ankerson et al 2012).

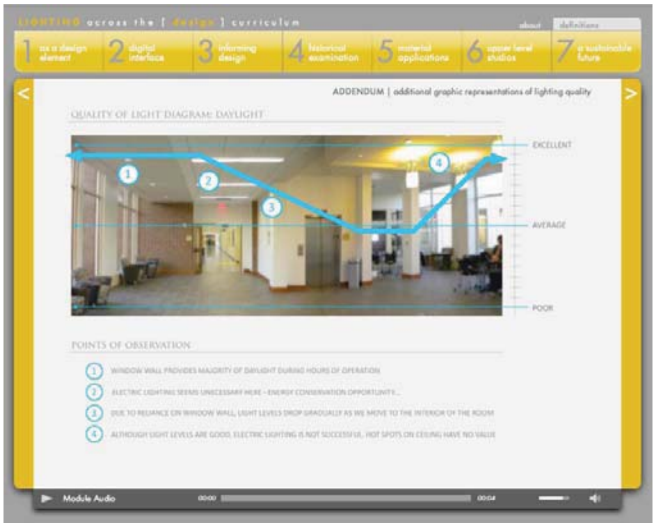

Figure 6: Lighting Across the Design Curriculum seven learning modules. Source: (Author and J. Brice Hamill 2012)

The seven modules are pictured in the sample web page shown in Figure 6. The Lighting Across the Design Curriculum resource received funding from the Nuckolls Fund for Lighting Education.

4.0 CONCLUSION

This study aims to provide information about the potential of designing with luminances to an architectural audience. To this end, it reviews the use of illuminance and luminance metrics in architectural lighting, exposing the objective and subjective aspects of light that these terms measure. This paper addresses only a thin slice of the broad spectrum of lighting design research that is underway. The variety and volume of current research reveals a shift to a cross-disciplinary, user-centered way of thinking about architectural lighting, in opposition to the numerically centered 'watts and footcandles' counting approach often left by the architect to be handled by the project's engineer. The way forward is to promote a blending of engineering 'best practices' and 'architectural' approaches as society continuously refines what it means to have an architecture featuring well-tempered, well-lit, environments.

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Building Knowledge: A Framework for a Translational Research Culture in Architecture

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ABSTRACT: The built environment in the United States is failing. Economic, social, environmental and technological performance of buildings as well as the industry responsible for their creation has not kept pace with other industries essential to a ensuring a healthy society. While research activity is prevalent in academia as well as, to some extent, in professional practice, the building industry is slow to change. This paper proposes a framework for the development of a translational research culture in the discipline of architecture as a means to more rapidly implement positive change within the building industry. Modeled after the successful approach implemented in the medical profession, translational research results in a feedback loop where basic research is tested in application. The results of this application become inputs to a new round of basic research, which will then be tested again. This cycle continues with the new research questions continuously being influenced by the limitations of the previous questions. Its application in medicine was originally intended to ensure that new treatments and research knowledge actually reach the patients or populations for whom they are intended and are implemented correctly. Establishing a translational research culture within the discipline of architecture provides a potential stopgap to slow and reverse the declining state of the building industry. By more directly connecting the efforts of research in academia with the application in practice, there exists the potential to make research more visible to both those with the power to implement it, practitioners, and those able to benefit from it, end users.

KEYWORDS: Architectural research, translational research, professional practice, collaboration, building production

INTRODUCTION

As has been pointed out by Paul Teicholz of the Center for Integrated Facility Engineering, Stanford University, productivity of the U.S. construction industry has been on a steady decline for close to a half-century. This is compared to all other non-farm industries, which have seen a steady increase in productivity as they have leveraged the benefits of integrated processes and digital technologies (Teicholz et al. 2001). Edward Mazria founded the non-profit organization, Architecture2030, with the goal of reversing the negative impact the building industry has on energy use, climate change and sensitive fluctuations in economic health (Architecture2030 2012). What is ironic is that this decline in productivity and these negative influences of the built environment have occurred while there has been rise in the quantity and size of research-oriented programs within schools of architecture. The first research unit in a school of architecture was established over 60 years ago (King 1984). Since that time, research-based M.Sc programs and PhD programs have only continued to increase in number and focus and now consist of a wide range of areas of specialization and emphasis including: design, history and theory, building science, computation, sustainability and urban design, to name just a few (Groat and Wang 2002). In addition to these post-professional degree programs offered to students of architecture, there are ever-increasing pressures on faculty to produce research as part of tenure and promotion. This influx of new knowledge generated by faculty and students could lead one to believe that the profession of architecture would be inundated with innovation and progress. While as Teicholz and Mazria have pointed out, just the opposite is true; the building industry is mired in inefficiencies and excess.

1.0 RESEARCH IN ARCHITECTURE: FROM PRACTICE TO THE ACADEMY

1.1. Learning by doing

If research is understood as “systematic inquiry directed toward the creation of knowledge”, (Snyder 1984, 2) then historically research occurred through the mere act of building. The master builder of the Gothic and Renaissance eras required the knowledge to coordinate and integrate all aspects of a project’s completion including aesthetics, proportion, function, acquisition of materials, scheduling of manpower, and controlling of cost. Trial and error experimentation led to the development of new building materials, structural systems and building forms. The master builder was architect, engineer, material scientist, surveyor, and general contractor all rolled into a single individual and hence through systematic observation of these aspects of building projects was responsible for the creation and dissemination of new knowledge related to these fields (Groat and Wang 2002). This knowledge was not for dissemination to a broad audience, but rather was closely guarded by members of the various building guilds and only passed down to its members to be utilized on future building projects. While the master builder model, in one form or another, continued up to around the turn of the 19th century, Leon Battista Alberti dealt it quite a blow when he drove the first wedge between design and construction. Alberti was the first to call for the separation of design as an art from building construction as a craft.

1.2. From craft to profession: university education of architects

The spilt began by Alberti, with regard to the functions of design and construction, was only widened by the increased need for specialization encouraged by developments during the Industrial Revolution. Advancements in tools, means of production and material science led to internal division amongst the already separate disciplines of design and construction. A rise in expertise and a desire to improve one's status led in the 19th century to an increase in the creation of separate organizations and professional societies aimed at protecting the interest of their constituents. In turn, the need arose for educating future professionals and this responsibility fell upon the land grant universities formed in the decades following the Civil War (Woods 1999). The creation of early architecture programs at institutions such as the Massachusetts Institute of Technology, Cornell University and the University of Illinois led to a shift away from the apprentice model, to a more formal university based model for the education of architects.

1.3. Architectural research in the academy

Despite attempts by faculty in early architectural programs to ignore their relationship with the universities that housed them, university administrators soon began to expect these programs to behave similarly to other traditional academic programs; this meant the need for research. In order to acquire tenure and promotion within the university system, faculty members must show evidence of contributing to the advancement of knowledge within their respective discipline (Schluntz 1984). These institutional pressures, coupled with sheer human curiosity, fuelled early architectural research activity within the academy. As a discipline which resides somewhere between art and science, the role and definition of architectural research has always been a bit of a moving target. There are aspects of architecture that have ties to the more established research fields in the natural sciences such as physics, chemistry and biology. There are also parallels with the social sciences of sociology, anthropology and economics. Other fields where basic sciences are applied, such as the other professions - medicine, law and engineering – are perhaps most similar to architecture. Where architecture differs from these other professions is its close ties with the humanities and the arts (Leatherbarrow 2012). This wide spectrum of possibilities available to those exploring architectural research as well as the fragmented nature of the current building industry has led to discipline silos that hinder collaborative opportunities.

1.4. Architectural research in the profession

Contemporary architectural practice, long removed from its origins of master builder, cannot in and of itself claim to generate new knowledge in the same way as its historic predecessor. A discussion paper titled "What is Architectural Research?" issued by the Royal Institute of British Architect's Research and Development committee states that:

> Designing a building is thus *not necessarily* research. The building as building reduces architecture to mute objects. These in themselves are not sufficient as the stuff of research inquiry. In order to move things on, to add to the store of knowledge, we need to understand the processes that led to the object and to interrogate the life of the object after its completion.

As a result of this need to understand processes and interrogate the life of a building, some design firm have become more reflective and begun to make research an integral part of their practices. These research-based practices include large-scale firms such as Gensler and HOK, with Gensler dedicating 5 percent of its annual profits to research. In addition to a few large firms, midsize firms such as KeirenTimberlake and Architecture Research Office (ARO) have included research agendas as integral parts of their business plans. Lack of size and resources can be overcome by small practices, which often subsidize their research through joint academic appointments (Beck 2012). The emergence of digital fabrication, building information modeling (BIM) and integrated project delivery (IPD) has resulted in the process of practice itself becoming a topic of research in academia as well as practice (Deamer 2011).

1.5. Need for translational research culture in architecture

Translational research, adopted by the medical profession, is a systematic effort to convert basic research knowledge into practical applications to enhance human health and well-being. Translational research was designed for the medical world. It emerged in response to concern over the long time lag between scientific discoveries and changes in treatments, practices, and health policies that incorporate the new discoveries (Birmingham 2002). In general terms, translational research is a dynamic research model in which basic research is tested in application thereby revealing potential limitations which feed back into framing new research questions (Fig. 1). Just as the time between discovery and implementation in practice has been compressed within the medical profession, the promise exists for similar fast paced advances within the building industry. The building industry has traditionally been slow if not adverse to change. This is partly due to the deeply fragmented nature of the industry, with architecture being just one part of the multidisciplinary teams responsible for the design and production of the built environment. An advantage of translational research is that it is quite often multidisciplinary. This multidisciplinary nature helps to break down the disciplinary barriers within which research typically operates thereby more quickly implementing research into practice (Ewing 2010). Perhaps the most promising aspect of establishing a translational research culture in architecture is that practicing professionals have the ability to influence research agendas in academia (O'Donnell 2007). The approach to translational research has begun to be transferred to other discipline such as planning (Ewing 2010) and education (Jorgensen 2011). The need to establish a translational research culture in architecture is a necessary step towards improving the building industry by providing vested interests between those producing and those applying architectural research.

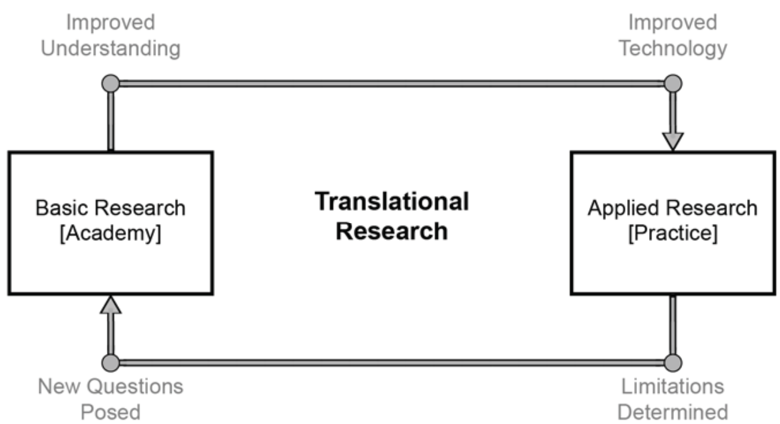

Figure 1: General translational research model in architecture between the academy and practice.

2.0 MODELS OF TRANSLATIONAL RESEARCH IN ARCHITECTURE

What follows are three models for establishing a culture of translational research within the discipline of architecture. While existing versions of these models are currently being implemented between academia and practice, in one form or another, both parties would benefit from more explicit definition of these relationships and an understanding of the theoretical cost to benefit ratios of each.

2.1. Practice embedded in the academy

The number of permanent faculty members teaching in architectural programs who are also active practitioners has declined as a result of the more rigorous qualifications for faculty required by universities (Gutman 2000). Professionals frequently teach design studios on an adjunct basis and while this often involves the practitioner utilizing a recently completed or currently active project brief as the focus of the studio project what is not usually achieved is a rigorous research-based approach to that project. By leading a research-based design studio, practitioners are able to leverage resources of the university and benefit from the knowledge gained, while at the same time exposing students to 'real-world' problems, whose complexities can never be equally simulated by boilerplate projects repeated year after year. The return on investment by the practitioner involves multiple solution variations with perhaps deeper levels of research than could have been achieved by the practitioner alone. Other opportunities involve leading subject specific seminars that either share the practitioner's existing knowledge or develop new area of expertise in the safety of academic environment.

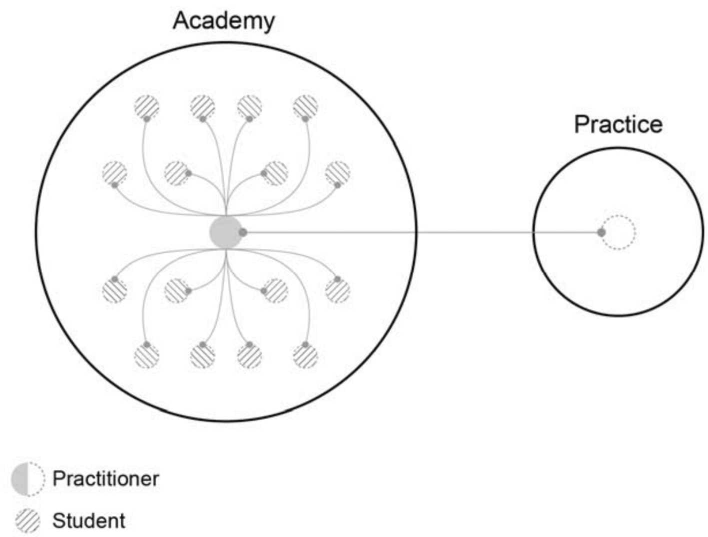

Figure 2: Practitioners embedded in the academy.

2.2. The academy embedded in practice

Another compelling model for the shift to translational research in architecture is the model proposed by Mark Burry and utilized by doctoral students in his Spatial Information Architecture Laboratory at RMIT in Australia (Burry 2012). Doctoral candidates are embedded within a design practice and participate in research that the practice might not otherwise have the resources to undertake (Fig. 3). This model is similar to ones implemented by doctoral students in medicine and science, but has yet to be widely adopted in architecture or other design disciplines. The fact that several candidates are embedded in different design practices simultaneously creates the possibility for cross-pollination of research agendas thereby informing new potential research opportunities (Burry 2012). This model is not exclusive to doctoral candidates alone and could be extended to other research-based degree programs as well as advanced professional-degree seeking students. While this model is similar to the longstanding tradition some universities have for practicum or internship programs that embed students within design firms to gain hands on professional experience, the difference here lies in the focus on utilizing the student's efforts on activities resulting in either the creation or application of research rather than completing rote actives such as picking up redlines.

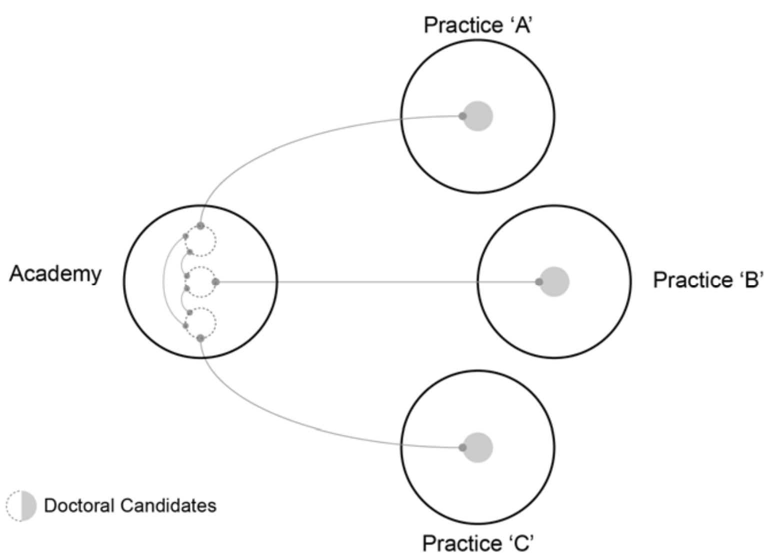

Figure 3: Doctoral candidates from the academy and embedded in practice.

2.2. Collaboration

The third model for translational research within the architecture discipline involves one of collaboration between practitioner and faculty/research center (Fig. 4). Firms with the resources to do so can sponsor research projects with faculty or research centers within the university. A good example of this form of collaboration is the Center for Architecture Science and Ecology (CASE). CASE is a multi-institutional and professional research collaboration co-hosted by Rensselaer Polytechnic Institute and Skidmore, Owings & Merrill LLP. CASE is pushing the boundaries of environmental performance in urban building systems on a global scale, through actual building projects as research test beds. A more approachable version of this model consists of faculty members with particular areas of expertise being hired as consultants to a design firm on a project-by-project basis thereby gaining direct access to that individual's knowledge and providing opportunities for direct implementation of this knowledge on realized projects (Reigle 2011).

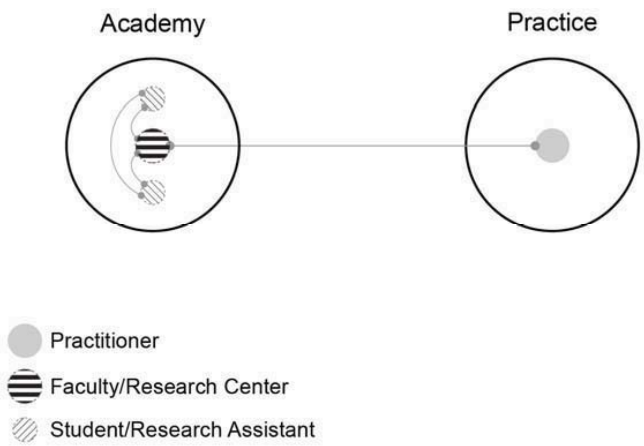

Figure 4: Collaborative research between the academy and practice.

2.3. Closing the communication gap

The form that the interaction between academia and practice takes is less important than the form in which the information resulting from this interaction is shared with a broader audience. The intention of translational research is not to only benefit the parties directly involved in the research and application, but to disseminate the knowledge created. This requires a closing of the communication gap that exists between academic and professional publications. Academic journals and conferences are too insular and often only used by academic faculty for the purposes of meeting university standards for tenure and promotion, essentially 'preaching to the choir'. Alternatively, the profession lacks rigorous research publications where in-house scholarly research can be shared. Therefore, firms often resort to self-publication of information via print or digital formats. The two major trade journals, *Architect* and *Architectural Record*, are not rigorous enough to compare with the standards of academic publications and often result in little more than marketing fodder for firms. Despite the efforts of organizations such as the Architectural Research Centers Consortium (ARCC) and the American Institute of Architects' (AIA) Knowledge Communities, there still exists a wide gap between academic and professional knowledge. Despite technological advances, this problem has not improved much since writing almost 30 years ago Jonathan King noted that:

> Today most of our significant architectural research work is squirreled away in isolated pockets, inaccessible to most of those who need it. The architectural community ought to be moving toward the achievement of an openness that can include the academic institutions as well as the private and public sector research agencies and of course, the users of architecture.

The users, those who are most impacted and could benefit most this knowledge, are still yet to be fully brought into the fold.

CONCLUSION

The buildings industry is failing, research is not finding its way into the right hands and thus not fully impacting the quality of the built environment. The separation between academia (research) and practice (production) must be bridged in order to stop and reverse the damage done by the built environment. Establishing a translational research culture within the discipline of architecture lends itself to ensuring that research has meaningful and practical impact of those who most need it, the end users. Achievement of this goal will reveal the value of the knowledge in influencing positive change in the built environment.

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Design and Visualisation Strategies in Parametric Building Components

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ABSTRACT: New digital programming and fabrication techniques enable the development of parametric building components. These processes use a repertoire of working methods that differ from those commonly used in building projects. This paper presents five examples of parametric design and digital manufacturing carried out in Latin America, reviewing the graphic tools used in relation to the architectural design process, in order to clarify the characteristics and possibilities of these technologies. Particular project resources identified are; presentation of global parameters, modular programming, production drawings and assembly instructions. All serve to complement the conventional building design, to provide massive but variable manufacturing solutions. These new technological procedures require to be normalizing in order to integrate properly into architectural design and construction.

KEYWORDS: Parametric Design, Digital Manufacturing, Mass-customization, Architectural Design, Visualization.

INTRODUCTION

The recently developed parametric design and digital manufacturing technologies allow the manufacture of particularly complex building elements, with a wide variety of shapes, materials and uses. These new technologies provide the opportunity to create works of architecture with sophisticated pieces, encouraging the design of different elements with a similar design and execution procedure. Parametric building components can have diverse geometric configurations and applications, while still maintaining an operational relationship and flexible production strategies. Thus, a way of working is developed that differs from that of conventional architectural design which normally seeks a unique formal solution to erect in a specific location. In contrast, the following examples using new programming and manufacturing techniques utilize variable shapes and varied materials with numerous fabrication and installation options.

In order to visualize and realize these different possibilities, the development of parametric building components employs different graphic tasks and techniques to those traditionally used in architectural projects. Geometric programming systems and manufacturing and assembly plans can be seen in the experiences using variable digitally manufactured elements, new graphic tools that broaden the repertoire of resources used in the conventional work of architecture. Such design and visualization processes and techniques must be identified and regulated in order to foster appropriate and effective use in the building process. This paper reviews some experiences, acknowledging the graphic resources used and their working conditions with a view to normalizing these methods and techniques in order to integrate them appropriately into the design building process.

1.0. PARAMETRIC DESIGN AND DIGITAL MANUFACTURING TECHNOLOGIES.

Two independent but mutually supporting technologies are usually combined in the production of variable building components: parametric design and digital manufacturing. Both are emerging technologies with products or equipment still under development and used in different fields. Parametric design refers to digital systems (software) that enable geometric programming, and by other hand digital manufacturing involves machines (hardware) that produce physical elements based on numerical data. Digital manufacturing equipment can be produce designs developed by parametric systems or by regular drawings or written instructions. In turn, shapes generated through parametric software can be realized with conventional manufacturing processes. In other words, both technologies can be used separately, and also combining their capabilities.

Parametric design is a concept emerged from the origins of computer graphics, and present in almost every vector-based design or CAD program, through the interactive manipulation of numerical modification of geometry. In some design systems it has been implemented more expressly through written modifications, and also recently in utilities with textual or graphic programming, such as Generative Components (for MicroStation), Digital Project (from CATIA) and Grasshopper (in Rhinoceros). Parametric design has mainly been used in the field of architecture to refine complex structures or roofing systems, as well as in temporary installations and some large-scale production systems (Meredith, 2006; Madyour et al, 2009, Woodbury, 2010, García and Jofre, 2011).

Digital manufacturing has also emerged out of the metalworking industry and consists in diverse equipment that mould or sculpt a material with CNC (computer numeric control) using a variety of different machine sizes and processes (Seely, 2004). LIke knife cutting for card or vinyl, laser cutters for wood or plastic and lathes and milling machines to elaborate timber, polyurethane or non-ferrous metal blocks. As well as worktops to cut and or shape composite panels, water jet cutters for metal plates or robotic arms to sand or join elements, also integrated into centralized manufacturing. Besides 3D printers to create small-scale volumetric models by consolidating liquids, particles or gases, and even large-scale parts by contour crafting. This equipment is been used in the construction industry to produce components such as metallic pillars and beams, tiles, panels and furniture, as well as to create experimental models or prototypes (Kieran and Timberlake, 2004; Stacey, 2004; Gramazio and Kohler; 2008).

2.0. EXPERIENCES WITH PARAMETRIC BUILDING COMPONENTS

In recent years we have conducted several academic experiments in Latin America, creating variable building elements through parametric design and digital manufacturing, with the support of several partners, collaborators and companies, in academic researches and industrial agreements.

2.1. Pixel-Wall

This development is a design and fabrication system to build flexible partitions made of interlocking rectangular pieces, named “pixel-wall” (Bruscato and García, 2010). The system was carried out as university research in the period 2009-2010, and has included CAD designs and digital 3D modelling, parametric programming, structural analysis, elaboration of a dozens of physical prototypes and until now five full-size constructions up to 10 metres long and 2 to 4 metres high in different materials manufactured with laser or CNC cutters. The pieces can develop straight or curved longitudinal configurations as well as domed structures, for spatial divisions or decoration. Wooden boards and plastic sheets have been used for pieces, with some metallic connectors to improve resistance, but giving in all cases a fast procedure of assembly and also re-assembly of different configurations with the same pieces. The development has received sponsorship from three different companies, was twice awarded funding from government entrepreneurship schemes and is currently being run as a start-up company.

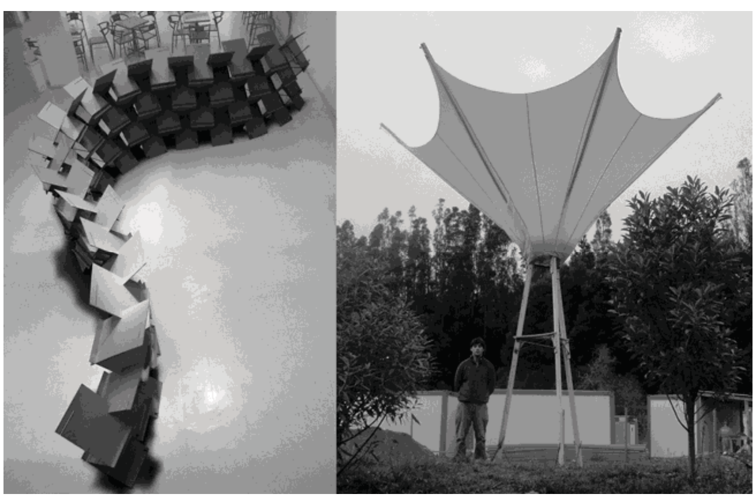

Figure 1. Installations of Pixel-Wall and Tulips (Author, 2010, 2011).

2.2. Tulips

Another design and manufacturing procedure has been developed for a fabric roofing module with variable hexagonal frame and triangular central support made with timber bars with CNC-manufactured connecting nodes (García; 2012). The system was developed over the 2011-2012 period, mainly during an intensive multidisciplinary seminar and also ensuing architecture and civil engineering degree projects. The design looks to have different layouts of roof and support according geographic or functional conditions of the place, as well as diverse arrangements of modules for varied uses. The development has involved CAD design and 3D digital modeling, parametric programming, structural and climate analysis, a number of scale prototypes and two 9x9m and 6m high units, made with regular fabric and wooden pieces. It has received funding from companies and institutions and is now being developed independently by the students previously involved.

2.3. G-House

This experience aimed to develop an incremental housing system for warm climates called “Generative House”, made with double compressed timber panels (García and Turkienicz, 2010). It was developed as an international cooperation project between Chile and Brazil in 2010 for massive low-cost housing, with support from companies, research agencies and undergraduate and postgraduate students. Urban-scale programming and parametric definition were used to elaborate a generative design of different layouts and arrangements, numerous scale models and about a hundred CNC components were made and two full-size module constructions 6m by 4m in plan and 3.5m high were exhibited in industrial trade fairs. These prototypes involved around thirty panels in one-week manufacturing process, more diverse tests of execution, with an assembly of a couple of hours each time.

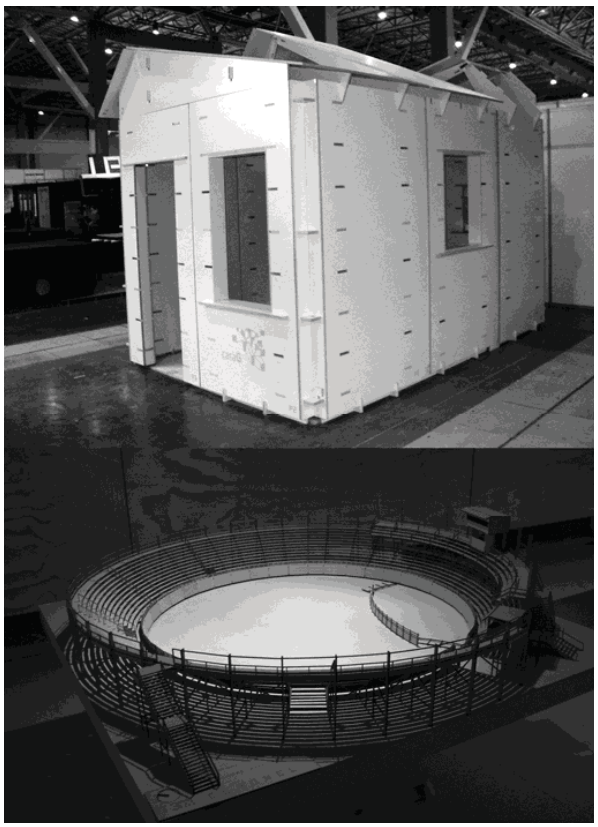

Figure 2. Prototypes of G-House and model of Medialuna (Author 2010, 2009).

2.4. Medialunas

This work was targeted to a prefabricated design for a traditional rural rodeo stadiums (called “medialunas” by the shape as half-moon of the central yard), composed of steel sheeting elements combining stands, booths and corrals in a variable system (Garcia et al., 2009). The design was developed in a semester-based studio in 2009 with architecture students and collaboration from local institutions, in order to develop a prefabricated system for diverse layouts. The project included CAD design, geometric programming, plans for laser-cut manufacture and six scale models. Each of them had different conditions and assembly with around two hundreds of pieces of twenty similar shapes, so they can change configurations and well as to enlarge the initial stadium.

2.5. Eco-slabs

A research to get sheeting optimized through structural topology for mezzanine floors in buildings was conducted. These plates are planned with a curved base created with prefabricated molds that reduce the material used by 50%, in turn reducing the building's environmental footprint, so they were called "eco-slabs" (García and Otárola, 2012). These elements were developed in a university research project between 2011 and 2012 as part of several civil engineering degree projects. The work has included numerous structural analyses, digital models, parametric visualizations and constructions and scaled down prototypes in polystyrene, timber and concrete constructed with CNC milling machines. Industrial development is ongoing with financial support from companies and institutions.

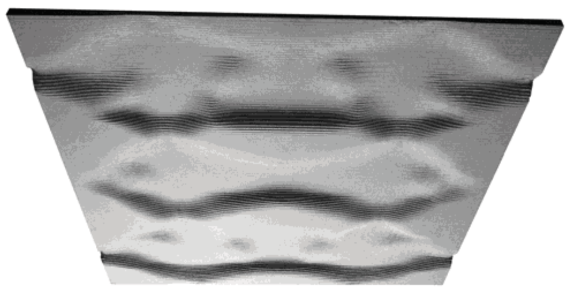

Figure 3. Model of Eco-slab (Author, 2012).

3.0. GRAPHIC PROCESSES AND TECHNIQUES

In those case studies developed in parametric building components, the following procedures appear according to the sequential stages of the architectural project:

3.1. Design conception.

In parametric and digital manufacturing experiences the graphic means used in the initial design phases are not clearly expressed (as also occurs with traditional processes). Certain physical conditions or geometric relationships are proposed in order to define the general shape of each element, as well as some features of likely uses, but mainly the development and even assembly details are usually described. The general volume or specific parts of the design are occasionally sketched by hand, precise performance, spatial or size criteria may be indicated and sometimes a natural or functional design allegory is identified. Rarely is any characteristic of the site or functional organization expressed at this stage, both aspects that frequently condition conventional architecture projects. Actions pointing towards a developing shape predominate (these are usually called "generative" or "evolutionary" processes) without predefining any set result. It is almost as if the design emerges without any explicit intervention from the designer, although the process established determines the possible results. This is an integral and interactive activity guided by only very general requirements and conditions.

In this sense, a more explicit and detailed description of the initial geometric conditions is proposed, for example, general or modular sizes, performance values and construction features (cost, time execution, etc.), all of which can be interpreted as global parameters (Lyon and García, 2011). In this way the form-generating processes can be defined with greater precision and permit creativity and effectiveness. Some typical aspects of any architectural project, such as the site survey or list of interior spatial requirements and distributions are notably absent since the designs developed are usually sited in non-specific locations and for diverse activities. However, some form of global sizing and definition of use criteria (climatic, operative and time-based) as well as certain specific operating conditions, ranges of sun protection, structural resistance, price, etc. can be determined and integrated into the design procedures. Indeed, such aspects are valuable tools in structuring the developing process. Intentions of aesthetic expression are also relevant and these tend to motivate processes and provide special working conditions, seeking to lend meaning to the design. In this way clear goals can be set with which to assess the resulting form of the project.

This description requires the graphic visualization of certain formal global conditions, numeric or conceptual expression of other aspects with relevant (minimum and maximum expected) values or points of reference. Consensus is reached over expected conditions, based on eventual use patterns and needs, probably requiring some methods of industrial production or from the building market, while partly using conventional methods of architectural project design. Schematic views of the general volume and specifications are obtained as well as some degree of analysis regarding manufacture and mass production.

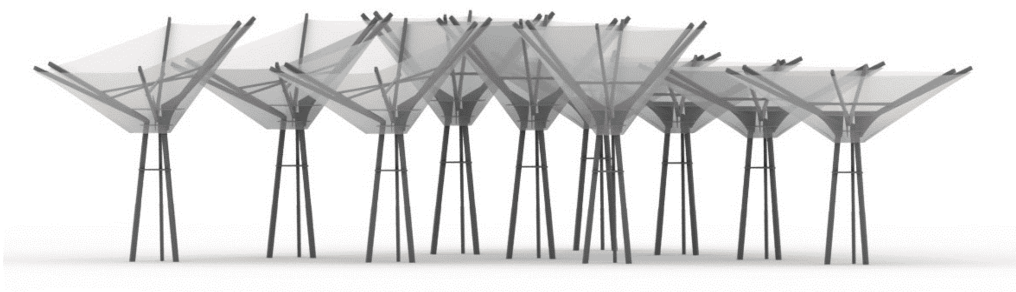

Figure 4. Design Concept of Tulips (Author, 2010).

3.2. Project Development.

There are considerable differences in the resources used in these experiences in the process of working out the design. In contrast to predominance of the orthogonal views normally used in the traditional architectural design, works with parametric design and digital manufacturing shows written or graphic programming that generates diverse geometries displayed in three-dimensional representations. The programming consists of an ordered list of instructions written in a code or graphic sequence that indicates geometric actions and conditions. This list is implemented into a digital system that interprets it and presents the results on other additional screens. Conditions or connections affecting the generated shapes can be modified, thus creating various different versions of the designs and these in turn can be visualized in different ways. Usually instructions or graphic components collect external information from other analysis or are able to send data to the processing or visualization systems or to the manufacturing equipment, carrying out additional steps to generate further information about the geometric form. An example would be to generate sections through the design at appropriate intervals according to the material used, thus optimizing materials.

The growing development of these programming experiences has generated controversy regarding the establishment of modules or structures to organize and generalize use (Barrios, 2006; Davis et al, 2011). This involves determining segments of programming that carry out a series of actions that can be independently handled, intervened in or reused. Such a measure facilitates input data recognition and the resulting information. This would be useful since programming is usually carried out by a specialist in an interactive process that generates a labyrinth of instructions difficult even for other specialists to follow, thus reducing the possibilities of creating new or broader versions of any design. Programmers are increasingly sharing parts of their data input processes in order to facilitate design development. In this context, these new technologies would benefit from a degree of standardization, although such a task would surely require an institution-led process of normalization.

Three-dimensional visualization of the geometries by means of digital representations generated by the same or another design program are used to complement the process, using diverse forms of visual expression or even creating additional static or animated presentations. An approach that permits simultaneous display of multiple possibilities of form or animation of the digital model in a generative process is advantageous. At the manufacturing stage, the diverse forms of the project elements should be identified and displayed in order to enable better design management since the process generates a large number of independent pieces, some very similar to each other (in contrast to conventional design which works with general views or written specifications). To this end, lists, alphanumeric coding and graphic tables are drawn up displaying the different types and sizes of elements in order to resolve and process physical production. Occasionally, the digital models developed are used to demonstrate dimensioning and relationships between the building components since some are connected to each other or their length is determined by the general design and in this way intersections and distancing can be reviewed. (Mechanical or BIM software can detect this automatically but this technology is not usually linked in with parametric programming). This instance also serves to update general design dimensions or construction details when necessary. Component sizing in comparison to final building scale is also reviewed as well as equipment types and materials, and even costs involved, generally leading to adjustments in individual pieces in the graphic tables or coding lists.

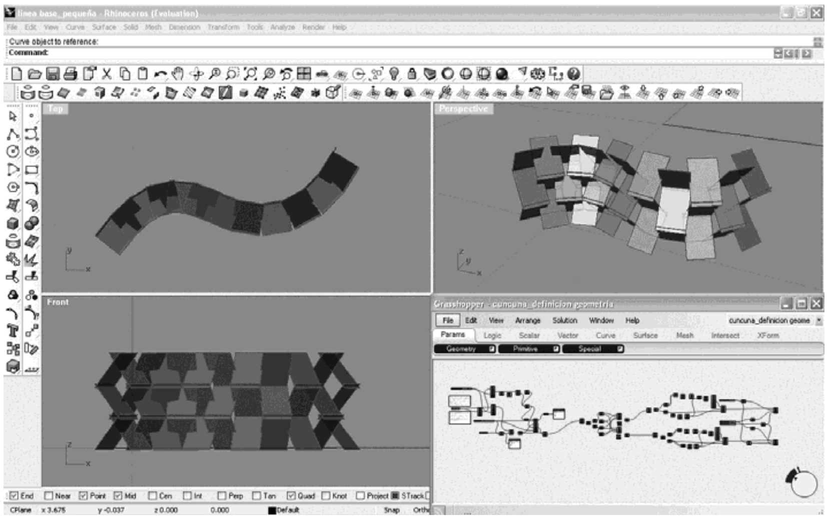

Figure 5. Programming of Pixel-Wall (Author, 2010).

3.3. Execution

Two kinds of graphic document are used to complement general construction drawings in the physical manufacture of the design with digital equipment. These are the production drawings and the graphic assembly instructions. Both are common in other manufacturing sectors but are not normally used in architecture projects (except perhaps in large-scale buildings).

The production plans are needed to elaborate the different components in the digital manufacturing and their nature depends on the specific machine used (although a number of general formats exist). In other words they are created as part of the production process or the designers already know which kind of equipment they will use. Nevertheless, the nature of these plans can vary considerably since the project duration and materials used may still be uncertain, making it impossible to determine costs or the processes involved. This equipment traditionally uses “G code” programming language but many now operate with DWG format drawings or alternatively printer controls can be installed that permit the use of any design programme. It is only important that the representation that is created contains an adequate description for the manufacturing process, while excluding all irrelevant information.

The final representation can be based on conventional drawings or data from the parametric programming but the graphics file must be made suitable for manufacture. This means eliminating all graphic elements that will not become physically manifest (such as measurements, labeling and projected views) leaving only sectional profiles and remove areas. Sizing depends on the proportions and dimensions of the material to be used (sheeting or block, or correctly speaking, the “working surface” of the machine on the material, according to the point of origin or processing surface) which may need modifying if a scale model is to be made. The component or model must be adequately laid out or distributed upon this working surface or volume in order to guide the manufacturing process and make the best use of the material while reducing work times. In fact, specific programs are able to analyze the layout of flat shapes or volumetric forms in order to minimize waste. However, some manufacturing processes either require a set distance between pieces or specify fixing positions, as well as particular arrangements or marks for handling. Some processes even create printed lists or copies of the plans to aid production in the case of a large range of elements. The aforementioned component lists or coding require careful management since some manufacturing processes produce each piece separately or in a different order to that required by the designer. Some machines can register the code number onto the component itself or a label may be attached. Likewise, packing and dispatching of components requires control procedures.

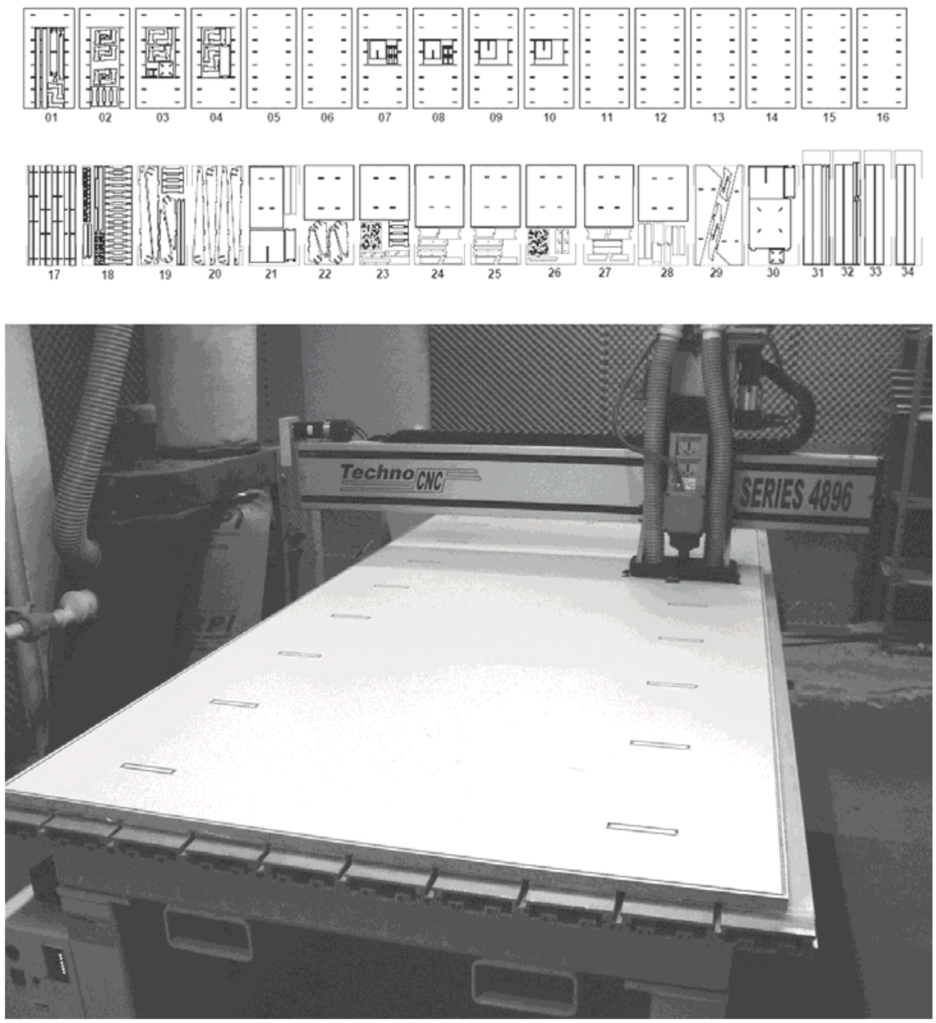

Figure 6. Production Drawings and Manufacturing of Panels for G-House (Author, 2010).

Subsequently, assembly plans are required. Although configurations are usually improvised in the case of the earlier trials with few components, as the size and diversity of elements increases along with a greater complexity of connecting details and component sequences this process must involve adequate planning. Sometimes transport, storage or handling aspects require specific instructions. In really large-scale and complex designs physical scale models are usually made with the sole purpose of determining the most efficient assembly process or partial mock-ups or ground plan configuration trials are carried out before final construction on-site. In cases where the designers will not carry out the final construction themselves the assembly process must be fully and carefully detailed (as in the case of furniture assembly). In this situation assembly plans are usually drawn up using isometric sequences with step-by-step instructions (and suitably labeled components) and a drawing of the completed design. Construction requirements are also specified (number of people, tools, connecting pieces and time scale) as well as site requirements (space, ground area, etc.) or recommendations regarding weather conditions. As digital models are available, animated sequences are frequently used to describe the assembly process. Stop-motion videos may also be made using models or test pieces in the component workshop (with a fixed position camera taking consecutive shots at each of the different assembly stages) and these often prove to be the clearest way to explain the assembly process.

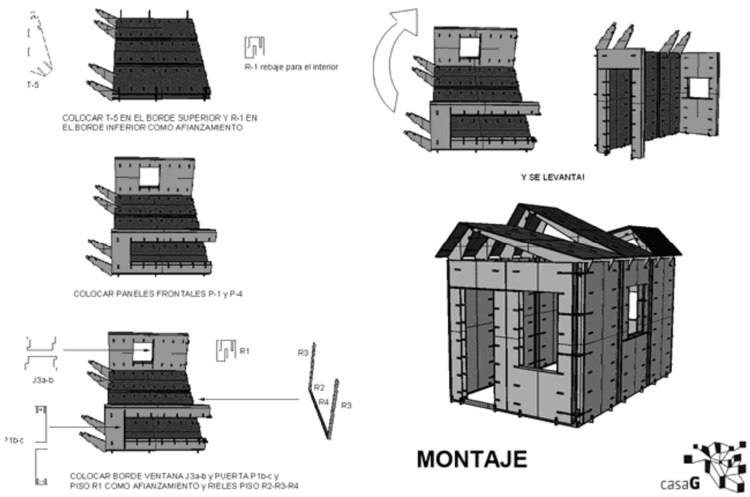

Figure 7. Assembly Instructions for G-House (Author, 2010)

CONCLUSION

The above experiences in parametric design and digital manufacturing reveal the use of specific graphic resources in the production of building components that serve to complement usual design techniques. More specifically, these involve the visualization of global aims, geometric programming, manufacturing plans and assembly instructions, all of which must be normalized to regularize their use. In this way, the repertoire of development and construction strategies of works of architecture can be broadened.

Parametric design and manufacturing are still applied in small experiences and elements. The use of these techniques in larger scale projects requires not only the training and availability of equipment, but also to understand and manage the massive customization of designs. Building process is traditionally oriented to unique result, so these tools can suggest more possibilities for the specific work as well as other applications. Introduction of these procedures can motivate practitioners and patrons to apply these capabilities for diverse building needs.

Besides, this variety of design resources allows clearer representation of project conditions, definition of form and physical concretion. It reveals geometric and constructive characteristics that offer diverse functional and aesthetic possibilities. One significant characteristic of these technologies has been the electronic linking of information (the so-called “digital chain”) into the process of project, design definition and final construction, thus expressing the aspects involved and their specific relationships more clearly, providing a platform for collaborative work and a diversity of solutions and uses. However, a higher degree of technical knowledge is undoubtedly involved, making more demands on the preparation and infrastructure, for teaching, design and production. These design activities must be integrated into current possibilities but also presents a challenge to traditional architectural processes.

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Revealing the Energy Efficiency of Housing in Chile

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ABSTRACT: Over recent years, Latin America has experienced continued development of vast residential areas with growing energy consumption of mostly imported and non-renewable fuels. Chile has been the first country in the region to set up programmes and regulations to improve environmental behaviour of dwellings, but there is a lack of detailed information on the energy performance of its housing stock. This paper presents the analysis and conditions for housing in the centre-south area of the country, in order to foster effective procedures to improve energy performance. Analysis is based on building statistics and the review of fifty actual homes, as well as energy simulation systems, with modelling and long-time monitoring of a dozen of these case studies. Some experiences of improved housing design and refurbishment were also examined. This research work identifies energy performance patterns and related architectural characteristics in housing in the area. It has managed to normalise specific aspects of residential energy simulation, such as climate, geometry, occupancy, materiality and equipment, demonstrating differences in comfort levels and building quality. The study exposes a novel strategy of review and improvement for residential areas, that reveals a conjunction between life expectations and construction quality, through analysis and appropriate actions, must be adapted to fit with local development.

KEYWORDS: Housing, Energy Simulation, Environmental Performance, Refurbishment, Chile.

INTRODUCTION

A large part of human activity takes place within the home, where construction and occupancy generates nearly a quarter of the growing global energy consumption. The Latin American continent has the highest urbanisation rate in the world, with sustained economic growth generating widespread housing development with poor environmental control and a high demand for imported, non-renewable fuels (IEA, 2012). Chile holds an exemplary position in the region, thanks to the country´s extensive support for dwelling and the recent implementation of energy improvement plans and standards for housing. However, there is a lack of detailed background information on home energy performance that could contribute to the design and use of environmental considerations (CNE, 2009). This paper presents a review of housing conditions in the centre-south area of Chile, based on general statistics and an exhaustive study of fifty actual homes, including building shape, materiality, occupancy and environmental monitoring as well as long-time review with energy simulations in twelve of the case studies. Regional experiences in housing design with high energy standards and refurbishment of existing homes were also examined in order to foster effective paths of action to analyse and improve housing energy performance.

1. HOUSING CONDITIONS IN THE CENTRE-SOUTH OF CHILE

The centre-south of Chile (the Maule, Bío-Bío and Araucanía regions) covers about 100,000 km^2 and stretches north-south from 34° 41' to 39°37' latitude and west-east from 71°15 to 71°30´ longitude between the Pacific coast and the Andes mountains. It has a temperate climate with different seasons, maximum summer temperatures between 10° to 25°, winter temperatures of 5° to 15°, relative humidity around 70% with mean rainfall levels close to 1,850 mm/year mostly in winter and mean radiation of 300 cal/cm^2/day. There are nearly four million inhabitants in the zone, mostly living in cities in the central valley and the main metropolitan area of Concepción on the coast. Homes are mainly located in low density urban periphery zones. They are mostly one or two-storey constructions of reinforced brickwork (15cm thick brick walls) and/or timber structure (2"x4" timber framed walls and ¾" timber board or sheet facing) with sloping roofs covered in fibre cement or metal sheeting (CCHC, 2011).

In 1977, environmental concern in the country led to the implementation of a climatic-housing zoning system with design recommendations and a register of construction materials used. In 2000, compulsory standards were introduced for the vertical elements (wall structures) used in housing and in 2007 for roof structures. Maximum thermal transmittance levels for the different building components in the region were fixed at 1.7

$W/m^2/K$ for walls (previously values reached over 2.5 $W/m^2/K$) and 0.4 $W/m^2/K$ for roofs (previously as much as 1.0 $W/m^2/K$ or more) and suspended floors (which are uncommon); limits were also set for overall percentages of glazed areas. In recent years financial benefits have also been offered to install domestic solar heaters or more efficient electric heating equipment and to refurbish existing homes to improve their energy performance, although without setting specific technical regulations (Bardi y Rozas, 2010). A voluntary energy efficiency certification scheme is currently being applied to new housing units comparing different construction materials for the same design. These measures, although far inferior to equivalent European standards, are the precursors in Latin America and have influenced the development of some 200,000 new homes in the region over the last decade. However, it must be noted that over 80% of the existing housing stock in the area does not comply with these standards and will remain in use for several decades yet.

Figure1. Location of the region studied (left), map of urban areas (center), and view of residential zones (right).

1.1. Housing register

Fifty homes were surveyed in order to review the characteristics of housing in the region. Architecture and construction degree students were invited to submit data on their own homes (or those of nearby relatives) and in this way ensure involved and qualified observers. This group of homes was then compared with general residential building statistics to determine how representative they were of the population in general and to select a dozen case studies for more in-depth examination, including energy simulations and environmental improvement studies.

90% of the surveyed homes are located in urban areas (mostly around metropolitan Concepción) and 85% are single-family homes, which matches up with national and regional statistics (INE, 2002; Fissore, 2012), so the subsequent selection of case studies for more detailed review was made from these surveyed buildings. Almost half the houses surveyed are one storey and the remainders with two-storey, and similar distribution of detached constructions and semi-detached, in a variety of layouts. The volumes showed individual shape and wide variety in their design as is typical in the country and indeed in most of Latin America. Building materials are a mixture of brickwork and faced timber structure, both typical in the region.

Floor areas of the houses studied varied between $50m^2$ and 250 m^2, close to twice that on official records, mostly due to the common practice of adding unregulated extensions at ground or roof level, in sites with area around 250m2. The study included both initial constructions and subsequent unregulated but similarly built extensions (in contrast to other countries where illegal extensions tend to differ from the original constructions). The buildings studied were of different ages, from 3 to 60 years old, with an overall average age of 25 years, in line with the age and renewal process of the country´s housing stock.

1.2. Occupancy and infrastructure

The houses studied had an average of 4.9 permanent occupants per unit, rather higher than the national and regional average of 3.6 inhabitants per home (INE, 2005), with an average age of 29.3, similar to statistics but with a predominance of young people between 20 and 25 years of age since the majority were older families, being homes of university students. On this account, the homes chosen for in-depth simulation, were selected from younger families (relatives of students) and average occupancy dropped to

3.8 per unit with a demographic age distribution more in line with general statistics while maintaining a similar size, materiality and shape diversity.

Annual family incomes varied between US$10,000 and US$60,000 per unit, with an average of about US$25,000, equivalent to the middle sector of the national population. Between 5% and 10% of income is spent on utility services, half of this on winter heating costs, which totals between US$250 and US$2,500 per unit annually.

All houses had fully-equipped electrical and sanitary installations with the vast array of domestic goods and appliances corresponding to national records (CDT, 2010) and typical of an emerging economy, including many energy efficiency accessories from national campaigns. They possessed a variety of heating systems (none had air-conditioning) and fuels with wood the most common choice due to its lower cost, but including paraffin, gas and electric heaters, mostly mobile units for occasional and combined use. According to the corresponding power conversion rates, energy consumption varies between 5,000 and 25,000 kWh per year, mostly dependent on family income levels, and not related with size of houses or users.

1.3. Environmental monitoring

Dry bulb temperature and relative humidity digital sensors were installed in the main living space of the fifty homes surveyed for one week. Also, in a dozen case studies, whole campaigns have been set up to monitor environmental performance in summer and winter periods, including the use of sensors in different parts of the house, both aerially and on inside and outside surfaces. Lighting and CO_2 levels are measured, as well as leakage (with blower door tests), thermographic images and local meteorological information are included. There has been some difficulty in managing and visualising data but the results have been consistent with regional estimates and other studies (Sarmiento and Hormazabal, 2003; Fissore, 2012). Indoor temperatures average about 18°, with a variation of ±2° and an average daily oscillation of ±3°, depending on outside temperatures, with relative indoor humidity averaging 75%. These figures are below those of conventional comfort levels and adaptive value calculations (which give a range of between 18° and 24°).

The thermal transmittance and solar radiation variables measured in the in-depth monitoring confirm both the values used in simulations and those set by housing standards. In contrast, the permeability values measured for indoor space proved considerably higher than both national standards and the values used in the simulations, reaching between 1 and 6 air renewals per hour. There is significant variation in these values for different rooms and according to the construction quality (and values are also high in some newly built houses). The thermograms also show significant differences in heat loss and comfort conditions according to the different construction types and interior spaces.

Figure 2. Monitoring of a House.

1.4 Comfort consultation

Normalised surveys (according to ISO 10551/95), interviews and observation were used to reach a qualitative notion of comfort and occupant behaviour. The assessments revealed that occupants were satisfied with their home environment; that is to say, the temperatures detected correspond to required comfort levels. However, those homes with lower temperatures and spending were less satisfied and the interviews revealed considerable variations. Differences were particularly marked within the homes (namely, differences between ground floor and first floor, or north and south-facing aspects), specific locations of heating equipment and timetable disparities between occupants. Thus, comfort levels were dependent on areas within the home and time-related aspects (during the day or year) and hence normalised assessment methods that review global aspects with specific consultations are inadequate to characterise such conditions.

In conversations and visual records other notable determining factors were the place of origin of occupants (when they come from rural or peripheral sectors), age and gender. However, the effects of these aspects are difficult to generalise since they are also influenced by size of family income (and hence spending), HVAC (heating and ventilation) and building quality. Therefore, income levels, which showed considerable disparities, also determine comfort expectations and change progressively with average family age. This situation fits with the expected conditions of an emerging economy with economic inequality and social mobility markedly more apparent with each new generation (AIM, 2008). For example, there is increasing functional disparity between occupants. Family groups are maintained but with increasing diversity in the activities of members of different ages and genders (such as studying or working from home). This can be seen in the low or single-person use of the social spaces in homes and high occupancy recorded in bedrooms as well as their different timetables. Therefore, comfort situations tend to differ from individual to individual (Frontczak, 2011). These personal tensions make conventional comfort measurement assessments as well as constructive solutions more difficult to achieve, demanding spatially and temporally differentiated analysis and resolution strategies.

2. ENERGY SIMULATIONS

There are currently a number of computing systems capable of analysing energy performance of buildings in line with standard methods (ISO 13790:2008-09 and ASHRAE 90.1), including programmes with a broad range of costs and capabilities and, more recently, web-based systems (EERE, 2012). We carried out extensive review of a dozen systems, including installation costs and basic testing, analysis of the same home with each system and interviews with expert users, as well as other studies (Crawley et al, 2008; Attia et al, 2009). A distinction was identified in the programmes between ease of use and range of capabilities. On the one hand more expensive and complex programmes used in larger-scale projects or by users with more expertise. On the other hand free, simpler systems that demonstrated rapid processing but with implementation difficulties and broad, limited results. These programmes can be used from time to time by professionals to obtain individual and preliminary estimates. The more advanced systems required greater effort at the processing stage but provided precise and diverse analyses. Then, they can be used by experienced users for more extensive studies in large-scale projects. Some intermediate programmes achieve good usability and technical attributes, and also provide information interchange. Following this review, a combined use of modelling software (Ecotect or Design Builder) was determined suitable with a complete calculation engine (EnergyPlus), Excel spreadsheets for analysis, and building information system (Revit) for design and documentation.

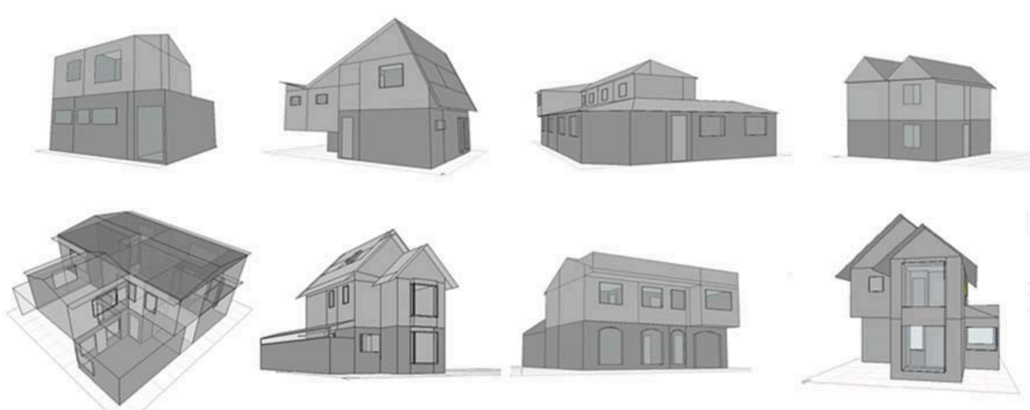

Figure 3. Some models of houses simulated.

2.1. Modelling of houses studied

Detailed studies of energy analysis of a dozen homes are being carried out by the same students living there or by their relatives. The weather information was established with IWEC database and local stations for verification. Geometric elaboration was regularized with initial outlines of measures on field that were then exported in dxf to generate thermal zones in the energy modelling software, controlling the superposition of planes and insertions of openings, as well as basic surroundings. Data consistency was verified due reiterated difficulties. The materials of each plane were defined in order to calculate thermal transmittance values for each building envelope according to the measurements taken. Calendars were drawn up for occupancy and for use of services according to the collected data. The process was normalized with a tutorial and group sessions.

2.2. Initial results

The modelling process took several hours for each case over a number of sessions, while the complete data was recorded and initial learning aspects and difficulties with the programmes were overcome. In the initial sequence of simulations information about climate, materiality, occupancy, heating and ventilation was verified generating variations of 5% to 10% in the results. Comparative simulations were then carried out between all the case studies (called the "base simulation") with a comfort range according to adaptive value calculations of between 18° and 24° and 2 air renewals per hour, according to mean recorded values.

The energy demands in the base simulation of all the houses analysed were mostly for heating over the winter period with heat loss through vertical elements of the vertical building envelope. Global heat loss variables were between 3,000 and 30,000 kW/year and between 50 and 200 kWh/m^2 (for surface area), values consistent with estimates for the region and recorded consumption although distribution is somewhat different. Higher values occurred in the larger houses and highest losses per surface area were in the older homes in poor condition. All houses built over this decade have transmittance values of below 100 kWh/m^2 , due to incidence of recent thermal transmittance regulations and an overall improvement in building execution. Energy demands according to different zones within the home show significant disparity due to geometric and building configurations. Annual and daily fluctuations in indoor conditions respond to weather patterns so differences in location and solar orientation seems doesn't have great influence in the demand.

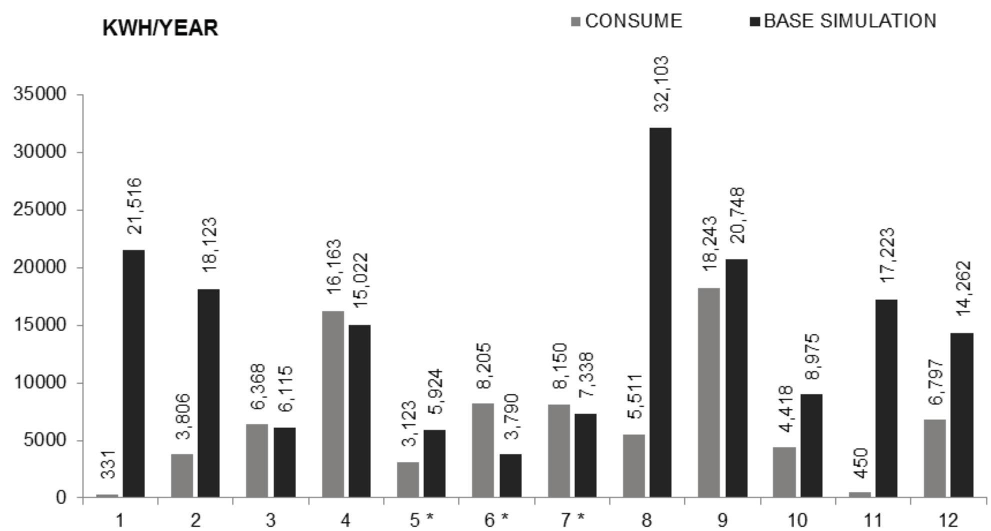

Figure 4. Results of energy consume by actual expenses and energy demand by base simulation.

2.3. Simulation adjustments

Several simulations were then carried out that were differentiated according to each case to achieve modelling equivalent to the real situation (called "adjustment simulations"), reviewing some details and modifying comfort and air renewal values according to individual recorded values since substantial differences were noted due to these factors. Results regarding demand were calibrated to recorded consumption levels, while also reviewing temperatures detected, infiltration test results and occupancy and heating calendars. Comparison with base simulations showed a similarity in some cases (in the more regular buildings) and considerable disparity in others (particularly lower income homes with low expenditure). Comfort levels rose in newer homes and by modifying certain variables in two or three further simulations values came much closer to real consumption levels. The oldest buildings in poor condition achieved much lower comfort levels (with a minimum of as low as 14°), thus increasing the number of building refurbishments. Therefore, infiltration and temperature levels present the greatest oscillations when seeking a reliable analysis of house building in the region.

2.4 Energy performance improvements

A number of design and construction measures have been suggested to improve environmental conditions in houses, in particular through some studies and experiences in the region (Trebilcock et al, 2003, Bustamante et al, 2005; Bustamante, 2009; Hatt, 2012, Carrasco and Kokogiannakis, 2012). These initiatives emphasize to increase thermal transmittance of the building envelope and implement servicing systems to recuperate heat or make use of solar absorption. Some advanced new-build houses with high energy standards in the region have proved the economic and technical feasibility of these possibilities, although without considering large-scale developments or demonstrating their real effectiveness once implemented. This research work seeks to provide specific energy performance improvements with massive possibilities, based on the analysis carried and verification of some proposals as following;

a) Geometric relationships of housing volume to reduce energy demand; comparative simulations were carried out on a single home with different shape configurations and orientations that demonstrate the incidence of volume compactness and contiguity in almost half of the energy demand and also lowers surface areas of outer walls and air volumes to be heated, pointing to the advantages of more densely built and terrace-type housing.
b) A procedure to design and evaluate insulating and sealing outer facing material, based on refurbishment experience carried on in existing homes. Energy simulations and budget calculations have demonstrated substantial improvements in comfort and energy efficiency with initial investment that can be recouped in only a few years. Monitoring occurred prior to and following installation and experts and inhabitants were consulted to verify performance, technical viability and social acceptance, with a number of alternative finishes used to incorporate diversity.
c) Parametric devices, as small-scale solar spaces added to some homes to capture passive solar radiation in thermically weak areas of the house. Sealed and insulating divisions in circulation spaces to separate different thermal zones within the home, in order to compensate and concentrate heating efficiency. Simulations and constructions are underway to test these devices to determine feasibility, performance and acceptability in homes.
d) A prefabricated housing design is being worked upon, with support from a local industry, including a number of extension and internal layout options, with highly insulating and heat absorbing perimeter components. Energy simulations, digital and material modelling is made to review behaviour, costs and appearance, as well as consults to industrial partners, agencies and users.

Any general use of these measures requires a reliable and integral assessment process of the design, building process, economic feasibility and occupant acceptance for a variety of case studies. Energy simulations adjusted to real living conditions lie at the heart of this process, interwoven with constructive modelling, budget analysis and financial and social validation processes.

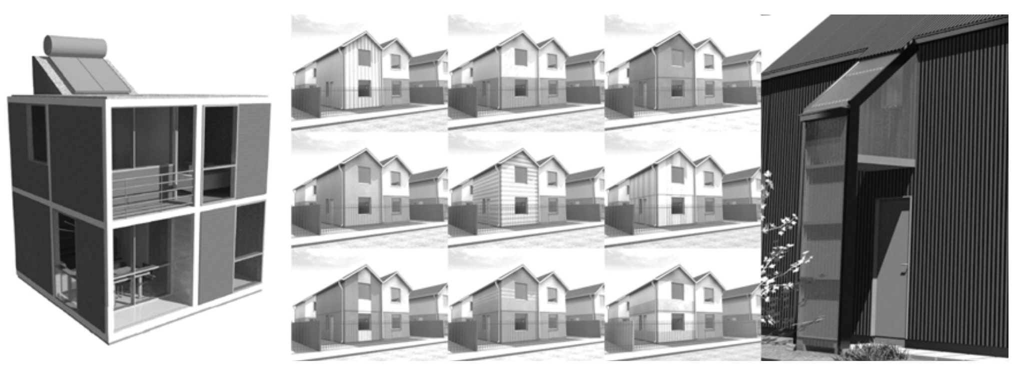

Figure 5. Prototype of energy efficiency-housing (left), alternatives of refurbishment with external insulation (center) and addition of solar space and door protection (right).

CONCLUSIONS

The review of living conditions in the centre-south of Chile reveals a predominance of diverse detached single-family homes with high and differentiated energy consume and reduced comfort levels, that are generally accepted by inhabitants although considerable disparities are detected within the different areas of each home. Energy simulation systems can be applied to these residential buildings and, with moderate effort in modelling selected case studies in a number of programmes, it is possible to estimate environmental improvements fairly accurately. Climate data can be regulated, as well as geometrical configuration, building conditions and occupancy. Simulations take into consideration both adaptive comfort and relatively high permeability. Significant variation remains concerning the diverse needs of individual occupants and existing cold bridges and air infiltration in buildings. These aspects are linked to individual expectations and building quality respectively. They seem to be influenced by family income levels and personal background, expressed in a preference for a variety of basically habitable spaces with individual internal divisions in terms of use patterns and comfort needs.

Energy efficiency improvements involve consolidating building volume and materials, sectoring and draught-sealing living spaces and incorporating passive solar heating or efficient heating systems. These measures can all be assessed with a combination of constructive modelling, energy simulation, budget studies and occupant consultation tools. These procedures would serve to determine the differential economic and social feasibility and promote effective refurbishment or new-build measures in either private projects or large-scale development programmes. This study exposes a novel strategy of review and improvement for residential areas, that reveals a conjunction between life expectations and construction quality, through analysis and appropriate actions, must be adapted to fit with local development

The next step for this research is the creation of an integrated system of analysis of energy performance, construction and economic aspects, with social visibility to demonstrate, in some cases, the use and effectiveness of energy efficiency improvements in the home.

ACKNOWLEDGEMENTS

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Digital Tools for Masonry Design and Construction

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ABSTRACT: One view of conceptual design in architecture is as a negotiation between materials and forms. The process of configuring materials: organizing them, ordering them, arraying them emerges in the creative nature of design practice and the underpinnings of this process are embodied in the tools of architectural inquiry, traditionally: sketching, diagramming, modeling and drawing, and now in the digital age: another form of modeling, in design scripting, and in simulation. Two paradigms dominate digital design tools – surface modeling tools that provide few formal boundaries and no feedback on material realities – and material-aware building information modeling tools that are pre-coded with material and assembly logics. This paper focuses on the difficult middle ground, on design tools, envisioned by architects and technologists, that seek to preserve design flexibility, while embedding design reasoning and material logics. The focus is on masonry materials and systems. Masonry has come late to BIM because of its many forms, types and patterns and because its ability to adapt to complex shapes, make it difficult to instantiate in current BIM platforms. This paper reviews and analyzes four notable masonry buildings, and envisions the computational tools that would support the design, detailing and analysis of these buildings. It represents one component of a comprehensive project, funded by the masonry industry, to develop a software specification and workflows for integrated computational tools to support masonry design and construction.

KEYWORDS: parametric modeling, building information modeling, BIM, masonry

1.0. INTRODUCTION

Contemporary architectural practices engage a wide range of digital tools for the exploration of complex forms. The use of surface and solid modeling allows for the rapid generation of formal propositions – but with few clear strategies for assessing the structural or constructional implications of these propositions. CAD systems that are based on parametric modeling and design scripting facilitate the process of geometric generation, but do not host the semantics necessary to assess the implications of complex geometry. In sophisticated practices, architects embed their knowledge into the models implicitly, and argue that the means of architectural production map in some way onto the means of building production – thus making the implicit explicit (Schön 1992). Other design practices rely on specialized architectural consultants such as Front and Gehry Technologies to help “rationalize” their forms, via the creation of sophisticated parametric models imbued with the consultancy’s fabrication knowledge (Derix 2009). This material agnostic or *amaterial* approach to conceptual design is generally supported by surface modeling tools such as Rhino, form-Z and Maya.

A second approach in the development of building propositions lies in the use of building information modeling or BIM tools, in which the geometric descriptions of architectural elements such as walls, columns and beams are instantiated within a parametric model, and geometric elements are linked to functional descriptions of the objects. This geometric-functional linkage, embedded in the software by its developers, allows the BIM software to assist the architect by negotiating between building objects as they are placed and refined in the building model (Lee, Sacks et al. 2006). A potential limitation of the BIM approach is that the geometric-functional linkage is supported primarily for normative construction assemblies, and generative ideas beyond these norms are not supported. In addition, early-stage conceptual design is not easily accomplished in BIM environments, as the geometric-functional linkage cannot be asserted early in a design process where floor plates, column grids, and elevations are as yet undefined.

The amaterial and the BIM approach are not mutually exclusive, and in many design practices it has become the norm to start with a surface model and transition to BIM at the later stages of design. This transition leads us to consider the role and integration of material knowledge into the models in both phases: do the early surface models require a consideration of materiality and structure or can such considerations be delayed until later stages of design when BIM tools become more relevant? At what point in the building design process does the architect wish to consider materiality and constructed systems? At this earliest consideration, how should the materials be modeled? What material feedback is desired by the architect? In this paper, these questions are asked specifically for buildings constructed with masonry materials. The project reported on in this paper is funded by a wide range of masonry industry participants including material suppliers in clay and concrete masonry, professional societies, mason contractors, and labor unions. The goals of the project are to identify the masonry materials and systems that should be represented in building models, develop the data schema for their computational representation, and interfaces through which architects will interact with this masonry knowledge.

Prior work by the author and his colleagues has focused on embedding masonry knowledge in early-stage design tools, which are useful for formal explorations of load bearing masonry prior to BIM (Cavieres, Gentry et al. 2011). The work has also considered the structural implications of complex masonry configurations, and means to model and analyze non-planar masonry structures (Gentry, Al-Haddad et al. 2011) and has demonstrated the parametric modeling and structural principles developed through the research in a small-scale constructed demonstration (Al-Haddad, Gentry et al. 2012). A forthcoming work describes the requirements for masonry BIM as a function of stakeholder viewpoint and project phase (Gentry, Eastman et al. 2013).

This paper looks briefly at four buildings to consider a series of questions about architectural design, material feedback, and the role that masonry plays in contemporary practice. Through each example, the functional considerations regarding masonry design and the scripting and building modeling that could have been brought to bear in support of the case-study designs are described. These considerations are speculative, as the masonry software envisioned by the research does not yet exist. Therefore the process is one of inferring the knowledge of the architect, speculating about intentions and design process, and then envisioning the software functionality required to support the architectural endeavor. Where possible, the viewpoints of the architects – and their position on masonry and the resulting building is considered in light of the technical challenges faced by their choice of masonry.

2.0. PERSPECTIVES ON MASONRY DESIGN AND CONSTRUCTION

The motivation for and trajectory of this paper is based on a number of observations regarding masonry design and construction in the United States. From the author's perspective, they are objectively true, but some are difficult to establish by citation. First, architectural knowledge regarding masonry design, detailing and construction, and especially the use of load-bearing masonry structures, is waning. The same is true of structural engineering knowledge regarding masonry – especially in non-planar forms of load-bearing masonry (Heyman 1997). At one time masonry was the pre-eminent architectural and even structural material, but the development of new load-bearing orders and lightweight facade systems, coupled with the desire to construct faster and with fewer workers on-site have reduced the perceived competitiveness of masonry systems (Sweis, Sweis et al. 2008).

In addition, modern architecture has had an ambivalent relationship with masonry: the rigid frame of steel or cast-in-place concrete and the curtain wall skin led to the dematerialization of design ideas, and masonry construction is at the heart of materiality (Collins 1998). In his *Pathos of Masonry*, Moravánszky documents Alvar Aalto's struggles to create a an architectural setting for materiality in a modern masonry proposition: Baker House on the MIT campus (Moravansky 2002). In the end, it seems that Aaltos's decision was one of texture, and the brick he chose for Baker House was a wood-molded, sun-dried brick, and the variation in the brick's surface and color was inherently linked to Aalto's view of the building proposition (Charrington and Nava 2011). Compare this to Wright's choice of brick for the Johnson Wax building, and his search for brick companies that could produce bricks in a wide range of custom sizes, to exacting tolerances, all while holding the brick color constant (Lipman 1986).

This example reinforces the obvious conclusion that masonry is selected for a wide variety of reasons, from the pragmatic, e.g., to meet municipal or campus architectural guidelines, to the sublime, as in Piano's IRCAM Extension in Paris (Davies 1989) – where bricks in stack bond are locked into steel grids, but are not mortared. It is difficult therefore to imagine a set of digital tools that support the full range of architectural speculation on masonry. Nevertheless, a series of guiding principles can be established. First, modern examples of masonry design envision the cladding of complex forms, and the computational environment for brick design must support and manage this complexity (Mitchell 2005). Second, the early stages of architectural masonry design focus on masonry rationalization – defined here as understanding the relationships between architectural objects, and their dimensions and placement; masonry patterning; and masonry unit dimensions. Third, to understand these relationships, and permute them during design, the objects and patterns must be represented parametrically, so that variations in pattern and geometry and can adjusted without the need to continuously remesh and remodel. To this end the work of Schumacher (from the theoretical perspective) and Aish (from the implementation perspective) are particularly relevant (Shea, Aish et al. 2005, Schumacher 2009). And finally, any computational environment developed for early-stage masonry speculation must be linked to later-stage structural analysis, detailing, and contract document production.

3.0. MASONRY BUILDING CASE STUDIES

In this section, four building case studies are presented and briefly discussed to consider the interaction between architect and elements of design specific to masonry, and to illustrate the software tools needed to support this interaction (essentially a process of reverse engineering). The interaction is between architect and the conception of masonry – the design idea of masonry, abstracted at first and then clarified through the design process. Ponce de Leon and Tehrani describe these conceptual tenets as the "geometric and syntactic laws permitted by particular units of construction" (Ponce de Leon and Tehrani 2002b). The case studies do not provide a complete description or analysis of the buildings, but focus only on those decisions that impact the design and construction of the masonry. These buildings are: the Johnson Wax Building by Frank Lloyd Wright, the Tongxian Gatehouse by Office dA, Yale University Health Services by Mack Scogin Merrill Elam Architects, and the SPSU Design Studio II building by Cooper Carry Architects.

3.1. Johnson Wax Building

Frank Lloyd Wright's Johnson Wax Building was constructed in two phases, with the administration building completed in 1936 and the research tower completed 8 years later in 1944 (Fig. 1A). The buildings are constructed with reinforced concrete interior columns and cores, and a load bearing reinforced masonry exterior. The masonry exterior, with a curved geometry inspired by the streamlined moderne, is a two-wythe brick wall, laid in running bond, and bounding an interior layer of cork insulation, with copper ties bridging the cork and joining the two reinforced wythes (Lipman 1986). One layer of brick acts as the exterior finish, and the other as the interior finish. The brick-clad forms include straight walls, radiused walls, and walls with transition from straight to round. Over 200 types of custom brick were made for the building by the Streator Brick Company, all in Wright's signature Cherokee Red color. To accentuate the horizontality of the building, the vertical masonry joints were struck flush, and painted or mortared red. The horizontal joints were deeply raked. Many of the wall segments float above the ground over openings, and are supported by steel lintels integral to the reinforced masonry structure.

The archival record does not identify the mason contractor for the building, or whether masonry shop drawings were completed for the project (though this is unlikely). Regardless, a team of detailers in Wright's office or in the mason contractor's office was required to rationalize Wright's design, in terms of the number of types and design of the custom brick. Photographs of the construction indicate that tight control of the vertical running bond joints was achieved, meaning that straight-sided, radiused and transition bricks (bricks that start straight and initiate the radius) were required for the project – as the radius in many of the curved walls was too small for these curves to be created with cut straight-sided brick (Perlman 1993). Because the project contained brick in the interior as well, a matching set of bricks with offset radii were required for the interior walls. In addition, Wright's bricks for Johnson Wax were specially textured on the back side, to ensure that they would bond with the concrete cast behind them.

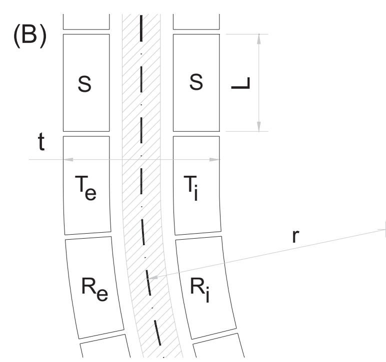

Figure 1: (A) Johnson Wax Building, Frank Lloyd Wright, base of research tower (image credit: Wei Ping Teoh), (B) Five .brick types needed to achieve straight wall transitioning to curved wall of a given radius (r).

What computational approaches could be taken to rationalize Wright's masonry design – and to support the design, analysis and detailing required in contemporary practice? First, all wall plan and elevation dimensions could be checked and adjusted to verify that they were integral to the brick modular length and height. Second, bricks could be defined parametrically as straight (S), radiused (R) or transitioning (T) and the dimensions for these bricks could be calculated automatically from the centerline geometry of the walls. In the example shown in Fig. 1B, it is shown that five unique bricks are required to achieve a straight wall section that transitions to a section with a circular radius. In addition, if bricks of a given modular stretcher dimension L were desired, then the masonry computational model could adjust the radius (r) or overall thickness (t) of the wall in order to ensure that the radiused portion of the wall could be constructed with an even incremental number of bricks. A computational model of the desired geometry could be used established whether the desired geometry could have been achieved with few custom bricks, by using cut bricks or a small number of radiused brick.

3.2. Tongxian Gatehouse

Office dA designed the Tongxian gatehouse as the first of multiple planned structures for an artist colony in Tongzhou, Beijing, China (Ponce de Leon and Tehrani 2002a). The architects describe their motivation in the design of the gatehouse (Ponce de Leon and Tehrani 2002b) as follows:

> ... the visible deformations of the body of the building are, at once, the result of programmatic pressures that guide the form, and also the result of geometric and syntactic laws permitted by particular units of construction ... in this project we have used brick as both formwork and finish, thereby securing an unmediated relationship between the bonding, its layout, and the ultimate effect.

In this case, the unit of construction is brick masonry, laid in Flemish bond, with many of the brick headers corbelling out from the surface mean. The masonry walls share some aspects of the Johnson Wax building, as they are mortared in place from behind, becoming molds for the reinforced concrete walls that support them. In many locations the walls are two-sided – with an interior and an exterior brick condition. The reinforced concrete walls that support the brick allow for a significant cantilevered condition on the front of the building, and some of the walls are non-planar and non-plumb.

In the Tongxian gatehouse, as compared to Johnson Wax, the parametric modeling of the brick façade is not dependent on rationalizing the number of types and configuration of the bricks, but rather on the rules that govern the texture created by the block headers (Fig. 2). The patterning required is envisioned to occur in two steps. First, the brick coursework in Flemish bond must be mapped onto the NURBS surface. This task is simple if the surface is planar, but is complex if the surface has single curvature and even more so as the surface becomes doubly curved. Algorithms for locating the bricks on a doubly-curved surface, and meeting the bonding requirements to the greatest degree possible, have been discussed by Cavieres et al (2011). As the curvature of the walls increase, individual mason units must be cut, and mortar joint thickness must be adjusted meet the masonry bonding pattern. The algorithms can provide feedback to the designer as to whether the curvature envisioned can be met without wholesale cutting of masonry units, or result in the general dissolution of the desired bonding pattern. In the Tongxian gatehouse, most of the walls are essentially planar, and the modest curvature is easily accommodated within the mortar joints, without apparent cutting of masonry units. This seems to support the architects' intentions to adhere to the systems geometric and syntactic laws. The second task in modeling the brick façade on Tongxian is to establish rules for describing the corbelling of the brick from the mean surface. This is relatively simple to imagine, with one NURBS surface representing the mean plane of the wall, and a second offset NURBS surface representing the extrusion of the headers out from this mean surface.

Figure 2: Tongxian gatehouse by Office dA (image credit: Nader Tehrani, NADAAA).

The presence of non-planar walls in the Tongxian gatehouse leads to significant structural questions in this reinforced masonry – reinforced concrete hybrid. An important requirement for architectural modelling in this example is the linkage between the architectural model and the structural analysis of non-planar eccentric walls. To facilitate this interaction, the mid-surface of the structural portions of the walls, whether of reinforced concrete or masonry, needs to be tracked in software, and the boundaries of the walls, with openings, needs to be translated into a finite element model for analysis of gravity and lateral loads. The basic functionality for the structural analysis (for planar walls) is available in commercial software (Lashway and Troop 2008), but the facilitated exchange of information between architectural and structural masonry models does not yet exist.

3.3. Yale University Health Services Building

The Yale University Health Services Building was designed by Mack Scogin and Merrill Elam architects with construction completed in 2010 (Fig. 3(A)). The building features a non-planar brick facade, with some walls more than 2 meters [6 feet] out of plumb. A custom bull-nose brick was designed to serve both architectural and engineering requirements: to add visual depth to the facade and to engage the mortar bed joints for the transfer of eccentric loads to the masonry backup system (Fig 3(B)). The design and engineering of the building facade is extensively described in a recent paper by the design team (Filloramo, Scogin et al. 2011).

The complex brick facade led to many design challenges – most of which were addressed through the use of surface modeling and design scripting tools and are documented by the team in their recent paper. The first is the situation of rectangular plan door and window openings in a warped (non-planar) facade. In this case, the magnitude of the warping was mild enough to allow for a planar jamb and proper flashing of the windows. The second is the documentation of wall out of plumb-ness, which was necessary for the construction of the planar steel stud backup system. Horizontal slicing of the surface model was used to determine the number of bricks in each course, and to establish the elevations for window and curtain wall rough openings.

The Yale design team made extensive use of physical mock-ups to understand the detailing and construction aspects of the canted masonry system – including window openings and masonry coursework. It is unlikely however that they were able to generate a computational solid model of all of the brickwork on the facade, to assess the termination of the brickwork coursing at the non-orthogonal curved boundaries of the NURBS surfaces (Fig 3(C)). Software for propagation of individual masonry units in non-planar arrays, within a solid modeling environment does not exist at this time, and is an ongoing focus of the research initiative supporting this research.

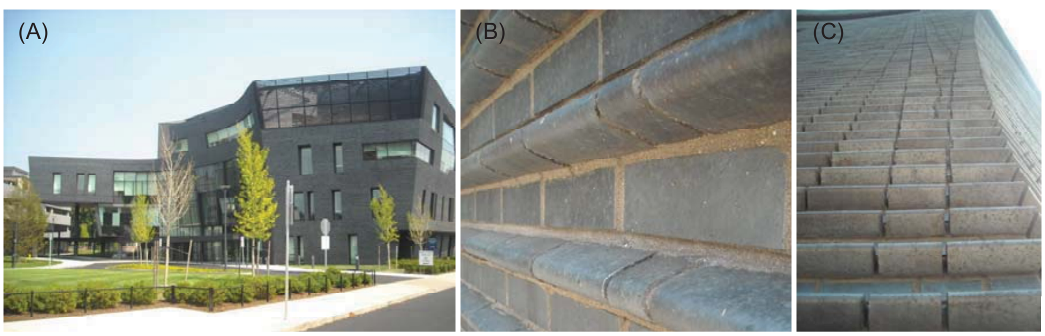

Figure 3: (A) Yale University Health Services building by Mack Scogin Merrill Elam Architects, (B) detail of bullnose brick, (C) brick coursing at non-orthogonal corner (image credit: Tristan Al-Haddad).

3.4. SPSU Design Studio II

The Southern Polytechnic and State University, Design Studio II building was designed by Cooper Carry Architects. The reinforced concrete building features four brick facades with a rotating brick that is indexed along the facades (Fig 4(A). Every other brick course is a typical stretcher course, which bonds the units together in a continuum. The architects developed the idea of the masonry patterning in discussion with Jollay Mason Contractors, who mocked up the generative idea during early conceptual design (Fig. 4(B)). The project was delivered using a conventional CAD/BIM process, and the architects provided detailing of the brick coursework that allowed for the templating of the masonry wall during construction. Details specific to the installation included the use of stainless steel ties and heavy gage adjustable anchors between the brick wall and the concrete backup wall.

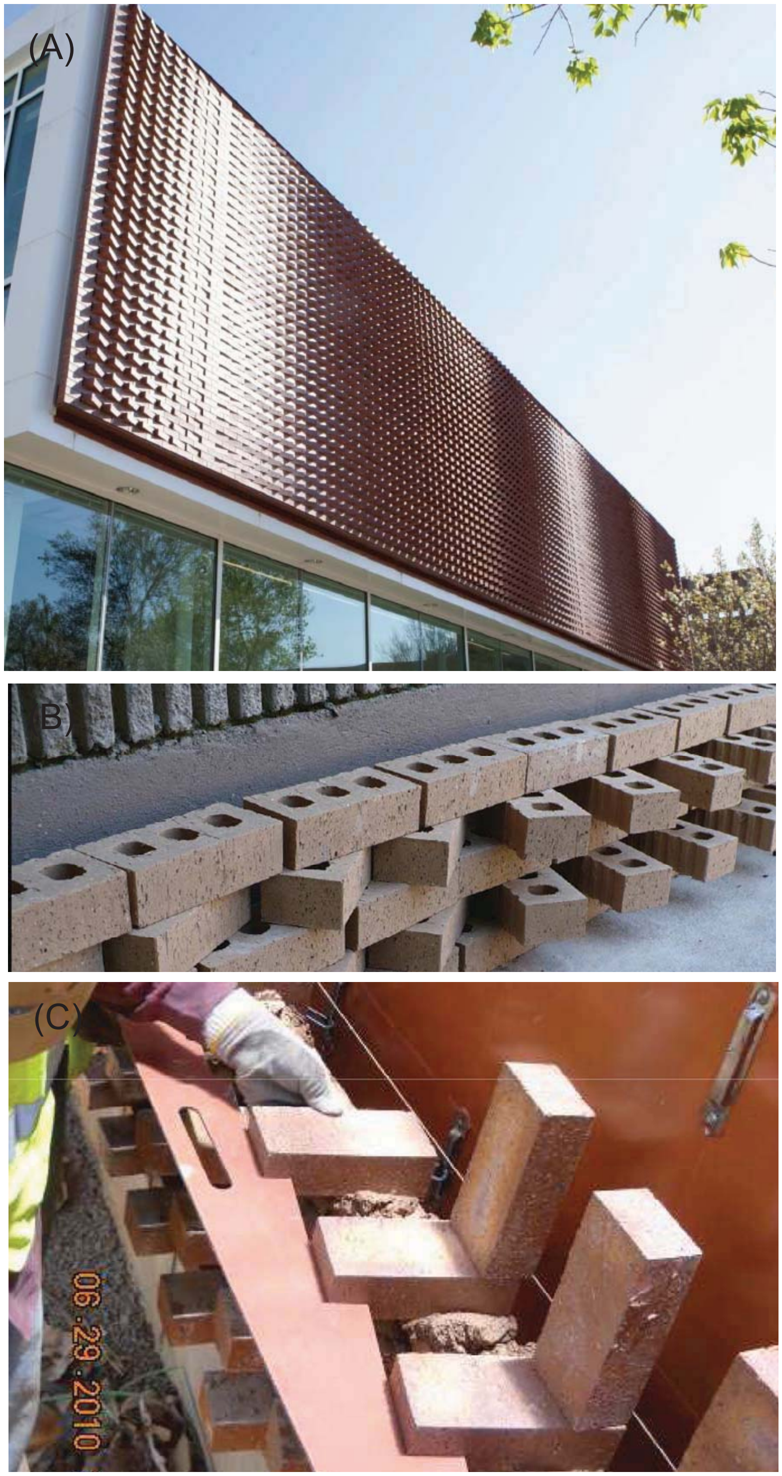

Figure 4: (A) Southern Polytechnic State University, Design Studio II, by Cooper Carry Architects, (B) conceptual strategy of brick coursework, (C) templating of rotating brick during construction (image credit: Cooper Carry Architects).

In this case, the primary use of a computational design tool for masonry would be the automatic instantiation of the brick coursing rule onto the plane of the facade, allowing for parametric variation of the pattern as a function of the various facade dimensions. In discussions with the design architects, it was clear that they desired to assess the visual impact of the moiré pattern of the bricks through visualization, and especially the comparison of the effect on facades of various lengths, before committing to the design idea. In addition, the use of the computational model to drive the CNC fabrication of the templates was made easy due to the modeling completed by the architects.

CONCLUSION

These four case studies demonstrate a wide range of design strategies and the potential for computational modeling in architectural masonry. Though it unlikely that any one closed-form computational tool can represent all of the complexity demonstrated in these four buildings, a few conclusions regarding masonry computation for early-stage generative design in masonry can be made. First, the relationship between the masonry coursing and the underlying NURBS surface must be represented. If the masonry bonding patterning takes precedence, then the boundaries of this surface must be adjusted carefully to adapt to the coursing rules. This seems to have been taken place in the Tongxian gatehouse, for example. In some cases, the bonding pattern rule can be linked to an overall surface dimension (SPSU). If, the bonding pattern must conform to non-orthogonal boundaries, then rules for adapting the pattern must be established and assessed (see Yale Health Services, Fig. 3(C) for example). Second, these patterns are likely to vary from region to region on many masonry buildings, and thus the computational tool will need to provide support for negotiating the coursing at the boundaries. Appropriate responses could be adjusting the size of regions to best accommodate the natural bonding dimensions of the masonry, adjusting mortar joint size to accommodate the bonding pattern within the specified region, or the cutting of masonry units. Finally, the transition from surface modeling to BIM must be accompanied by the ability to represent individual masonry units as solids within a parametric modeling environment – so that the “geometric and syntactic” implications of the masonry systems can be assessed in the context of complex geometry.

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Making Visible: Creating an Architect's Guide to Customized Repetitive Manufacturing

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ABSTRACT: With the use of computer numerical controlled (CNC) equipment, architects and manufacturers have been working together to customize the molds, jigs, or patterns used in repetitive manufacturing for specific project design's building components. I am proposing the term 'customized repetitive manufacturing', or CRM, to reference this type of work. CRM is a necessary alternative to mass customization for the manufacturing of architectural components. CRM includes those repetitive manufacturing processes with relatively low capital costs and that can support low- to mid-volume production runs of repeatable objects. CRM allows for customization from the designer, while balancing the need for repetition in order to remain cost effective. This balance makes CRM easily applicable for the custom design of architectural components.

This paper will make visible architects and building designers that have used CRM for their building designs. Through my research, I have selected twelve recently completed case studies; each of the case studies customized a different repetitive manufacturing process. Unfortunately, through my research I have found a lack of resources that are available to educate architects about customizable repetitive manufacturing processes. This paper will demonstrate that there is a need for a resource that illustrates the possibilities of customized repetitive manufacturing to architectural design.

KEYWORDS: architecture, building components, customization, repetitive manufacturing

INTRODUCTION

In recent years, mass customization and computer-aided manufacturing (CAM) technologies have transformed design and off-site building component fabrication. Simultaneously, traditional repetitive manufacturing still dominates the majority of the production for architectural components. The benefits of repetitive manufacturing are that it produces objects quicker and often at a lower cost than CAM. At the same time, CAM's computer numerical controlled (CNC) machines have also made the fabrication of molds for repetitive manufacturing easier. CNC milling machines, electrical discharge machining (EDM), and hot-wire foam cutters are used to create molds for repetitive manufacturing. With the use of CNC equipment, architects and manufacturers have been working together to customize the molds, jigs, or patterns used in repetitive manufacturing for building components used in a specific project's design. I am proposing the term 'customized repetitive manufacturing', or CRM, to reference this type of work.

CRM is a necessary alternative to mass customization for the manufacturing of architectural components. Since CRM is defined by a customized and yet repetitive manufacturing process, the manufacturing processes included in CRM must make repeated use of the mold, patter, or jig in the production of the component. In other words, components must be designed to be used in multiples. At the same time the production runs of CRM are relatively small, as they may only be used to create components of a particular building's design. CRM includes those repetitive manufacturing processes with relatively low capital costs and that can support low- to mid- volume production runs of repeatable objects. CRM allows for customization from the designer, while balancing the need for repetition in order to remain cost effective. This balance makes CRM easily applicable for the custom design of architectural components. Through my research, I have selected twelve recently completed case studies, with each of the case studies having customized a different repetitive manufacturing process. The case studies are located around the world and demonstrate a global application of this approach. To demonstrate the relevance of CRM to today's architectural practice, I have limited the case studies to buildings that have been completed in the past 15 years. The wide range of case studies demonstrates that architects are interested in customizable repetitive manufacturing for building design.

This paper will make visible architects and building designers that have used CRM for their building designs. Unfortunately, through my research I have found a lack of resources that are available to educate architects about customizable repetitive manufacturing processes. This paper will demonstrate that there is a need for a resource that illustrates the possibilities of customized repetitive manufacturing. This paper will make visible existing case studies of this work, establish parameters for these processes, and show sample architectural applications. The long-range goal of this project is to demonstrate to designers and architects that there are numerous repetitive manufacturing processes available for customization.

1.0 CUSTOMIZED REPETITIVE MANUFACTURING

1.1. Overview

Manufacturing is "to make from raw materials by hand or by machinery… especially when carried on systematically with division of labor" (*Webster's Dictionary* 1988). Repetitive manufacturing is the "continuous production of similar products on relatively fixed production lines" (Steiner 1981, 35). Repetitive manufacturing reuses its jigs, molds, and patterns to create similar products. Although repetitive manufacturing often uses computers to run the machinery, it is distinct from CAM. In CAM, CNC equipment uses a computer controlled tooling to shape directly the manufactured item. Once programmed into the computer, alternative shapes do not necessary slow down a CNC machine or alter its operation. For CRM, I am excluding those manufacturing processes that use CNC equipment to manufacturer repetitive objects.

The production runs for repetitive manufacturing is varied and it can range from prototypes and small batch productions to over high volume productions that produce over 1 million units. The production run length is dependent on the process, the material, the labor, and most often the cost of the mold. For example, because of the low capital costs to make a pattern, sand casting can be used for small batches. Conversely, plastic blow molding, which is used to make prescription pill bottles, is more appropriate for high-volume production. Often the product's production run offsets the production costs, so that high production runs are necessary for processes that have high capital costs. For example, if a mold costs $50,000, but produces 100,000 units, the added cost of a custom mold would be just 50 cents per unit.

Customized repetitive manufacturing balances the value of repetitive manufacturing with the ability of the designer to customize a repeated building component. Customized repetitive manufacturing can make best use of those processes that require low-to-mid volume production runs. Since architects are most likely to use customized repetitive manufacturing on a building-by-building basis, I focused on those repetitive processes that have production runs under 10,000 units. 10,000 units may seem high, but if we consider exterior facing materials such as brick, terra cotta tiles, or metal panels, 10,000 units is easily achieved. For one of the included case studies, Hierve Diseneria used 7,723 CRM wood-molded, blown glass spheres on the Hesiodo, a 27,000 square foot apartment building in Mexico City.

Customized repetitive manufacturing has a number of valuable benefits. First, this process reuses its jigs, molds, or patterns during production. Depending upon the mold, the process, and the medium a mold can produce up to 500,000 units. Secondly, repetitive manufacturing typically only use as much materials as the mold, pattern, or jig needs. By reusing tools and reducing raw material requirements, customized repetitive manufacturing can have little to no production waste. Next, manufacturing tolerances for most of these processes are high and have the potential to rival the tolerances of CNC equipment. Fourth, because each unit uses the same design, the soft cost most likely will be lower than CAM (Pillar 2004). Next, because of typically low capital costs, designers can customize the molds, patterns, or jigs, with limited additional costs. Finally, there is a range of materials and processes that are available in repetitive manufacturing for customizing.

1.2. CAM and CRM

The use of CNC equipment has made it much easier to fabricate molds for customized repetitive manufacturing. Machines such as electronic discharge machines (EDM), water-jet cutters, and CNC routers allow for a faster and therefore less-costly way of manufacturing molds. This causes a tension between CAM and CRM. CRM is dependent on the technology of CAM in order to bring mold costs down, while at the same time it is an alternative to CAM. CRM relies on the balance between a particular production run that will distribute the molds' costs over a particular number of units while at the same time keeping the costs of the molds down so that each mold can be customized to a particular project. Because of the tension caused between CAM and CRM, this paper will use as its case studies only those projects that have been completed in the past 15 years. This ensures that the designers had the option of choosing CAM for their building component fabrication needs, but still choose CRM as the alternative.

1.3. Outcomes

There are a number of historic examples of the use of customized repetitive manufacturing. Examples include Frank Lloyd Wright's textile concrete blocks (c. 1923), R. Buckminster Fuller's thermoformed metal or plastic prefabricated bathroom for the Dymaxion House (1940)[1], Harrison & Abramovitz's stamped metal aluminium panels for the Alcoa Building (1951), or Gio Ponti's pressed glass tiles for the Denver Art Museum (1971). At the time these projects were completed, the molds most likely would have been fabricated by hand and would have been very costly to produce. A large production run would have been necessary to offset the mold's costs. In search for high production runs to offset mold costs, Wright and Fuller designed their architectural component with the possibility for mass-production. Similarly, DAM uses a large number of the custom tiles on both on its interior and exterior walls and the Alcoa Building is a high-rise; therefore both buildings are making use of a high-volume of produced units.

2.0 CASE STUDIES_12

This is a selected list of case studies of architects and building designers who have used CRM in their buildings. The selected case studies are of components that are neither intended for mass production nor available for mass consumption. There are of course numerous examples of architects who have gone into product design (e.g. Michael Graves) and of architects that have designed building products (e.g. Zaha Hadid's lever doorknobs and Robert A.M. Stern's light fixtures) for mass consumption. Both mass production and conception requires that the designs be speculative; they are for products that are either available for retail and are intended to be placed in buildings not yet designed. All of these case studies are examples in which the architect customized a component for a specific architectural design. The architects and building designers have customized the building components for a particular project.

The case studies are organized in reverse chronological order with the most recent examples first and the oldest examples last. Each case study was selected to represent one particular repetitive manufacturing process. There are many more examples of CRM in architecture, but I focused on the best examples of an architectural application of a particular repetitive manufacturing process.

2.1. Villa Nurbs

by Cloud9 (under construction) Empuriabrava, Spain

This house used humped ceramic tile to form the South wall's exterior rainscreen. The manufacturer, Ceramica Cumella (located just outside of Barcelona, Spain) worked with Cloud 9 to manufacture the clay tile. Over 325 tiles and 8 different tile shapes were manufactured. The manufacturing process included extruding the clay into a slab, using a template to hand cut the clay slab, laying the cut clay onto a CNC-milled polystyrene mold, and pressing the clay onto the mold. A mixture of the clay's weight and handwork shaped the clay into the 2-directional curve of the mold—in a process called humping.

2.2. 290 Mulberry Street

by SHoP ARCHITECTS (2010) New York, NY

Figure 1: Photograph of 290 Mulberry Street under construction. flickr (Creative Commons): (joevare 2008)

This apartment building has a precast concrete and brick veneer composite panel on its exterior façade. The master for the panels was fabricated using a CNC router and then a rubber mold was made from the master. Brick were hand laid onto the rubber mold and concrete poured directly onto the back of the brick surfaces. The concrete filled the spaces between the brick to give the appearance of mortar joints. A large mold was created and was subdivided with dams to create smaller composite panels as per the design. The mold was used repeatedly throughout the manufacturing of the panels.

2.3. North Carolina Museum of Art

by Thomas Phifer and Partners (2010) Raleigh, NC

Figure 2: Photograph of the NCMA ceiling coffers. flickr (Creative Commons): (Chirag D. Shah 2008)

The NCMA's West gallery building has custom designed ceiling coffers. The oculus at the center of the coffer has a diffuser and skylight at the top. The coffer distributes the natural light emitted from the oculus throughout the gallery. The coffers are manufactured using traditional, contact molded, fiber-reinforced plastic (FRP). Because the coffers are FRP, they are lightweight and weigh just over 400 pounds each. The coffers are demountable, which allows building maintenance to access the diffusers and building systems when necessary.

2.4. Walbrook

by Foster and Partners (2010) London, England

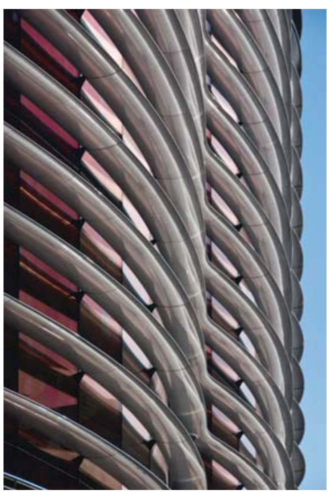

Figure 3: Photograph of the Walbrook's exterior fiberglass louvers. flickr (Creative Commons): (Myxi 2009)

Foster and Partners designed custom exterior, free-spanning louvers for this office building in Walbrook. The louvers are hollow and were manufactured by inflating the interior of a fiberglass and resin layup against a hollow mold. The louvers are lightweight, stiff, and weather well. The louvers' shape is a complex curve, curving in both cross section and in plan. According to *Detail*, serial production was the most cost efficient way to make the louvers. The mold was designed to create repetitive cross section and plan curvatures, while allowing for varied lengths (Gabler 2008).

2.5. 3.1 Phillip Lim

by Leong Leong Architecture (2009) Cheongdam-Dong, Seoul, South Korea

The architect designed fiberglass-molded, precast concrete tiles as the building's rainscreen. The tiles are double convex curves, creating a pillowed effect for each tile. This gives a quilt-like feeling to the façade. There are seven square tiles with seven different values of convexity, ranging from pillowed to flat in profile.

An eighth L-shaped, pillowed tile was used to allow for windows. Fiberglass molds are inexpensive to make and can produce more units than Styrofoam or rubber molds. The fiberglass mold gives the precast concrete a smooth and slightly glossy finish.

2.6. Argos Cement Electrical Generator Building
by MGP Arquitectura y Urbanismo (2008) Yumbo Valle, Colombia

This project uses steel-molded, precast concrete panels to create an exterior screen for the electrical generator building of this cement factory. The building uses low-density concrete for the screen. MGP designed two different panels for the screen. By reducing the variety of different panels, the cost per panel is reduced, as not a many molds are needed.

2.7. Spanish Expo-Pavilion
by Francisco Mangado (2008) Zaragoza, Spain

Figure 4: Photograph of Spanish Expo-Pavilion. Wikipedia Commons: (Sergio 2008)

Mangado designed a custom, half-round, extruded clay tile that clad the pavilion's round steel columns. The project uses 28,000 terracotta pieces to clad the 750 columns. Metal angles that were attached in the factory to the columns support the terracotta pieces. Two manufacturers worked together with Mangado to design and manufacture the pieces.[2] The manufacturers extruded the ceramic pieces with a temporary support structure that would be broken away prior to firing.

2.8. Castellum Theater
by Kraaijvanger Urbis (2005) Alphen, Holland

The Castellum Theater is clad in customized corrugated aluminum panels. The corrugations are small and form a wave-like pattern, referencing the nearby river. The panels are manufactured using explosive forming. Explosive forming uses the force of an explosive charge in a medium (often water) to form a metal sheet against a mold. This process has relatively low capital costs and is good for small to mid-volume production runs. It has very high tolerances and can produce large curved panels (similar to car hoods) or small details such as those on the Castellum Theater.

2.9. World Exposition, Spanish Pavilion
by Foreign Office Architects (2005) Aichi, Japan

Figure 5: Photograph of Spanish Pavilion at the 2005 World Exposition. flickr (Creative Commons): (Keemz 2005)

This pavilion uses custom pressed clay to form the screen tiles of the Spanish Pavilion. The tiles are an irregular hexagon shape. There are six different hexagons and each hexagon either is formed solid or with an opening. Each hexagon is formed with a separate front and back pieces that conceal and are supported by interior metal supports. This process has relatively low capital costs and is good for small to mid-sized production runs. Ceramica Cumella (Barcelona, Spain) was the manufacturer for the tiles.

2.10. Hesiodo

by Hierve Diseneria (2003) in Mexico City, Mexico

This apartment building uses wood-molded, blown glass spheres as a screen between the city and the exterior apartment corridors. There are 7,723 spheres on the building. The spheres were hand-blown inside of a wood mold so that the spheres would be consistent in size and shape. Craftsmen in a Guadalajara workshop manufactured them.

2.11. Prada Store

by Herzog & de Meuron (2003) in Tokyo, Japan

A portion of the windows in the exterior glazed curtain wall of the Prada store was manufactured as a complex curve. To achieve the double curve, flat float glass was slumped against a custom mold (Schittich 2006). To slumped glass, a manufacturer slowly heats a flat glass sheet. The sheet will begin to sag and deform from its own weight. Using a mold for this process precisely controls the curvature of the glass. Reheating the glass to create the curvature also achieved a partial pre-tension on the glass (Shittich 2006) and thus increased its strength compared to annealed glass.

2.12. Nasher Sculpture Center

Renzo Piano Building Workshop (2003) Dallas, TX

Figure 6: Photograph of the Nasher's custom sunshade devices. Photo taken from building interior. Spanish Expo-Pavilion. flickr (Creative Commons): (Diorama Sky 2008)

This project uses custom designed sunscreen to control natural light into the building. The monitors are shaped to eliminate direct light and to maximize the amount of indirect light. The monitors' shapes are specific to this building in this location with this shape of roof (patent pending)[3]. The sunscreen is made of cast aluminium and is manufactured in 4 feet by 4 feet units. 912 units cover the building's roof and each unit weighs 150 lbs. La Societa Sider s.r.l. (Bologna, Italy) manufactured the units.

3.0. AVAILABLE LITERATURE

There are a number of books that focus on repetitive manufacturing, and they tend to fall within two categories—technical or designer oriented. The technical oriented books may be directed towards either industrial or manufacturing engineers and engineering students. These books are often production-oriented, giving information about the production speeds, material flows, mold design, etc. They are specific for an engineer to manufacture a particular product. Often these texts are not accessible enough to a designer; information is often buried in text and there often are a number of calculations for production speeds, mold pressures, and material flows. The texts do not highlight the critical information in which a designer is interested—such as typical size restrictions, tolerances, draw angles, typical production runs, finishes, typical materials, and sample products manufactured by a particular process.

The alternate category of books is those that are designer-oriented. The design-oriented books tend to use visuals and graphics to describe the process. They include images of products that already manufactured with a particular process and they often include images of the manufacturing processes. The goal of these books is to give the designer an overview to the processes and to provide some design guidelines for each process. They most often are intended to engage the industrial designer or other visual disciplines (Lesko 2008). These texts are often enough to give a designer an overview to a particular process, but because of the lack of technical information they necessitate the designer to work closely with a manufacturer to actually develop a product for manufacturing.

For both of these groups of texts, I have only selected those texts that I have found the most useful in my teaching and research in CRM. The selected books focus on the limitations of the process and provide information that would be critical to any designer. Most of the books include the processes that may work for a prototype or small batch production, or they may be good for high volume productions (up to 1 million or more units). Most sources include CAM manufacturing as well as repetitive manufacturing. Most of these books are geared to product or industrial designers. They do not highlight some of the issues that an architect may be interested, such as maximum size of products produced or typical production run sizes. The books explore materials that are typical to product design, but may not include materials typical to architecture. For example in architecture, the manufacturing process of extrusion typically includes plastic, metal, and clay; however most of the texts found primarily focus on plastics. The books also do not cover some of the manufacturing processes (e.g. precast concrete with a rubber mold) that may only be applicable to architecture.

The list of books is organized alphabetically by author.

3.1. Allen, Edward. *Fundamentals of Building Construction: Materials and Methods*. 2009. John Wiley & Sons: Hoboken, NJ.

Although this book primarily focuses on standard manufactured architectural materials (e.g. brick, concrete, dimensional wood, steel, etc.) and construction methods, there is an introduction into the manufacturing processes of clay and precast concrete. This is one of the few identified sources that includes the manufacturing process for architectural materials (e.g. concrete and clay). Unfortunately, Allen is limited in his description. He describes the manufacturing process for structural precast on steel casting beds, but does not include information about architectural precast concrete cast on coated MDF, fiberglass, or rubber molds. In addition, Allen illustrates brick manufacturing and discusses some of the custom shapes that brick can take, but does not describe the design parameters for a designer to engage with extruding clay.

3.2. Guidot, Raymond. *Industrial Design Techniques and Materials*. 2006. Editions Flammarion: Paris.

Guidot's book offers a strong historic and current perspective on industrial design techniques and materials. The book is organized by manufacturing materials. Guidot offers a brief introduction and history to the material and introduces the reader to the manufacturing and fabrication processes available for that material. The processes are described verbally with about half of the processes illustrated with either diagrams, photographs, or a mixture of the two. The book does a thorough job of describing ceramic, glass, and metal manufacturing—all of which are applicable to architecture. Guidot organized the book as if it is to be read from cover to cover, rather than as an encyclopaedic resource for the designer.

3.3. Hudson, Jennifer. *Process: 50 Product Designs from Concept to Manufacture*. 2008. Thames & Hudson: London.

Hudson's book investigates both the design and manufacturing processes of 50 case studies. It demonstrates the design process, philosophy, design iterations, and collaborations of a designer working with the manufacturer in order to get a design to production. The case studies often offer information as to how a designer may have customized a particular manufacturing process, or worked with a manufacturer to develop a new process. Outside of the case study, Hudson's book does not offer further information about a manufacturing process or technique. This book is a reference about the design process for CRM rather than a resource for an architect to learn about repetitive manufacturing.

3.4. Lefteri, Chris. *Making It: Manufacturing Techniques for Product Design*. 2007. Laurence King Publishing: London.

Lefteri's book is an encyclopaedic reference book that provides an overview to all of the currently available manufacturing processes. Lefteri focuses on those manufacturing processes that form goods, and organizes the processes according to categories. Processes are grouped within category headings and are located in the book next to similar alternative processes. For example, pultrusion and extrusion are included under

“Continuous”. This allows the reader to understand better the differences between the two, and when one may be more applicable to a particular design. Lefteri also includes a number of specialized manufacturing techniques (e.g. inflating metal and Pulshaping) that may be trademarked or available through limited manufacturers. Lefteri included many high-design examples of products that use a particular manufacturing process.

3.5. Lesko, Jim. *Industrial Design: Materials and Manufacturing Guide*. 2008. John Wiley & Sons: Hoboken, NJ.

This is an introductory text geared toward second-year industrial design students. Lesko gives an overview of the manufacturing processes and materials so that designers are aware of the possibilities available to them. It is also presented visually, so that designers more easily access the information. The book is organized according to material types with metal and plastic being the primary focus. Unlike Lefteri and Hudson, Lesko includes very few high-design examples and instead focuses on the everyday manufactured items (e.g. cast gears, rolled I-beams, and faucets).

3.6. Schrader, George F. and Almad K. Elshennawy. *Manufacturing Processes & Materials*. 2000. Society of Manufacturing Engineers: Dearborn, MI.

This book gives a good overview of manufacturing and its place in the United States and the global economy. The book provided more technical information, such as describing the cellular structure of certain materials. The book primarily focuses on metals, both ferrous and nonferrous alloys, and discusses the forming, shaping, manipulation, and joining of metals together. Only one chapter in the book is dedicated to non-metallic materials (e.g. plastic, rubber, clay, and glass) and in that chapter only the manufacturing process typical to plastics (e.g. compression molding, transfer molding, pultrusion) are illustrated or discussed in any depth.

3.7. Thompson, Rob. *Manufacturing Processes for Design Professionals*. 2007. Thames & Hudson: London.

This large survey book offers information about all of the manufacturing processes readily available. It is organized by forming, cutting, joining, and finishing technologies and includes a separate part on standard materials. Thompson organized the section “Forming Technologies” by material and is further categorized by similar and possibly alternative processes. The book uses high quality photographs and diagrams to describe the manufacturing processes, but do not offer the designer many of the design parameters associated with a process. Most forming technologies include an in-depth case study of a particular manufactured product. Thompson’s case studies and materials covered are more alighted with product design rather than architectural design.

3.8. Thompson, Rob. *Prototyping and Low-Volume Production*. 2011. Thames & Hudson: London.

This book focuses specifically on those manufacturing technologies that are best suited for prototypes or small batch productions. Thompson divided the book according to forming, joining, and finishing technologies. The forming technologies are those manufacturing process that form objects. Thompson gives equal weight to repetitive manufacturing and CAM. Although this book excludes processes that have a mid-sized production runs, under each prototyping or low-volume production process, Thompson indicates what larger-volume production process would be similar. High quality photographs and diagrams are used to describe the processes, but very few design parameters are given to the reader.

CONCLUSION

This paper proposed the term CRM to refer to repetitive manufacturing processes that are customized to a particular architectural project. With the use of CNC equipment, architects and manufacturers have been working together to customize the molds, jigs, or patterns used in repetitive manufacturing for building components used in a specific project’s design. CRM included those repetitive manufacturing processes with relatively low capital costs and that can support low- to mid-volume production runs of repeatable objects. CRM allows for customization from the designer, while balancing the need for repetition in order to remain cost effective. This paper made visible architects and building designers that have used CRM for their building designs. I selected twelve recently completed case studies and presented a literature review of the existing resources for architects and building designers to understand better CRM.

The existing literature on repetitive manufacturing includes books for the designer that would allow them to design products for small to mid-volume production runs. The current literature educates anyone about available manufacturing processes, and illustrates how those processes work. Most of the available texts are geared to product or industrial designers, or to engineers. Most of the current literature does not illustrate the processes or materials primarily applicable to architects. As the CRM processes identified by the case studies, the associated manufacturing processes are not those typically used by industrial designers. The case studies included atypical processes such as extruded, humped, and pressed clay, slumped glass, wood-molded blown glass, and precast concrete—not all of which are addressed in the majority of literature on manufacturing processes.

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ENDNOTES

[1] In the patent filled with the United States Patent Office, Fuller states that his prefabricated bathroom can be made of metal or plastic. Fuller, Richard Buckminster. 5 November 1940. "Prefabricated Bathroom". No. 2,220,482, United States Patent Office.

[2] The two manufacturers were Ceramica Cumella (Barcelona), founded in 1880, and Ceramica Decorative (Valencia), founded in 1862.

[3] Campbell, Duncan, Alistair Gunthrie, Renzo Piano. 15 December 2004. "Light Transmission System and Method for Buildings" No. EP1485544 A1. United States Patent Office.

HP2: The Design of a 3D-Printed Partition for the Healthcare Environment

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ABSTRACT: As of 2012, the methods in which the construction industry fabricates a non-load bearing partition are virtually the same as 100 years ago. This process and assembly is perpetuated by a construction culture that thrives on convention. Sheet building materials are nominally controlled, assembly definitions are outlined through building codes, and trades continue a system of apprenticeship where techniques are passed down through generations. This is further complicated with a construction process that is the mediator between the conception of the designer and the built artifact. The aim of this research was to reconceive the conventional construction techniques of the partition in high performance, technology-specific locations; an area that begs for development within a contemporary fabrication environment where new cnc technologies are able to translate mass-customized form into full scale, built assemblies.

HP2 was a design research project into the potential of a fully digitally fabricated, high performance interior partition placed within the healthcare environment. Initial research indicated areas where design could assist in more effective delivery of healthcare. For example, altering the ways healthcare providers enter and exit the room, as well as the way air is moved through the room could better protect patients in these facilities. Additionally, research aimed to integrate the inclusion of digital form generation and fabrication techniques to consider the partition of tomorrow – one that allows synergy between the form, space, and various building systems.

The design process investigated areas of acute care patient rooms, structural surfaces, architectural wall infill (poche), narrow spectrum sanitary lighting, adjustable and variable perforation, and patient room air ventilation. This process culminated in the manifestation of a 3d printed scale mockup of the partition with all systems present. Current projections of this project speculate on the potential of large scale 3d printing as a means to establish better connections between the high technology systems being requested and a fabrication technique which is supportive of that endeavor.

KEYWORDS: healthcare, fabrication, monocoque, 3d printing

INTRODUCTION: LIGHT GAUGE PARTITIONS AND THE CONSTRUCTION INDUSTRY

As of 2012, the methods in which the construction industry fabricates a non-load bearing partition are essentially the same as 100 years ago; repetitive structural members spaced equally with a modular, mass produced surface applied and finished on the construction site. While there are most certainly variations on this theme that might respond to contextual conditions such as materials (wood vs. steel studs), systems and their routing, budget, or temporality, this system has seen very little significant change.

The physical artifact of a partition is most often an assemblage of various materials and components, each serving a specific function. This might include materials such as drywall or wood panels and componentry such as aperture, hardware, mechanical vents and diffusers, electrical/data devices, grab bars, or lighting for example. Each of these elements is designed in isolation and is flexible enough to accommodate diverse contextual conditions. The system referenced is also a product of a dated manufacturing culture – one that foregrounds mass production and modularity, and in turn, sameness. This process and assembly is perpetuated by an entrenched construction culture that thrives on convention and tradition. Sheet building materials are nominally controlled through market demands such as 16” increments and consistent thicknesses. Partition assembly definitions are outlined through building codes and laboratory testing specifications that quantify traits such as fire spread and resistance, acoustical transmission, and structural load deference. Further more, although often unmentioned, the building trades continue a system of apprenticeship where techniques are passed down through generations adding to a quasi-institutional knowledge in the construction industry. Lastly, this context is further complicated with an communication and translation process that is the mediator between the conception of the designer and the built artifact. The

actual assembly of the partition is often times at least 2 levels removed from its conception through contract documentation, to contractor or shop drawing, to fabrication by trades person.
This composite condition became the context of the critique and the basis for this research project.

1.0 THE HEALTHCARE CONTEXT

The healthcare environment is one of the largest growing industries today with populations living longer and care needs growing proportionally with that age. It is expected that the healthcare industry will produce nearly 4 million jobs over the next ten years and will see an annual increase of 3.0%. This increase is followed closely by the construction industry that is projected to see annual increases in the range of 2.9%. (Thomas, 2012) Rapid growth and significant linkage between both industries suggests that status quo will not meet the growing needs of both, and that healthcare environments are ripe for new designed responses. Increased care will dictate more space for patients and increased patients will require need for more workers.

Initial research, as a result of this project, identified several areas where design might assist in the delivery of healthcare and the quality of spaces it occurs within. The design process gathered healthcare industry literature as well as interviews with various specialized design professionals. This information was reviewed and analyzed to identify areas in which design might offer a more efficient and effective space for both the caregiver and the patient. Additionally, the overlap of these areas provided for hybrid conditions that could, through their juxtaposition, enhance both scenarios. As a result, the acute care patient room, and more specifically the partition that exists between two rooms, was selected as a locus for testing design strategies both for its ubiquity and simultaneous possession of the various topics in which the research indicated potential.

Room types position the components of the restroom, healthcare professional, and the patient in various places to create synergistic opportunities and desired adjacencies. (e.g. Fig. 1). While opinions vary across the United States, our research and interviews determined that the outboard room type was optimal for its connections to the corridor and efficiency in healthcare delivery. This type allowed for the nurse's station to be located in the corridor providing more area at the corridor wall for of a door and window thus increasing visual connections from the nurse's station. This connection meant care providers could perform most of their rounds without having to enter the room, thus decreasing the times in which air and surface contaminants could enter the patient room. The only pronounced negative trait of this room type is a reduction in the amount of exterior wall and resultant window to the outside, but that was seen as possessing less significance with regards to the overall function of the patient room.

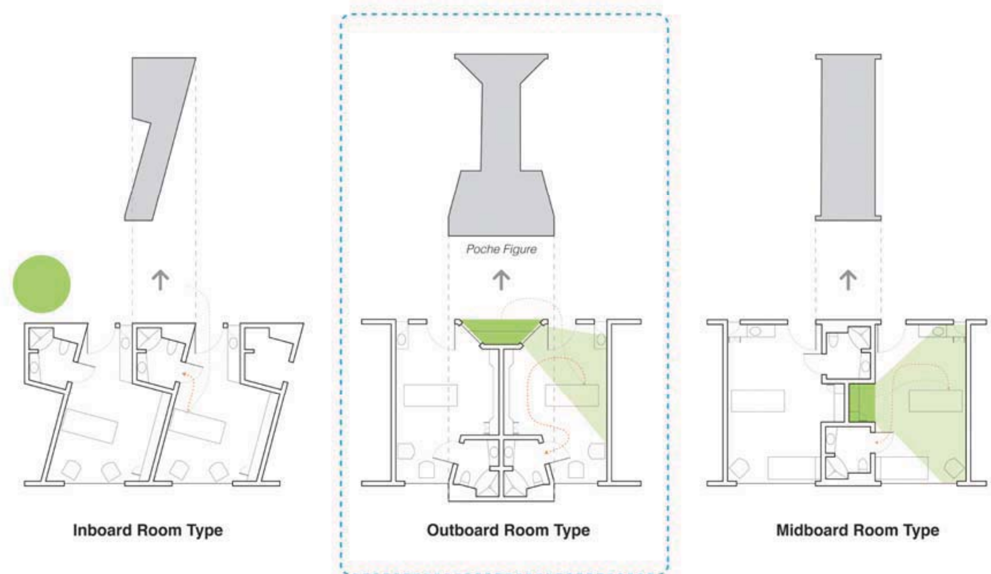

Figure 1: Patient room typology. Source: (Author 2013)

The entry into the acute care patient room presents the highest potential for contamination of room air and surface. When a user enters the room from the corridor, airborne contaminants in the adjacent corridor have opportunity to migrate in the wake of a moving person. Typically, room ventilation is planned to create positive air pressure in the room so air moves toward the corridor when the door is opened. Additionally, healthcare workers who might sanitize when leaving one room are immediately prone to contamination when entering the next room through contact with surface and hardware. This room entry plays an important role in keeping the patient safer with regards to air and surface-borne contaminants and research gathered through this project indicated that altering the ways healthcare providers enter and exit the room, as well as the way air is moved through the room could better protect patients in these facilities. (e.g. Fig 2)

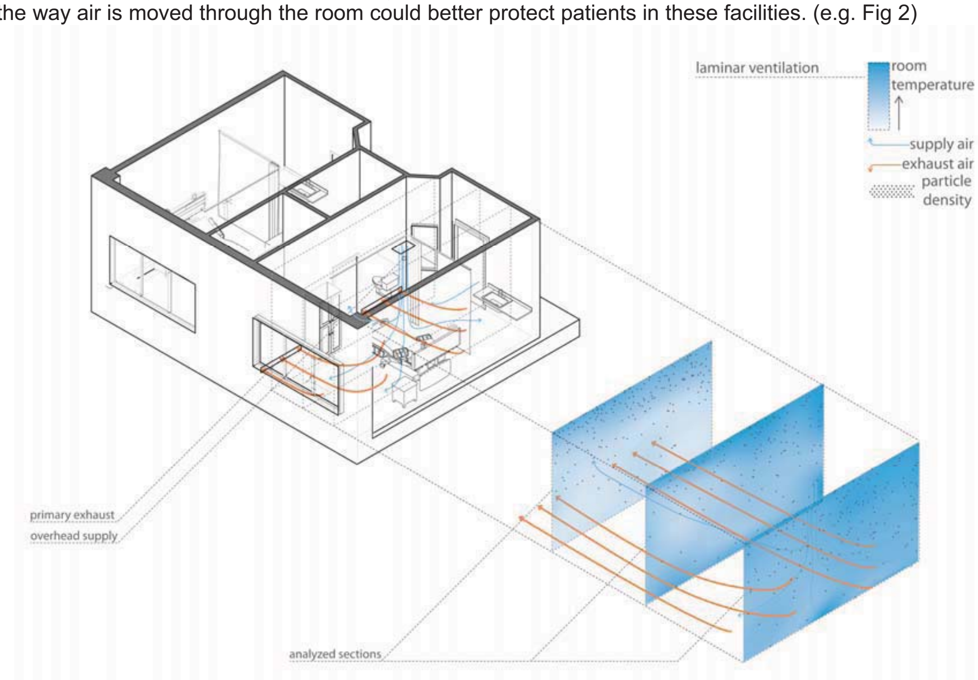

Figure 2: Patient room ventilation analysis. Source: (Author 2013)

Building systems within a healthcare facility typically move vertically in areas where they are able to be aggregated and decrease the distance to delivery. Often this means poche space within the restrooms contains a high amount of water, air and electrical systems. As a result of positioning the restroom towards the exterior wall, the vertical systems that are feeding multiple floor levels in the facility are also located toward the exterior wall. This core of systems, which includes the supply of fresh air to the patient room, provides excellent placement for responding to desired airflow directionality decreasing the infiltration of airborne contaminants into patient rooms. (e.g. Fig 3)

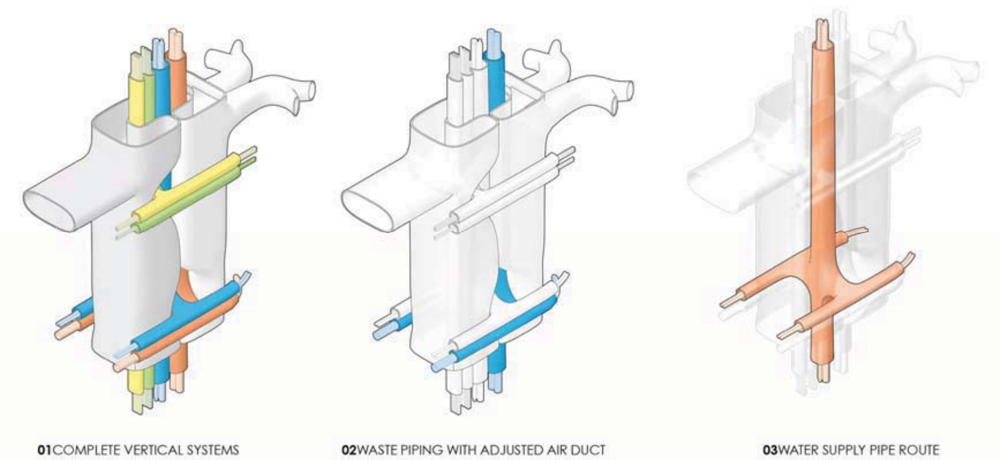

Figure 3: 3d printed building systems diagram. Source: (Author 2013)

2.0 DESIGN STRATEGIES

HP2 was a design research project into the potential of a fully digitally fabricated, high-performance interior partition placed within the healthcare environment. The aim of this research was to reconceive conventional construction techniques of the partition in performance and technology-specific locations such as healthcare facilities. The design process investigated areas of acute care patient rooms, structural surfaces, architectural wall infill (poche), narrow spectrum sanitary lighting, adjustable and variable perforation, and patient room air ventilation. The previous subtopics became catalysts in the development of the design research project contained within.

Architectural poche, a representational technique which dates back deep in the history of architecture and its representation, typically infills the space between the lines indicating the outside wall surface. For the purposes of this project, poche was manifest at two scales – in its traditional sense within the interior of the partition, and at the scale of the larger object located within a field. (e.g. Fig 1) The interior volume of the wall where, typically, repetitive structural member are located was cleared to make way for more efficient routing of internal systems. This was achieved through the repurposing of the wall surface to be structural – a monocoque. At the larger scale, the collective composition of the partition as it moves from the nurse's station at the corridor through the patient room and encompasses the restrooms was seen as an object in the space with specific demands and functions with potential to be redefined through alternative constructional logic and retooled systems delivery.

In an effort to reduce consumption of materials, and eventual relocation to a landfill when these materials have outlived their usefulness, change in the construction technique is necessary. With new fabrication technologies available, the use of traditional construction systems (i.e. studs and drywall) is not as relevant. New fabrication systems allow for customized partitions that offer more flexibility than was possible in mass-produced sheet goods. One of these, 3d printing, is rapidly increasing in accessibility and feasibility and seems, at this point, to only be limited by the size of equipment used to fabricate. Materials available for printing are also increasing becoming more diverse, economical, and performative with regards to strength, transparency, maintenance, tolerance, and sustainability. Several groups, including Objet and D-Shape, are investigating large format 3d printing and the potential of mass customized architectural assemblies. Printing full-scale architectural components or parts in addition to the full envelope are no longer fictional narratives but rather attainable goals.

The traditional partition is a product of the 20th century, a timeframe of manufacturing defined by mass production of materials and products. This partition type does not allow for difference outside of a few variables. Any deviation outside of these variables results in the increase of cost and labor for manipulation. Mass customization on the other hand establishes a more robust set of parameters resulting in higher degree of performance specificity. 3d printing allows this specificity through variation in formal conditions and material options. Initial prototypes were mocked up in ABS plastic to test flexibility, strength, form, and proportion. Future studies will investigate the potential of a reusable, corn-based material that can avoid the landfill of traditional construction materials by being reconstituted. For modification of 3d-printed construction, portions of the wall can be removed, processed, and reused to create an infill panel. To extend this logic further, entire partitions can be processed when they outlive their use and be recycled into new constructions.

The inclusion of systems into this new fabrication typology begins with the surface and its diversity of parameters including material, thickness, and orientation. The surface is a ubiquitous condition in the built environment where a high percentage of those surfaces are single use and highly underutilized. Surfaces exist in extremely diverse ranges of materials, contours, scales, thicknesses, and workability. These parameters are typically selected based on a determined use and performance standard with regards to durability, maintenance, acoustics, transparency, initial workability, and aesthetic manifestation.

Monocoque is a term derived from the Greek word combination that translates to 'single shell.' First introduced through aircraft construction in early 20th century, it offered an ability to integrate what was previously two systems, structure and skin and developed a hybrid which simultaneously performed the duties of both with reduced weight and comparable strength. The potential of monococque construction in the partition displaces the structural role of the wall to the surface thus releasing the interior of the wall, the poche, to allow for freer movement of systems and the ability of those systems to work synergistically. Even more, where the space is not needed for systems, it can be completely removed and the surface itself can perform the duties of structure and separation. Acoustical concerns are addressed through cellular materials that isolate sound and decentralize vital air space into a dispersed network of air pockets. In turn, this can decrease weight in the partition construction depending on material selection.

Within aforementioned strategies and technologies, the design began with inventory of the context and analysis including function, anthropometrics, and systems integration. Critical anthropometric wall sections (nurse station, sanitation area, task surface, etc.) were established to address use requirements through pushing and pulling the wall surface, accommodating various technical concerns. (e.g. Fig 4) Surface design was generated through analysis of various performance markers that are parametrically manipulated through the use of software. Unlike mass produced sheet goods, variables such as wall thickness can be differed based on what they are tasked with doing. Surface geometry was analyzed and parametrically controlled in ways that added material where necessary, and lightened the skin where not needed. Additionally, surface thickness can delaminate to create structural conditions and cavities for the transmission of air, water, waste, or power. Effective delivery of ventilation, coupling of systems to encourage synergistic transference, and integral systems printing including circuitry and ventilation were opportunities present with a new fabrication technique. Ventilation routing, which required the most poche space allocation, was conceived of as a morphing volume that was sometimes independent and other times grafted into the surface through delamination.

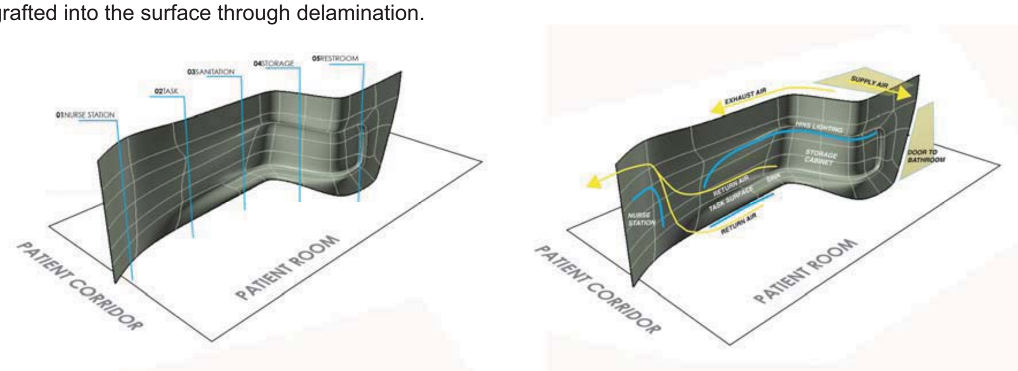

Figure 4: Critical anthropometric sections and performance criteria of the partition. Source: (Author 2013)

A series of prototypes were generated looking into the performative aspects of perforations on the architectural surface with the goal of eliminating elements such as the light and air diffusers. (e.g.Fig 5) This perforated strategy would be integral into the surface and variable based on local need. For example, where the surface of the partition needed to breathe more, the size and frequency of the perforations could be parametrically controlled to increase or decrease airflow. This condition would also work for variable lighting conditions allowing for light to be delivered at the appropriate intensity to the point of need and fade away where not necessary. These investigations also prototyped the effect that these surface manipulations would have on the potential of the surface to contour based on set criteria. (e.g. Fig 6) The use of perforations and surface manipulations were also seen as a way to integrate sanitation of air and surface. High intensity narrow spectrum (HINS) lighting is a recent development that is highly effective in the sanitation of air and surface. (ScienceDaily, 2010) This light type can be integrated into architectural spaces and assist in maintaining a cleaner environment without large amounts of space internally. The coupling of this technology with 3d printed surface conditions with variable perforations offers incredible opportunity to manifest a hybrid surface that performs relative to strength, contour, and delivery of building systems.

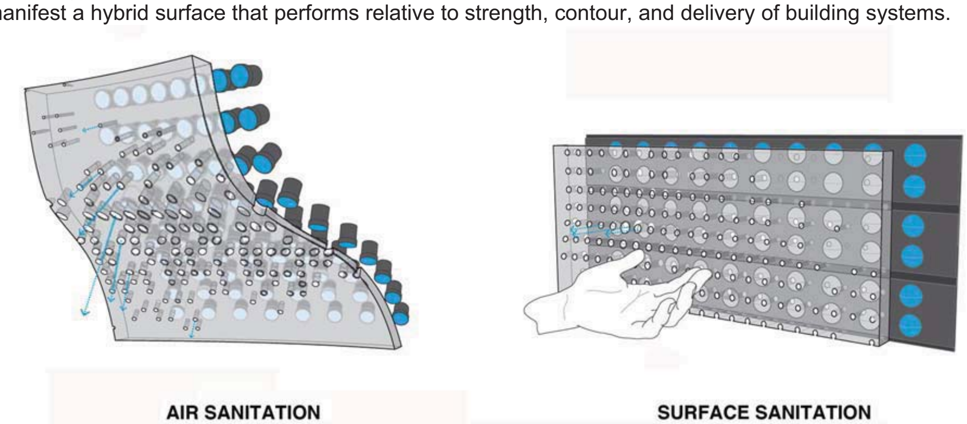

Figure 5: Surface and light sanitation through perforations incorporating HINS lighting. Source: (Author 2013)

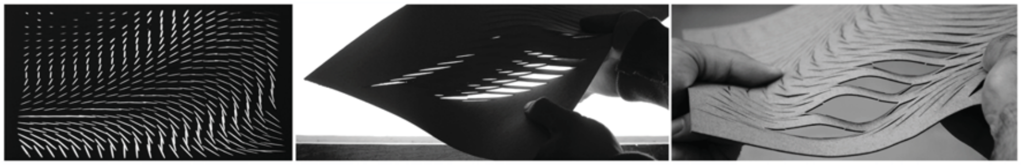

Figure 6: Initial surface perforation studies from parametrically defined patterns. Source: (Author 2013)

CONCLUSION
To this point, this process has resulted in the manifestation of a 3d printed scale mockup of the partition with all systems routing present. Current projections of this project speculate on the potential of large scale 3d printing as a means to establish better connections between the high technology systems being requested and a fabrication technique which is supportive of that endeavor. Additionally, future studies will determine the viability of reusable materials in the 3d printing process allowing prolonged use and flexibility through the life of the partition. This proposal suggests that fully integrated partition design might best be served through a fabrication technique that is offering more control and precision from conception to realization. The future trajectory is to test fabrication at full scale with 3d printing technology, focusing on areas of high systems concentration. By dissolving this division of systems and encouraging exchange, This design research project aspires to break disciplinary boundaries in turn redefine the future of high performance, technology-specific partition design.

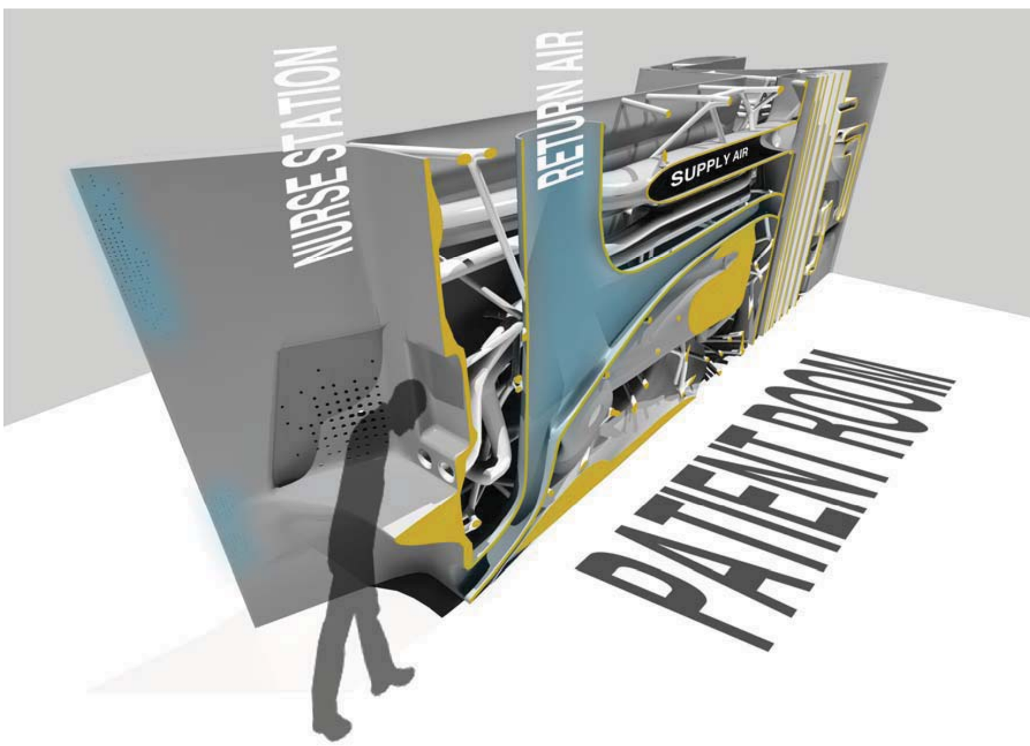

Figure 7: Sectional render of partition design. Source: (Author 2013)

Figure 8: 3d print prototypes fabricated from ABS plastic. Source: (Author 2013)

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Microbially Indurated Rammed Earth: A Long Awaited Next Phase of Earthen Architecture

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[1]University of Kansas, Lawrence, Kansas

ABSTRACT: Rammed earth possesses low embodied energy, high recyclability, and low toxicity while having little impact on biodiversity and virtually no depletion of biological nutrients. Although rammed earth is an inherently sustainable building material, it fails to meet the high compressive strength requirements of contemporary building standards. Attempts to rectify this shortcoming by importing advances from concrete construction have resulted in a degradation of its sustainable properties. Inspired by biomimicry, we propose to stabilize rammed earth using biomineralization through a process we are calling *microbially indurated rammed earth* (MIRE). This process offers the opportunity for earthen architecture to harmoniously reconnect to the natural world while simultaneously meeting contemporary performance demands.

The microorganism, *Sporosarcina pasteurii*, known to effectively induce calcite precipitation, was suspended in a solution containing calcium chloride ($CaCl_2$) and urea. The $CaCl_2$ is the calcium source for calcite precipitation and the urea is used as a nitrogen fertilizer to accelerate microbial growth. This microbial solution is mixed into a base soil at sufficient quantities to approximate the optimum moisture content, thereby achieving maximum bulk density of the soil material through a standard compaction process, which is common in rammed earth construction. The hyperactive ~1 µm long microorganisms are dispersed throughout the densified soil matrix and rapidly begin to modify solution chemistry to induce calcite precipitation at grain-to-grain contacts, cementing the material. In this experiment, MIRE cylinders achieved compressive strengths exceeding 2.5 times the strength of non-stabilized rammed earth. While this result is promising, related literature suggests that resistance to moisture degradation may also be substantially improved. This is significant because compressive strength and moisture resistance are the two greatest challenges in rammed earth construction. While much work is needed in order for MIRE to be a feasible alternative to cement-stabilized rammed earth, these preliminary results suggest much promise.

KEYWORDS: MIRE, MICP, rammed earth, biomineralization, *Sporosarcina pasteurii*

INTRODUCTION

The story of earthen architecture can be traced back to the mythopoeic cultural landscape of prehistoric people throughout the world. Earthen architecture once possessed a fertile legacy and was harmoniously bound to local ecologies and climates until the emergence of industrial societies, when it began to lose its status as a significant and sustainable building craft. The tragic rising action of this story is one of dislodging, abandonment, and an eventual recovery effort that imposes largely alien principles on the material and process. That is, traditional rammed earth has been altered in the most recent stage of its development to satisfy contemporary building standards using technology imported from advances in concrete construction.

Contemporary stabilized rammed earth (SRE) is often amended with Portland cement, lime, or an asphaltic emulsion, resulting in increased strength, durability, and resistance to moisture and erosion at the expense of its traditionally low embodied energy, low toxicity, inherent recyclability, and cultural significance. Our goal is to improve the material properties of contemporary rammed earth architecture by exploring the potential for natural soil microorganisms to enhance the built environment in what we are calling *microbially indurated rammed earth* (MIRE).

Natural soil microorganisms (especially the bacterium *Sporosarcina pasteurii*) are known to biomineralize calcite in soil pore spaces, aggregating mineral grains and enhancing desirable properties of earthen materials used in engineering applications. This research aims to illustrate that this technological advancement, which has accelerated within the past decade, has the potential to fundamentally transform rammed earth by strengthening the soil materials used while minimizing or even eliminating the need for highly processed industrial stabilizers such as Portland cement. This process holds the potential to advance the performance of earthen architecture while maintaining its environmental sustainability.

In this paper, we compare the compressive strength of non-stabilized rammed earth (RE) to that of MIRE and analyze the mineralogy to better understand the physical characteristics contributing to its compressive strength. We begin by mining data from existing literature on rammed earth architecture, civil engineering, and the earth sciences. We use this data to develop a model that aids in the selection of soils ideally suited to microbially induced calcite precipitation as well as to predict the optimum moisture content in order to determine the quantity of microbial solution to be added to the base soil, thereby streamlining initial research methods. We are interested in the material properties most relevant to rammed earth construction such as compressive strength, moisture resistance, and aesthetic quality. In this comparative study, however, we focus on compressive strength, a common performance criteria in earthen building codes and codes of practice.

1.0 THEORY

1.1. How microbially induced calcite precipitation works

To our knowledge, this experiment is the first to explore the phenomenon of microbially induced calcite precipitation as applied to rammed earth construction. Within recent years, this specialized area of research, however, has been applied to reducing the moisture absorption of bricks (Sarda et al. 2009), reducing the moisture absorption of concrete (Achal et al. 2011a), increasing the strength of concrete (Bang et al. 2001), stabilizing sandy soils that tend toward liquefaction (DeJong et al. 2006), improving security of wellbores during injection of super critical CO_2 into subsurface reservoirs (Ebigbo et al. 2012), and repairing cracks in concrete (Ramakrishnan et al. 2005). At a conceptual level, this technique has been proposed as a solution in halting the desertification of the African Sahel through the creation of a 6,000 km long biocemented sand wall (Larsson 2009). Microbially induced calcite precipitation (Fig. 1) is a new and growing area of research (Achal et al. 2011a; Dhami et al. 2012).

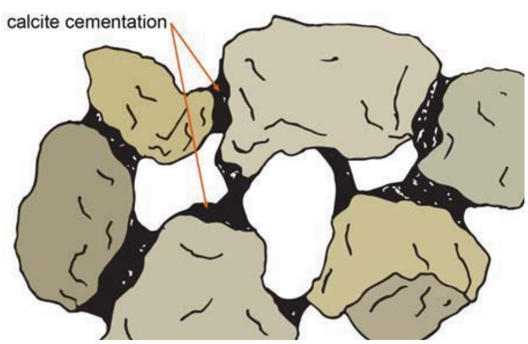

Figure 1: Diagram of calcite cementation occurring at grain-to-grain contacts.

Microorganisms mediate calcite precipitation through a number of different metabolic processes that supersaturate solutions with respect to calcite, most commonly by converting organic carbon to inorganic carbon and increasing solution pH (e.g. Warren et al. 2001). Ureolysis (hydrolysis of urea by microorganisms) is common in indigenous microorganisms in soils and sediments and has been used as a means of plugging or cementing geologic porous media with carbonate minerals (Ferris and Stehmeier 1992; Ferris et al. 1996; Stocks-Fisher et al. 1999). Microorganisms convert urea to ammonium, bicarbonate, and hydroxide, which drives calcite supersaturation through increased bicarbonate and pH in the presence of Ca^{2+} (e.g., Eq. 1; Ferris et al. 1996).

$$NH_2CONH_2 + 2H_2O + Ca^{2+} \rightarrow 2NH_4^+ + CaCO_3 \qquad \text{(Eq. 1)}$$

The kinetics of this reaction are fast (~10^{14} times faster than the uncatalyzed rate; Benini et al. 1996), are largely temperature dependent (Dupraz et al. 2009), and have been established in both aerobic and anaerobic environments (Tobler et al. 2011).

In particular, *Sporosarcina pasteurii* has been found to be a very effective producer of urease and an effective inducer of calcite deposition (Sarda et al. 2009). *Sporosarcina pasteurii* is ideally suited for larger scale activities, such as rammed earth construction, because of its ability to survive desiccation through spore-forming (Smith et al. 1952). In addition, *Sporosarcina pasteurii* has proven to be a good candidate for microbially induced calcite precipitation of sandy soils due to its tendency not to aggregate, thereby allowing for thorough dispersion throughout the soil structure. Furthermore, the size of these microbes allows them to move freely through granular sandy and silty material (DeJong et al. 2006), an important attribute if the soil medium is to be compacted. *Sporosarcina pasteurii* is conveniently ubiquitous in subsurface soil, where source material for rammed earth is gathered (DeJong et al. 2006). Sandy soils cemented using *Sporosarcina pasteurii* have performed similarly to specimens cemented using more traditional soil stabilizers such as gypsum (DeJong et al. 2006). Recent research has shown that microbial deposition of calcite has not only increased the compressive strength of concrete, it has significantly improved its moisture resistance as well (Achal et al. 2011b; Chahal et al. 2012; Dhami et al. 2012).

1.2. Predicting the physical characteristics of soil ideally suited to biostabilization

Existing research has shown that predictive models using benchmark performance criteria can be useful for selecting soils with appropriate properties (Burroughs 2008). Using soils from 219 stabilization experiments in New South Wales, Australia, Burroughs (2008) demonstrates that soils will consistently meet a benchmark compressive strength if they possess a gravel content ≥ 13%, sand content < 64%, combined clay and silt content between 21 and 35%, a linear shrinkage < 11, and a plasticity index < 30.[1] These figures were used as a guide in selecting an appropriate local soil as the base material for both test mixtures: non-stabilized RE and MIRE.

1.3. Predicting the optimum moisture content to aid biostabilization

Building upon this research, we combine a series of equations from the literature to predict the optimum moisture content for compaction of soil for biostabilization during the rammed earth process as follows. Maximum bulk density of the fine-earth fraction (MBD_{fe}) from the standard Proctor compaction test can be estimated following Zhao et al. (2008):

$$MBD_{fe} = 2.07 - 2.11\ LL + 0.0006\ clay \qquad \text{(Eq. 2)}$$

where MBD_{fe} is given in Mg m^{-3}, LL is the liquid limit of the material in kg kg^{-1}, and clay (i.e., <0.002 mm) is the clay percentage of the fine-earth fraction (i.e., <2 mm). Liquid limit can be expressed empirically as a function of clay content (Keller and Dexter, 2012):

$$LL = (17.52 + 0.86\ clay) / 100 \qquad \text{(Eq. 3)}$$

The porosity of the fine-earth fraction (ϕ_{fe}) after compaction can be found as follows:

$$\phi_{fe} = 1 - MBD_{fe} / \rho_s \qquad \text{(Eq. 4)}$$

where ρ_s is the density of the solid fraction assumed to be 2.65 Mg m^{-3}. The void ratio (e_T) of the total sample including gravel can be written as:

$$e_T = \left[\frac{\phi_{fe}}{1-\phi_{fe}}\right]\left[1-\frac{gr}{100}\right] \qquad \text{(Eq. 5)}$$

where gr is gravel content expressed as percentage of the total. The porosity of the total (ϕ_T) is found as:

$$\phi_T = e_T / (1 + e_T) \qquad \text{(Eq. 6)}$$

and maximum bulk density of the total (MBD) is found as:

$$MBD = (1 - \phi_T)\ \rho_s \qquad \text{(Eq. 7)}$$

Finally, maximum bulk density can be expressed as a function of optimum moisture content (OMC) for a given degree of saturation following Ishibashi and Hazarika (2011) as:

$$MBD = \frac{G_s \rho_w}{1+\frac{G_s OMC}{S}} \qquad \text{(Eq. 8)}$$

which we rearrange to solve for OMC:

$$\mathrm{OMC} = \frac{S}{G_s}\left[\frac{G_s \rho_w}{\mathrm{MBD}} - 1\right] \quad \text{(Eq. 9)}$$

where OMC is in kg kg^{-1}, G_s is the specific gravity of the solid fraction assumed to be 2.65, ρ_w is the density of water (approximately 1 Mg m^{-3}), and S is degree of saturation assumed to 80% following Hillel (1998).

2.0. METHOD

Typical rammed earth laboratory methods for compressive strength determination are illustrated in Fig. 2 along with the process for microbially precipitating calcite. This combination of conventional rammed earth and microbially induced calcite precipitation results in MIRE.

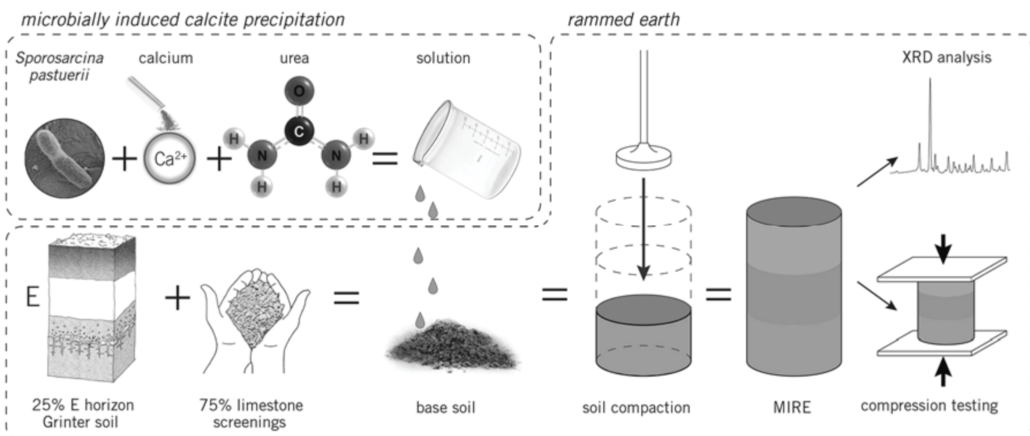

Figure 2: Diagram of the MIRE method used in this study; microbially induced calcite precipitation + rammed earth.

2.1. Culturing *Sporosarcina pasteurii*

Our experiments with MIRE began by cultivating cultures of *Sporosarcina pasteurii* (Fig. 3). This bacterium, formerly known as *Bacillus pasteurii*, was acquired from Robin Gerlach at Montana State University and maintained in the Roberts Laboratory at the University of Kansas.

Growth curves and yields for *Sporosarcina pasteurii* were established using commercial growth media (BBL; Brain Heart Infusion supplemented with 20 g L^{-1} urea) at 20°C. For experiments, cells were grown to mid-exponential phase then harvested under vacuum filtration and resuspended in artificial groundwater (AGW; based on that of Ferris et al. 2004) amended with 500 mM of Ca^{2+} and urea to an optical density (600 nm) of 0.07 (~10^6 cells mL^{-1}; e.g., Tobler et al. 2011). Control experiments were performed with uninoculated AGW.

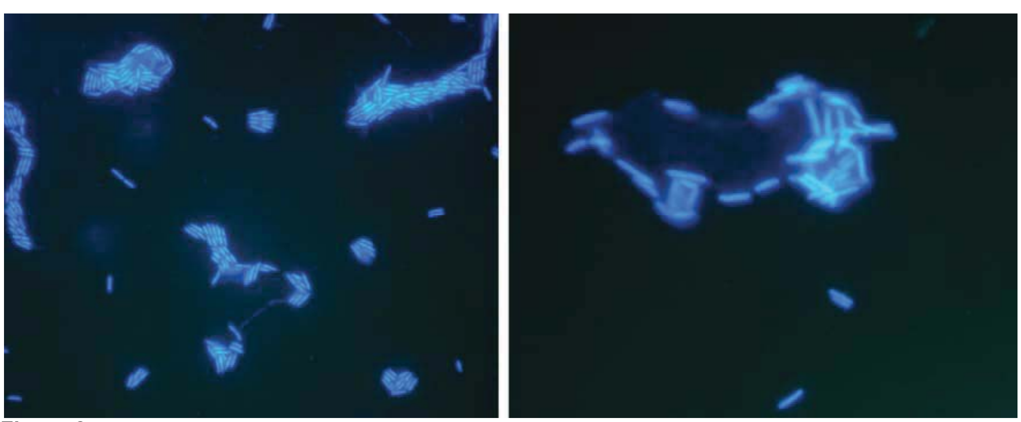

Figure 3: Photomicrographs of *Sporosarcina pasteurii* at 60x (left) and 100x (right) using UV epifluorescent microscope after staining with DAPI (4,5-diamidino-2-phenylindol). *S. pasteurii* are ~1 μm in length.

2.2. Preparing the soil

Based on our predictive models, a blend of 75% limestone screenings from a local quarry (comprised of 70% gravel, 14% sand, 11% silt and 5% clay) and 25% Grinter soil sampled from the University of Kansas Field Station (comprised of 80% sand, 16% silt and 4% clay), with a blended particle distribution of 52% gravel, 27% sand, and 21% of silt/clay, was selected as the base material for further experimentation.

The predicted optimum moisture content of the blended base soil, 11%, was compared with common field practices to determine approximate appropriate moisture content. Because the predicted values and the values estimated from field practices were strongly correlated, the field-based technique was used in the experiment to approximate optimum moisture content. Due to antecedent moisture in the soil prior to the addition of the microbial solution, the actual moisture content of the MIRE samples was slightly higher than that of the RE samples.

2.3. Preparing and testing cylindrical MIRE samples

Using our base soil material, a control mixture and our experimental MIRE mixture were prepared as follows:

- Control (RE): Unamended blended soil + uninoculated AGW
- Treatment (MIRE): Blended soil + *Sporosarcina pasteurii* inoculated AGW (refer to section 2.1)

For each of the mixtures, six 4” x 8” compression test cylinders were prepared. Two cylinders per mixture were tested for compressive strength at three days, seven days, and finally at fourteen days. For each test sample, soil was manually tamped into forms with an approximate 2 2/3” lift height. Compression test samples were removed from their forms 24 hours prior to testing to allow for additional drying and to cap the test specimen. Compressive strengths were tested using the ASTM Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens (ASTM C39/C39M).

2.4. Examining mineralogy

X-ray diffraction (XRD) was performed on post compression samples taken from control and MIRE treated cylinders using a Bruker SMART APEX single-crystal diffractometer equipped with a Bruker MicroSTAR high-brilliance microfocus Cu rotating anode X-ray generator, a graphite monchromator, MonoCap collimator and a SMART APEX charge-coupled device area detector in the KU Small-Molecule X-Ray Crystallography Laboratory. XRD was used to examine mineralogy of the samples and distinguish calcite and dolomite in the carbonate fraction. As expected, the mineralogy of the blended limestone screening and Grinter soil reveal the presence of calcite and dolomite in the carbonate fraction as well as the presence of quartz and mica in the sample (Fig. 4).

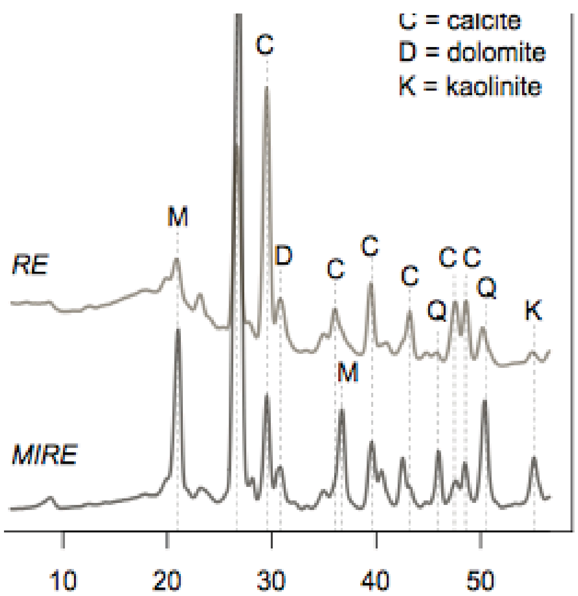

Figure 4: X-ray diffraction (XRD) of RE and MIRE samples indicating mineralogy.

3.0. RESULTS AND DISCUSSION

3.1. Compressive strength test results compared to controls

Results of the compressive strength test are shown in Fig. 5. After three days, the compressive strength of the control RE cylinders exceeded the performance of the MIRE cylinders. Although this discrepancy was unexpected, it may be due to the greater moisture content of the MIRE sample (9.9 compared to 12.0%). After seven days, the compressive strength of the MIRE cylinders surpassed that of the RE cylinders, suggesting that the activity of the microorganisms did not significantly alter the composition of the soil until sometime after three days. The final compressive tests, occurring at fourteen days after the initial cylinder preparation, resulted in a compressive strength ~2.5 times stronger than the RE control. We anticipate a continued increase in the compressive strength of the MIRE sample at the conventional 28-day benchmark due to the effects of *Sporosarcina pasteurii* activity persisting throughout most of the drying process. It is likely that the presence of carbonate from the limestone screenings is buffering the solution pH and creating an obstacle for further calcite precipitation. We speculate that the increase in compressive strength of MIRE over the control would be even greater in base soil where carbonate is minimal.

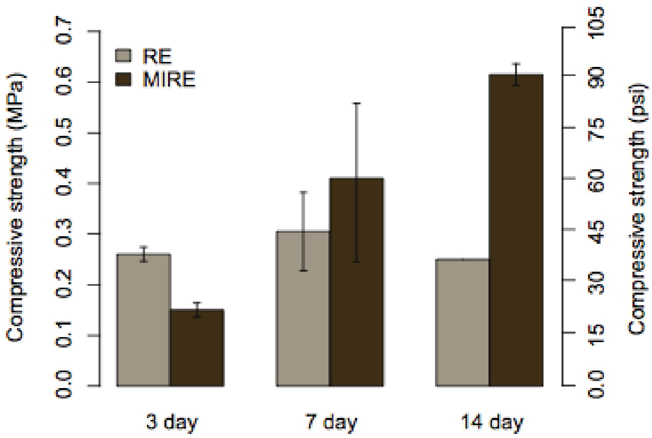

Figure 5: Comparison of compressive strength of non-stabilized rammed earth to microbially indurated rammed earth.

3.2. Key Challenges to Successful Microbially Indurated Rammed Earth

A significant challenge to successfully implementing MIRE in this study was related to the concentration and distribution of the *Sporosarcina pasteurii* microorganism and the dissolved $CaCl_2$. Antecedent moisture content in the soil limited the addition of microbial solution by approximately half of the expected quantity. While this had no effect on the resulting strength of the RE control, it likely had adverse effects on the MIRE sample.

In addition, the microbial solution was added to the MIRE soil mixture by pouring the solution in a fine stream over the spread of soil. This method was used to approximate the procedure used for the uninoculated AGW as it was added to the control RE soil mixture. While this reduced potential sources of experimental error, adding the solution to the samples in this way may have created concentrated domains of microbial activity resulting in a heterogeneous distribution of calcite. A more uniform delivery of the solution to the soil sample may further improve the resulting strength.

CONCLUSION

While further research is necessary, the preliminary results of this research illustrate the efficacy of microbially induced calcite precipitation in increasing the compressive strength of rammed earth material. Furthermore, existing literature in this nascent field of inquiry has shown significant increases in moisture resistance in a variety of materials utilizing these techniques, including concrete and sand cores. Although this was not a focus of our study, it is likely that equally significant increases in the moisture resistance of MIRE are possible. The critical challenges of rammed earth are directly linked to compressive strength and moisture resistance. MIRE, therefore, holds the promise of advancing this long dormant building craft into the twenty-first century.

Ancient rammed earth builders are known to have added organic substances such as pig's urine or ox blood to aid in stabilizing the soil. The precise reasons why ancient builders used these substances are not known;

like much vernacular architecture, the proof of the eating is in the pudding: what works is passed down to later generations. Today we know that mammal urine contains nitrogen-rich urea. We know that blood meal, a nitrogen-rich powdered substance made from animal blood, is an effective fertilizer. We also know that billions of microorganisms, including *Sporosarcina pasteurii* and others like it, exist in most soils. It is certainly possible that, unbeknownst to these ancient builders, they had already discovered the potential of MIRE. In that case, MIRE may be one of the oldest methods of construction on earth, as well as a clue to a more sustainable future. As architect Louis Kahn wrote, “What will be has always been.”

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ENDNOTES

[1] Burroughs uses the following soil classification using only sieve analysis: gravel > 2.36mm; sand between 0.075 and 2.36mm; clay + silt <0.075mm. We, however, are using the United States Department of Agriculture’s soil classification, i.e. gravel > 2mm; sand between 0.05 and 2mm; and clay + silt <0.05mm. This is also the classification system used by the North American Rammed Earth Builder’s Association.

Nanomaterials: Invisible Structures, Visible Performances

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Abstract: Nanotechnology is the study and manipulation of matter at the molecular or subatomic scale. Advancements in this diverse and vast field of science are rapidly producing innovative materials and processes with a wide range of applications. Despite the diminutive scale of nanotechnology, the influence of the field is far reaching and is poised to exert a profound effect on the built environment. Beyond self-cleaning surfaces and anti-fog coatings, nanotechnology suggests an extension of the scalar range at which architecture operates. Challenging its modes of fabrication, emerging research within this micro-science confronts energy intensive modes of material production in favor of ostensibly effortless processes that emulate nature. This paper considers the potential for research in the growing field of nanotechnology to instigate a new generation of performative materials made possible through the design of customized molecular structures that remain veiled from the naked human eye. Through a review of current nanotechnology research, it queries a series of shared principles between science and design in an attempt to identify productive areas for future collaborative research in architecture. Furthermore, it confronts the premise of *visibility of research* through the exploration of a state of materiality that is naturally imperceptible in its formal organization, yet strikingly conspicuous in its active and situated processes.

KEYWORDS: biomimicry, innovation, materials, nanotechnology, performance

INTRODUCTION

Nanotechnology is a broad field of study that spans chemistry, biology, physics, materials science, and others. The most widely accepted definition of the field identifies it as the manipulation of matter that is 100 nanometers or less in at least one dimension, a measure that is one thousand times smaller than the thickness of a sheet of paper. The prefix 'nano' is derived from the Greek word *nānnos*, which is translated as one-billionth. Put simply, the nanoscale is exceedingly small. The minute scale of matter associated with nanotechnology might lead one to believe that the ramifications of this science are proportionately trivial to the processes that occur at the human scale. To the contrary, the science of nanotechnology reveals the relationships between energy and forces at the nanoscale to the complexity of formal and structural logics at the macroscale, thereby broadening the lens of inquiry within the field of architecture. The advancements of scientific knowledge of the nanoscale suggests opportunities to embed material aptitude within the molecular structure of matter, revealing new opportunities for a performative architecture that persists in synergetic existence with its surrounding environment.

1.0 BACKGROUND

1.1 Scientific provocation

> Biology is not simply writing information; it is doing something about it. A biological system can be exceedingly small. Many of the cells are very tiny, but they are very active; they manufacture various substances; they walk around; they wiggle; and they do all kinds of marvellous things – all on a very small scale. Also, they store information. Consider the possibility that we too can make a thing very small which does what we want – that we can manufacture an object that manoeuvres at that level! (Feynman 1960, 25)

Enthusiastic over the future potential of the field of nanotechnology, physicist and Nobel Laureate Richard P. Feynman envisioned the prospect of manufacturing bespoke nanomaterials with advanced properties. In his famed 1959 speech entitled *There's Plenty of Room at the Bottom*.[1] Feynman challenged the scientific community to develop the mechanisms by which materials can be designed, manufactured, and evaluated at the nanoscale. Through simple mathematical calculations, Feynam posited the practicality of manipulating nanoscaled materials and hypothesized on the means by which his theories might be realized. Over 50 years later, the science behind Feynman's suppositions has been significantly advanced as research in the field of nanotechnology is now producing new materials with radical and innovative properties.

Projecting outside of the boundaries of his own discipline, Feynman theorized about the vast potential of this fundamental research to be applied to a multitude of innovations in all areas of science and technology. First and foremost, he identified critical gaps in scientific knowledge necessary to study, create, and manipulate matter at the molecular scale, also connecting this research to potential advancements in the digital realm. He goaded his peers in physics to vigorously pursue research in this field, personally offering monetary awards for those that were successful in meeting his challenges. Feynman cited the most critical apparatus necessary for the advancement of science to be the invention of a more powerful electron microscope capable of viewing nanoscale matter. Modestly, Feynman correlated the ability to *see* matter at the nanoscale with a resultant ability to *discern*, *analyze*, and *synthesize* new scientific knowledge of biological processes, chemical analysis, and the physical structure of atomic particles.

Without ever naming the field of study that he described, Feynman posited that the extension of our sense of sight into the nanoscale would provoke considerable advancement within the entire scientific and technological community. Ultimately his speech provoked significant scientific research in nanotechnology - later termed as such by Japanese scientist Norio Tanaguchi, including the development of molecular electronics, the discovery of buckyballs, and perhaps most importantly the development of the scanning tunneling microscope (Jain 2008). Returning to the conference theme of *visibility of research*, I will make a comparison here between modes of inquiry within design and science; in both the act of surveillance, close observation, is equally vital to the process of innovation. Therefore, it follows that architecture has also gained much through the consequent advancement of the field. I will expand on this proposition later.

1.2 The structure of living matter

To add historical context to Feynman's provocations, it is worth noting that six years prior to Feynman's speech, American geneticist James Dewey Watson and British biophysicist Francis Compton Crick, discovered the physical and chemical structure of DNA and revealed the processes by which living organisms replicate and grow (Johansen 2002). This breakthrough emanated from the observation of the molecular pattern and physical shape of the DNA molecule. The double helix structure of DNA molecules consists of two single polymers that store genetic information while also serving as a template for growth when divided into two single strands. The arrangement of DNA also carries information in the form of a genetic code that governs its growth and behavior in detailed and precise ways, such as the type of cell that it will become, its rate of growth, size, color, etc. Logical, efficient, and structurally stable, the DNA molecule exemplifies the efficiency and complexity of nature.

1.3 Biomimicry and synergetic relationships

Grounded within natural processes of form, biomimicry has emerged as a field of applied science equally as broad as nanotechnology. It is important to avoid misinterpretation of the science of biomimicry as simply providing creative inspiration for technological innovations that *mimic* the form of nature without significantly exploiting the underlying logic it embodies. Beyond a creative muse, biomimicry is the application of biological processes and systems to the research and design of technological innovations. As is the case with nanotechnology, biomimetic research extends across the boundaries of discrete disciplines as it is utilized within chemistry, materials science, engineering, agriculture, ecology, architecture, and many others.

Furthermore, as an applied science, biomimicry informs the field of nanotechnology serving as both a limiting schema and a motivating force. Recalling the words of Feynman, one might be led to believe that anything will be possible as the nascent science of nanotechnology matures. However, biologist and bimimetic expert, Janine Benyus, caution against such fallacious assertions noting, "We are still beholden to ecological laws, the same as any other life form" (Benyus 1997, 5). As knowledge of the processes, structures, and complexity of natural life is uncovered, this information must be used to avoid innovations that continue to threaten the overall viability of the natural ecosystem. To that end, biomimicry guides science and technology toward more integrated relationships between our built and natural worlds.

2.0 NANOTECHNOLOGY AND ARCHITECTURE

2.1 Towards new theories of materiality

The influence of scientific discoveries in nanotechnology and biomimicry has been wide reaching and has exerted influence on design thought for over 50 years. The capacity to view, fabricate, and manipulate matter at the molecular scale, suggests an altered approach toward materiality within architecture. The prospect of replicating natural processes of organic life within synthetic materials and virtual environments has been an area of particular interest. Evidence of the coding of genetic information and the processes of growth within nature offer a nexus between form, performance, and materiality, providing a basis for much of contemporary research in digital technologies and the production of smart materials.

2.2 Material aptitude

Architect and industrial designer William Katavolos conducted early research on the implications of the emerging field of nanotechnology within architecture. In contrast to the more metaphorical interpretation of science by architects such as Wright, Sullivan, and Le Corbusier, Katavolos proposed a notion of a "chemical architecture" that more directly considered the relationship of architecture to emerging research in the area of molecular nanotechnology (Johansen 2002). As co-director of the Center for Experimental Structures at the Pratt Institute since the early 1960s, Katavolos predicted that scientific discoveries would soon make possible the fabrication of materials embedded with "… a specific program of behavior built into them while still in the sub-microscopic stage" (Braham 2007, 149). He and his contemporaries theorized that the invention of synthetic chemical processes suggests new means of fabricating materials and assemblies in architecture. Within his manifesto essay entitled "Organics," Katavolos speculated that this new science would provoke an architecture that grows with "… ceiling patterns created like crystals, [and] floors formed like corrals…" (Braham 2007, 149). Directly related to current inquiry into smart materials, these theories suggest a correlation between the reduction in size of matter and a corresponding increase in material aptitude.

2.3 Science and digital technologies

> The modelling of these complex natural processes requires computers, and it is no coincidence that the development of computing has been significantly shaped by the building of computer models for simulating natural processes. (Frazer 1995, 13)

Scientific research into natural processes and behaviors has also pervaded the discourse surrounding digital processes in design. John Frazer, a British computer technician at the Architectural Association in London, conducted research on the development of an *evolutionary architecture* through the use of computational technologies beginning in the late 1960s. Suggesting an architecture that does more than imitate the formal gestures of nature, Frazer's research explores the notion of computer systems that embody "… the inner logic of [Nature's] morphological processes" rather than external form (Frazer 1995, 10). His research sought to formulate a "genetic language of architecture" comprised of a set of "responsive instructions" that are based on nature's processes of generating form (Frazer 1995, 11). Frazer's work investigated the interaction of exogenous forces of nature and concepts emanating from architecture.

Similar to Frazer's research, the Genr8 tool was a genetic algorithm developed by a team of architects and computer scientists at the Massachusetts Institute of Technology in 2001. This digital tool modeled natural processes of growth in a virtual environment with simulated environmental forces (Holland 2010). However, the Genr8 tool also allowed the designer to manually intervene in the automated process of simulated growth. In this case, the objective forces of the virtual environment are augmented by the subjective preferences of the designer. Collectively, both Frazer's work and the efforts of the M.I.T. team is exemplary of a body of research that explores forms of computational intelligence based on the scientific principles that explain the persistence of life through the organization of its genetic code at the molecular scale. These theories have laid a foundation for future applications of nanotechnology and other areas of science within the discipline of architecture.

3.0 PRINCIPLES AND PERFORMANCES

3.1 Shared tenets and performative principles

> Natural ecosystems have complex biological structures: they recycle their materials, permit change and adaptation, and make efficient use of ambient energy. By contrast, most man-made and built environments have incomplete and simple structures: they do not recycle their materials, are not adaptable, and they waste energy. An ecological approach to architecture does not necessarily imply replicating natural ecosystems, but the general principles of interaction with the environment are directly applicable. (Frazer 1995, 16)

Theories emanating from nanotechnology and related areas of physical and applied science have already had a measureable effect on architectural discourse. In addition to providing fertile ground for the research and development of smart materials and motivating advancements in areas of digital computing, the field of nanotechnology offers a compendium of shared tenets between architecture and the sciences. In lieu of replicating nature, these principles intimate a more synergetic coexistence between environments conceived by humans and those propagated by nature. In so doing, they suggest an evolutionary model of materials that is moving away from energy intensive means of material production towards modes that emulate the interactions within natural ecosystems. While the technology to apply all of these principles is not yet fully mature, the science motivating these developments suggests a course that departs from many currently accepted notions of materials. This section interrogates fundamental tenets of nanotechnology for the suggestive potentials that they embody for future advancements within the field of design. In contrast to the paradigm of materials as static and inert objects, these tenets incite a *performative* archetype of materials as dynamic, responsive and variable elements within the built realm.

3.2 On the matter of material efficiency

Long before the proliferation of nanotechnology research, 15th century Greek philosopher Democritus hypothesized that all materials were made of indivisible particles, which he named *atomos*, meaning "unbreakable" in Greek (Rogers 2008, 5). Democritus' theory on atoms was based on the fundamental belief conveyed by his famous expression, *ex nihilo nihil fit* - translated as "nothing comes from nothing." Today, knowledge of the structure and relationships between atoms is a cornerstone of science used to explain much of the universe. All materials consist of atoms. Therefore, it follows that all materials are affected by nanotechnology. Nanotechnology interrogates the fundamental properties of materials in order to discern the ways in which these properties shift as the amount of material approaches the atomic scale. Furthermore, it queries whether materials can be used in new ways if they are comprised of smaller pieces.

Nanotechnology proposes a "bottom-up" approach in which materials are made by the arrangement of atoms in specific locations, thereby proposing a process that produces very little raw material waste. This method suggests a significant shift away from the current paradigm within architecture of "top-down" engineering, in which larger sections of materials into smaller parts. The efficiency of "bottom-up" processes reveals perhaps the most significant tenet of nanotechnology, which is equally relevant to architecture−"*Do More with Less*" (Rogers 2008, 17). With obvious application to the physical processes whereby materials are fabricated into products used in the built environment, this principle supports current materials research into ultra-lightweight and high performing materials. It also suggests more ecological processes of fabrication that negate the need for post-industrial recycling by replacing current industrial processes with less wasteful means of production.

3.3 On the matters of energy and material fabrication

In nature, atoms are held together through inter-atomic forces, akin to molecular "glue," which exert attractive and repulsive forces on matter. At a particular distance, these forces balance each other creating a condition of equilibrium separation. At this distance, energy is required to move the atom in any given direction. The successive interactions of atoms to create molecules and ultimately solid materials operate on a fundamental principle of energy conservation. Nature operates with inherent efficiency; "*Energy is never wasted when a more efficient option exists*" (Rogers 2008, 97). For example, crystalline structures exist through the natural process of energy efficiency. With repetitive lattice structures that can extend in any direction, crystals sparingly utilize energy packing their unit cells into a complex three-dimensional array of points.

Working in normal ambient conditions, nature constructs materials without harming its environment using simple materials that are readily available. Current biomimetic research in nanotechnology queries such potentials for more efficient means of material fabrication of synthetic materials. Nacre, a naturally occurring nanomaterial that lines the inside of abalone seashells, is a composite of a hard and brittle inorganic material with a soft, but tough organic material. This extraordinary example has inspired research into polymer-clay nano-composites that are strong, tough, and easier to recycle than conventional reinforced plastics. Chemical engineering professor Nicholos Kotov of the University of Michigan has created nacre-like composites utilizing a layer-by-layer assembly process of clay and a polyelectrolyte, a specialized polymer (Berger 2007). Such materials utilize methods of production that will continue to produce more advanced and environmentally sustainable materials.

Nanotechnologists are developing numerous mechanisms of fabrication and material production that take advantage of the propensity of matter to judiciously utilize energy. For example, methods of self-assembly have been developed as autonomous processes where individual units of a material organize and assemble as stimulated by desirable environmental conditions, templating themselves to form a densely packed, yet thin layer of material. Such processes are currently employed to functionalize a surface, altering its properties. As many physical interactions are limited to the surface, the deposition of a thin layer of nanomaterials can modify and improve the performance of materials by increasing material efficiencies, decreasing friction and surface tension, and improving overall resilience and durability.

In the future, processes of self-assembly could also be used to fabricate materials with customized molecular structure at the nanoscale that generate performative properties and capabilities at the macroscale. For example, liquid crystal displays are comprised of an array of transistors that are printed on organic thin films that are only 20 nanometers thick (Rogers 2008, 108). Similarly, organic light emitting diodes (OLEDs) contain a light-emitting layer made of a flexible organic polymer that can be woven into textiles. Current nanotechnology is not capable of building complex structures directly from atoms and molecules; however, processes utilizing nanoparticles have emerged as a feasible alternative for the assembly of materials at the nanoscale. Nanoparticles can be efficiently produced in sufficient quantity and used to make a variety of products. Other processes, including template particle assembly, simplify the process while providing considerable control over particle positioning. As these fabrication processes continue to mature, the ability to customize the nanostructure of materials to include multi-functional characteristics in both the structure of the material itself and its surface properties is probable.

3.4 On the matter of scale

At the nanoscale, the laws of physics change. Gravity and inertia have little effect. Quantum effects and molecular forces govern material responses over the normative forces that control the macro world. As one of the first materials exploited for its altered properties at the nanoscale, gold demonstrates this fact clearly. At the macroscale, gold particles have a melting temperature of 1,064 Celsius degrees and possess the characteristic yellow-orange color that is commonly associated with the medal. However, at the nanoscale, gold melts at a temperature more than 300 degrees lower and appears red in color. Medieval artisans exploited this early form of nanotechnology, using molten gold to produce stained glass windows with a rich ruby red color.

In addition, the utility of materials changes as their size decreases from the macroscale to the microscale to the nanoscale. For instance, small wires have enabled complex and intricate networks that make possible faster and more powerful computing networks. As the size of wires moves into the nano- dimension, "they acquire new properties turning ordinary wires from passive components into active ones - sensors, transistors, or optical devices" (Rogers 2008, 104). Therefore, a third tenet of nanotechnology reveals that *the properties of a material are relative to its characteristic scalar dimension*.

A material's scale affects its surface to volume ratio, the means by which it interacts with external forces, and the interaction of its internal molecular energies. Engineers have devised methods to effectually approximate how the characteristics of something will change as its dimensions change. Termed *scaling laws*, these estimates amount to hand calculations that evaluate the effect of scalar adjustments and highlight the ways in which these scalar shift might enhance or impede a material's performance. Although scaling laws can provide useful information, these approximations can also lead to misleading or inaccurate results. At this time, mechanical systems scale very well even to the nanoscale, while the same is not true of electromagnetic and thermal properties. The accuracy of mechanical scaling laws would be quite useful to architecture and the building sciences to improve the precision of digital simulations that model the effects of energy and material properties among others. Improvements in architectural computational tools would allow for greater translation between the actual behavior of materials and the digital simulation of these effects.

In addition to altered physical properties and scaling effects, nanomaterials also blur the boundaries between material and machine. The diminutive scale of nanomaterials presents opportunities to embed performative capacities directly into matter at the molecular scale. Researcher Kris Pister of the University of California at Berkeley is pursing these potentials in his work with 'smart dust,' remote sensing devices that would integrate computing power, sensing equipment, wireless technology, and battery power into a material smaller than a grain of rice (Sutter 2010). Other research in nanotechnology is leading towards the development of nanoscaled materials that self-repair themselves through processes similar to those of living cells. The scalar dimension of nanotechnology suggests a merging of digital and physical realities as advanced materials are increasingly embedded with micro- or nanoscaled computing devices and interactive technologies.

CONCLUSION

Advancements in the science of nanotechnology significantly progress the theories of visionaries such as Richard Feynman and William Katavolos, who anticipated the capacity for materials to approach the complexity and performative capacities of living cells. Though concealed from plain sight, nanomaterials propose an efficiency of raw materials and energy, as they persist in a scalar dimension that is subject to altered laws of physics. Ultimately, the central tenets of nanotechnology collectively reveal the interdependency of materials, energy, and systems along the scalar continuum. The proficiency, economy, and innovative character of biological life suggest the potential for increased collaborative research between architecture and the sciences that is inspired by the creative productivity of the natural world.

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ENDNOTE

[1] Feynman's speech, originally offered in December 1959, was later published in the Engineering and Science in 1960 and remains a seminal work in the field of nanotechnology.

CULTURE

New Ideas, Minor Voices, and Topics on the Margins

“Casbahism” in Europe: the Journey of an Architectural Idea

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ABSTRACT: The paper examines how a new architectural idea gained visibility within post-WWII European architectural culture. By tracing its trajectory from Casablanca to Berlin, attempting to reconstruct the relationship between the Free University, often considered the prime representative of what later became known as the “mat-building” typology, and the North African “casbah”, the paper explores how the visual or perceptual, emphasized during interactions between the narrative’s protagonists or disseminated through architectural publications, played a salient role in popularizing the idea in European circles. The main argument the inquiry puts forward, by situating the original spark that launched the mat-building idea in research that its chief promoters conducted while in North Africa prior to instrumentalizing this research in later design projects, is that research can stretch the discipline's boundaries by introducing new ideas from plural sources, which can only enrich architectural culture and critique its prevalent, increasingly autonomous, practices. The paper thus elucidates a way in which foreign influences entered Western architectural discourse, constituting a palpable example of how modernist dogmas were challenged by its very agents, through a historicist as well as a cultural 'other', on the eve of postmodernism.

1.0 Recognizing a Genealogy

Alison Smithson published her legendary article *How to Recognise and Read Mat-Building: Mainstream Architecture as it has Developed towards the Mat-Building* in 1974. The article is often taken as a reference point by those probing the mat-building typology which gained significant attention in the last few years within architectural practice (thanks perhaps to the engagement of international architects with emerging cities in the Middle East, which called for solutions deemed authentic to the region), as well as scholarly circles (thanks to revisionist and critical historiography). Various genealogies that attempted to situate the idea historically have been written, and contemplating a new one seems superfluous. Yet what has not been attempted so far is a serious consideration of Smithson’s own suggestion of what she considers a legitimate pedigree for the mat-building. At the beginning of her article, Smithson coins the term “casbahism”, suggesting that the traditional Arab city is the mat-building’s “formative influence from the immediate past” (A. Smithson 1974, 573). In the last page of the same article, Smithson annotates a number of images representing examples of Turkish and Indian “Islamic architecture” apologetically, stating that “we know all too little [of the Islamic tradition] considering the direction of our [current] interests". It seems inevitable for anyone writing about the mat-building to consider these hints, and to study how Arab or Muslim cities became imbricated in the, essentially Western, mat-building discourse; yet this narrative seems to still be missing.

In fact, Alison Smithson herself does not follow her own lead. The majority of her article can be characterized as a meandering investigation, in text and images, of the mat-building idea, concerned ostensibly with tracking its antecedents, which find their logical conclusion in the recently completed Free University project in Berlin, by Candilis, Woods, Josic, and Jean Prouvé. But rather than an actual genealogy, the main body of the article ends up adhering largely to the purpose suggested by its title, that is, it ends up being a sort of manual for understanding what is meant by the mat-building, explicating its most important features. In imagery and accompanying captions however, Smithson does provide a loose genealogy that touches upon various building traditions, Western and non-Western, new and ancient, in an attempt to prove the historical continuity of the mat-building. Perhaps the most coherent narrative Smithson presents, of how the mat-building idea became recognized and celebrated, is paradoxically found in the following statement (A. Smithson 1974, 573):

> The way towards mat-building started blindly enough: the first Team 10 review of the field of its thought became collectively covered in the Primer (AD 12/61). The thought gradually got further bodied-out in projects, and these in the early 'seventies began to appear in built-form. At this point mat-building as an idea becomes recognisable. To be able to recognise the phenomenon at the end of this, its first, primitive phase, calls for a specially prepared frame of

mind... Mainstream mat-building became visible, however, with the completion of the F.U. (Berlin Free University)

Thus one end of the thread can already be caught: the role of Team 10 is instrumental to the formation and dissemination of the mat-building idea, first through their collaborative gatherings, and later in their built projects. Various iterations of the building type might be recognizable before the 1950s, but it was through Team 10 that the idea seems to have been articulated in the first place, allowing later identification of earlier structures that fit the description. This paper attempts to reconstruct the outlines of this particular genealogy, to trace the thread along which the idea of 'casbahism' has travelled from North Africa up to Berlin, and what took place during the process. The paper is not concerned with pondering the formal characteristics or performative possibilities or merits of the mat-building typology – a lot has already been written about that – but with constructing, or unveiling, an alternative narrative that can be assembled from original statements by the main protagonists or contemporary collaborators, particularly those of Team 10, instead of one that is based on individual conjecture.

2.0 Beginnings

Rather than starting from one historical end of the thread or another, that is, rather than starting from Casbahs and working up to the Free University, or vice versa, one can start from the middle, precisely at where Smithson points: the formation of Team 10. Indeed, the denouement of the narrative at hand, or its most salient episode, seems to have taken place in 1953 in Aix-en-Provence, France. It is here that the idea made its remarkable debut in Europe, gaining serious momentum and garnering sufficient interest, making the rest of its journey seem inevitable. It is also here that many of Team 10 young members had a chance to interact for the first time, at CIAM's 9th Congress.

The early role of CIAM in institutionalizing modernism, and transforming it from an ideology advocated by a few pioneers, into a large organization with a wide international membership, consolidating the movement into a set of agreed upon principles which CIAM members would simultaneously adhere to and propagate, cannot be underestimated. The heyday of architectural modernism may have been the interwar period, but one can claim that it was in the years following World War II that modernism actually had its opportunity to be tested on a wide scale, during the massive building campaign launched across Europe to rehabilitate the continent. CIAM became instrumental in this period. The significance of CIAM, for the inquiry at hand, probably lies in the fact that the organization became a forum where many voices were heard, and a pool of information to which a variety of sources contributed, making the set of possible references, hitherto mostly European, more heterogeneous. Due to some of its members' involvement in non-Western contexts, French architects working in colonized North Africa for example, contact with the non-West became unavoidable.

In 1953, CIAM-Alger, a group founded in 1951 and consisting of a number of French architects and urban designers working in Algeria, presented its study of an informal Arab local settlement to the rest of CIAM members at their meeting in Aix-en-Provence, France. The analysis was meant to represent a unique dwelling example from which other CIAM members can learn, as well as a demonstration of a possible response, through the recently completed projects, to the challenging cultural and environmental issues the group grappled with in North Africa. The presentation was apparently so effective that CIAM decided to hold its next meeting in Algiers in 1955. The meeting in Algeria did not go ahead eventually, despite preparations, due to several reasons, the most obvious of which was the deteriorating situation in the last years of French colonialization (Celik 2005). What is important to note however is not whether the event took place in Algiers or not, but the perceived salience of CIAM-Alger's work, and its pertinence to other members working around the world; what is also important to note is that the idea of holding a general CIAM meeting in a non-Western context was actually entertained for the first time (notwithstanding the fact that Algiers was a French colony then).

This is not surprising, given the fact that GAMMA (Groupe d'architectes modernes Marocains), another group of French modern architects working in Morocco, which included Victor Bodiansky, Michel Ecochard, Henri Piot, and most notably (because of their later activity and significance for the narrative at hand), Georges Candilis and Shadrach Woods, also presented studies on the housing theme, in the form of an analysis of recently completed projects in the region. In these projects, most famous of which is the housing development of *Carrieres-Centrales* in Casablanca (a joint project by Candilis's ATBAT-Afrique and Ecochard's Services de l'Urbanisme), GAMMA illustrated how Moroccan traditional living conditions were reinterpreted to create modern housing for the local population. The schemes must have attracted attention at the CIAM meeting, given their invention of novel housing typologies –new even for European modernists. Some of the projects involved adapting the traditional courtyard house for instance, stripping it down to what the architects thought was the most essential characteristic, namely the private patio, and stacking a series of these houses on top of each other, creating a distinct residential tower typology, with a volumetrically playful façade, but one almost devoid of any windows (Tom Avermaete 2005). These projects were presented to other members attending the 9th Congress through the classic CIAM method of the grid. GAMMA's grid, titled *Habitat du plus grand nombre,* was distinct from previous CIAM grids however, and it was by far the most exciting during that congress. Its innovation was in that it focused on the quality of life of the poor local inhabitants of the 'bidonville', for whom the GAMMA housing schemes were intended, rather than reiterating CIAM traditional formulas of analysis. Reflecting back on 1953's CIAM, Alison Smithson recalled that "it was the ATBAT 'Grille' from Morocco, not much larger than our own yet without waste space; with its golden suns on wands and new language of architecture generated by patterns of inhabitation that seized us. The nascent Team 10 found each other in their admiration of these schemes, about a third of which had got built" (Alison Smithson, "A Record of Team 10 Meetings", 1991, 19-20).

3.0 North Africa

ATBAT started in Paris in 1947, as a multidisciplinary firm the initial aim of which was to support the construction and engineering of Le Corbusier's *Unité d'Habitation* in Marseille. The firm was set up by Le Corbusier along with another firm, ASCORAL - the latter would undertake theoretical investigations, while ATBAT would handle practical ones, and both firms were meant to become extended arms of Le Corbusier's main office that was overwhelmed with work at the time (*Architectural Review*, 1987). The firm was on one hand a response to a need for closer collaboration between engineering and architecture to meet the reconstruction challenges following World War II, and on the other, it facilitated a more efficient project execution and building construction. Under the leadership of Vladimir Bodiansky, the firm, which attracted many young architects and started doing projects around the globe, soon produced offshoots, most notably ATBAT-Afrique, which established itself in Morocco in 1951. The latter's leaders, Georges Candilis, Shadrach Woods and Henri Piot, became involved in coming up with solutions to the housing problem which plagued North African cities due to rapid internal migration from rural areas. They collaborated with Michel Ecochard to produce the innovative housing solutions later presented at CIAM's 9th Congress ("ATBAT [Fr. Atelier des Bâtisseurs]", 2012).

Both Georges Candilis and Shadrach Woods worked at Le Corbusier's office on the *Unité d'Habitation* project, which is where they met prior to their later collaborations. Candilis met Josic in the main ATBAT office in Paris, after he returned to it in 1954. A year later, and following Woods return to France, the partnership Candilis-Josic-Woods was established, along with other collaborators. The firm expressed its dissatisfaction with conventional modernist ideologies that they believed could not address the challenges of post-war reconstruction. They chose to work on low-cost housing developments, and other practical schemes in which they could test the ideas they were simultaneously sharing with and learning from other Team 10 members. Their most memorable works today are their *Frankfurt-Römerberg* and *Freie Universität* Berlin in which they explored the mat-building idea ("Candilis-Josic-Woods", 2012).

Remarkably, it was members of the GAMMA group, such as Georges Candilis and Shadrach Woods, and other members of CIAM, most notably Alison and Peter Smithson, who were among the first to challenge established modernist dogmas, leading to the creation of Team 10 and the subsequent dismantling of the older CIAM. The dissenters shared a "mutual realization of the inadequacies of the processes of architectural thought which they had inherited from the modern movement", while each member of the new group "sensed that the other [members] had already found same way towards a new beginning" (A. Smithson 1968, 3). The group, in its attempt to reform modernism, was interested more in pragmatic solutions to contemporary urban problems than in abstract theoretical approaches, and advocated an active role for architecture in responding to the specific human conditions in a particular cultural context. What is perhaps most significant about Team 10 is the fact that the group, as a result of their practical approach that rejected universal blanket solutions, did not hesitate from actively borrowing and appropriating architectural and urban traditions from outside the West.

Alison Smithson testifies to a sort of maturity that GAMMA members seemed to have at the time when Team 10 was being formed, that allowed the French protagonists to contribute disproportionately more to the nascent organization. She suggests that "Georges Candilis had probably no need of any Team 10 interchange to evolve as an architect. His extension of modern architecture into his personal language had been worked out in Morocco"; Smithson went on to describe Candilis's impact on Team 10 meetings by relating: "in gearing his description of work in progress to the theme of the meeting, Candilis always helped to open up an interchange of opinions that would be distilled into that meeting's nebula of collective thought" (Alison Smithson, "The Beginning of Team 10", 1991, 14). It was thus GAMMA members' experience in Morocco, consisting of recently built projects, that seemed to largely define the topics around which Team 10 early gatherings would revolve.

But it was not only the experiences of CIAM-Alger and GAMMA members working in North Africa that had an influence on Team 10 members during their interaction in 1953. Aldo van Eyck, whose Orphanage project in Amsterdam is often invoked as a prime example of the mat-building typology, was very enthusiastic during the 9th Congress about work done in non-Western contexts. Van Eyck had not only studied Algeria and Morocco himself in the past, but also traveled there several times in the early 1950s, to survey the vernacular architecture of casbahs, market places, and oases, in which he discovered architecture that he thought "cannot have been so very different in Ur 5,000 years ago'" (quoted in: Eric Mumford 2001, 52). Although van Eyck's relationship to North African urban form was different, in that his admiration was more for the abstract, primitive, and seemingly timeless architectural forms than for the context-specific cultural values these forms putatively implied, after seeing the work in the Grids presented by the French architects from North Africa, van Eyck enthusiastically proclaimed that "CIAM now had no choice but to abandon its narrow Occidental viewpoint" (quoted in: Zeynep Celik 2005, 278). Indeed van Eyck's orphanage project executed in the mid 1950s predicted the later Free University in Berlin, proving a fascination with the mat-building typology within Team 10 that was not simply restricted to its French members.

4.0 Earlier Influences

In chronicling the contributions of individual Team 10 members, Alison Smithson recalls that "'Le plus grand nombre' was one of George's [Candilis] standard phrases for many years; confirming that the language of discussion, as the structure, emanated from Le Corbusier" (A. Smithson, "A Record of Team 10 Meetings", 1991, 19). Although Team 10's efforts are often seen as a mutiny against Le Corbusier's control of CIAM and his strict modern dogmatism, his architectural influence evidently continued well into Team 10's mature years. Indeed, this was particularly the case in the work and rhetoric of the French members, whose previous experience at Le Corbusier's office had a lasting effect. Soon after the ATBAT-Afrique's buildings were finished, they were celebrated by the Smithsons; the couple declared that they considered "these buildings in Morocco as the greatest achievement since Le Corbusier's Unite d'Habitation at Marseilles" (A. and P. Smithson 1955, 2). The comparison did not come from a vacuum. It was not only Candilis's and Woods's involvement in the Marseilles project that needs to be pointed out here, but their exposure to Le Corbusier's earlier work in Algiers.

Le Corbusier's work in Algiers, from site visits, numerous studies, to the several iterations of the uncommissioned proposal, reveals an interest in engaging and learning from the context's cultural uniqueness (Le Corbusier 1967). Not only was his architectural solution informed by the existing context, but it is perhaps most notable in how the proposal worked around, and delicately preserved, the old Casbah. As opposed "to the callousness he exhibited toward the vibrancy and charm of ancient Paris in Plan Voisin, a deep respect for the Muslim vernacular extending beyond the simple joys of *folklorique* emerges in Le Corbusier's descriptions and drawings"; Mary McLeod adds that Le Corbusier "declares, 'O inspiring image! Arabs, are there no peoples but you who dwell in such coolness and quiet, in the enchantment of proportions and the savor of a humane architecture'" (McLeod 1980, 65). In Algiers, Le Corbusier seemed to have found a primitive version of modern architecture that was spontaneous, popular, and happily inhabited; he recognized in it a sense of community, and the kind of symbiotic relationship between architecture and its inhabitants that he aspired to in his own work. His proposal for Algiers surely disregards the harsh realities of living in the Casbahs, or the colonial suppression of locals that took place at the time, and perhaps focused more intently on the poetics of vernacular architecture and the visual qualities of urban form he observed. Nevertheless, Le Corbusier's informal analysis of the Casbahs he visited, his fascination with the local culture, even if it was a removed or distant admiration, and his subsequent proposals which were situated as not only the outcome of these exercises but as an appropriate contextual response to the conditions of the city had a lasting impact; all of these factors must have provided a strong precedent from which later architects could learn. Therefore, Le Corbusier's role in the narrative at hand cannot be underestimated, whether it was through his early work which set the tone for a more meaningful engagement with a non-Western culture, in his centrality to the birth and success of CIAM which was the breeding ground for Team 10's ideas and relationships, or his direct interaction with members of Team 10 central to the narrative here.

5.0 Plurality

Indeed it is the fact that most of the protagonists in this narrative were French architects who worked in North Africa that makes it easy to fall for an identification of the mat-building with a French or European tradition. However, in a Team 10 meeting in Rotterdam, April 1974 (when the idea of Alison Smithson's famous essay was formed (A. Smithson, "Tuesday the 9th of April, A.M.: Facing 'consumerism'", 1991, 124)), Candilis confessed to the true origins of Berlin's Free University: "In Morocco with Shad, we began to work on an idea of a special conception to create place. Certainly the special concept was influenced by the Souks of Marakesh... Berlin has been decided in Morocco in 1952, where we had the opportunity to make a school, though never built" (in A. Smithson, "Tuesday the 9th of April, A.M.: Facing 'consumerism'", 1991, 130-1). It is not difficult therefore to connect the dots, and to sketch out a rather simple and straightforward genealogy delineating the path along which the mat-building arrived in Berlin: from the young architects working for Le Corbusier and getting exposed to his work in Algiers, to their own later work in North Africa, to their participation in CIAM meetings and subsequent formation of Team 10 through which the ideas were propagated to architectural communities in different parts of Europe, and finally realized in their own built work in various cities, most notably Berlin. This sketch is not meant to reduce the enormous complexities inherent in processes of influence, adaptation, and appropriation, but it is meant to elucidate the rather direct causal relationships admitted by Team 10 members themselves. The resulting genealogy is one that is simultaneously about the journey of an idea, and also about the journey of actual protagonists who believed in an idea and cared to develop it, share it with others, and implement it in various guises.

Once assembled, this genealogy is so simple and straightforward that it is surprising not to find it explicitly compiled to date. In fact, this particular genealogy seems to be overlooked, or perhaps even deliberately suppressed. This may be due to the fact that despite recent contributions to critical, culturally-inclusive historiography of modernism, the discipline seems to continue to be interested solely in established narratives that claim an exclusively Western architectural history of the movement. That is unfortunate because in avoiding engagement with cultural or hybrid aspects of architecture, the discipline cannot realize that Team 10 members' greatest achievement was perhaps their openness and engagement with building forms that were hitherto derided by architectural histories – an openness suggesting that in order to enrich contemporary architecture, it was as valid to reference a Casbah as it was to contemplate Rome. This attitude, welcoming and encouraging plurality, is what will remain the legacy of Team 10, and it is the role of architectural historians to illuminate it today.

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Spirituality in Place: Building Connections Between Architecture, Design, and Spiritual Experience

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ABSTRACT: Contemporary urban design practice in western society primarily focuses on addressing basic human needs (physical and physiological) without sufficient attention to higher-order needs, which are defined as 'self-transcendence'. Using psychological theory to establish a basis for well-being and health, an argument can be made for gaps in the hierarchy of human needs that current urban design practice does not address. And while contemporary urban design often addresses social aspects of public space it can still lack meaning for users, resulting in places that are not environmentally and socially responsible, and are, to a degree, devoid of elements that create a sense of humanity in place. How then does the built environment, public and private alike, address the more personal, and intimate needs of an individual? How do buildings and streets engage an individual in personal growth, creating a means of contemplation, curiosity and exploration, and knit together ideals and convictions that guide our lives? This project uses the notion of 'spirituality in place' to seek out the qualities of the built environment that contribute to places which, through their physical design, allow users to find greater meaning in their surroundings. Designers and architects often talk about meaning, beauty, poetics, connection, atmosphere and other ethereal, invisible aspects of a place. It is the objective of this research project to make more visible these invisible qualities of the built environment, by exploring the relationship between Buddhism and Taoism and contemporary architectural and urban design practice. This project defines spirituality in the context of the built environment, theorizes a framework for spirituality in place consisting of humanity, sensuality and sustainability, and deploys this framework to identify ways in which spirituality is manifest in the built environment through a critical analysis of select sites.

KEYWORDS: spirituality, sustainability, phenomenology, holism, framework, urban design, Eastern wisdom

INTRODUCTION

"Not to consider 'I am this', that is freedom."
The Buddha

In the fields of urban design and architecture, one of the primary goals is the creation of spaces and places that connect in a meaningful way to the user. The practices of the built environment aim to create beautiful places that are easy to understand and, increasingly, minimize environmental impact and maximize social responsibility. Architects and designers frequently talk about meaning, beauty, poetics, connection, atmosphere, and ethereal aspects of places. And while subjective, these facets of design are no less important than more quantifiable elements such as form, space, and order. Arguably, a seamless interface between the ordered, quantitative aspects of design and the qualitative, less tangible aspects prove critical to building successful places. Many treatises exist that adequately and eloquently define the quantitative elements of architecture and urban design. One need not look far to find an abundance of material on methods and theories of architecture|design that suggest numerous approaches to crafting ordered, understandable, and harmonious places. These texts historically achieve this by examining the form, the structure, and the physical elements of the built environment. But it is the subjective aspects of design, the production of beauty, poetics, atmosphere that becomes far harder to define and delineate. This lack of an understanding (definition) of the these elements has, to some degree, contributed to the development of places which are not sustainable, do not have deeper meaning, and do not adequately address the full field of human needs.

This paper and the research commensurate with it put forward an early exploration of the intersection between spirituality and place. What follows is the development and justification of a framework that begins to coalesce spirituality and place, moving toward a holistic relationship between architecture, people, and the environment. The objective of this paper is to present this framework as a point of departure for further research and to give cause for speculation on how the spiritual qualities of place are manifest. This is not to say that all places should or need to be deeply meaningful or evoke a heightened sense of spirituality, but by investigating and giving more consideration to those places that reach such ends, we as designers can perhaps better understand how places shape, connect to, and engage with a sense of self actualization and personal meaning. One of the primary challenges of this investigation is the inherent subjectivity of the central topic; that is spirituality. The word 'spirituality' holds different meaning for different people and both religious and secular directions. Additionally, a place that holds meaning, that is sacred for one person, will not necessarily hold meaning for someone else. Hence, a conceptual approach, which results in a relevant framework, seems appropriate. Rather than taking a prescriptive approach where A + B + C = a spiritual place, this research argues for the importance of thinking about spirituality and meaning in the context of the built environment and suggests a framework for doing so. The aim is not to determine what meaning should be derived by an individual from a place, but rather how, through the spaces and places an individual inhabits, that meaning is cultivated and hopefully realized. The lens of spirituality and, in particular Buddhist and Taoist philosophy, offers a unique approach of which little has yet been written. By developing a framework that facilitates an understanding of spirituality in the built environment this research makes visible the invisible qualities of space that reside at an intense, meaningful level for the individual user, and in doing so challenges the notion of visibility suggesting that beyond the conventional definition, the idea of visibility constitutes a complete awareness of one's environment and also one's connection to that environment.

1.0 SPIRITUALITY AND THE BUILT ENVIRONMENT

1.1. Why spirituality?

To situate the investigation of spirituality in place, Maslow's hierarchy of human needs provides a unique and valuable starting point. The five basic needs that Maslow originally identified were physiological, safety, love, esteem, and self-actualization. He determined that these needs are hierarchical and that as one need is "fairly well satisfied, the next prepotent ('higher') need emerges, in turn to dominate the conscious life" (Maslow 1943, 395). Nearly three decades later, Maslow determined that a sixth motivational level was required, above self-actualization, which results from an individual having "peak experiences" (Maslow 1961). Recent research into Maslow's journals has defined this sixth level as self-transcendence, characteristic of individuals that strive to further a goal beyond the self which

> may involve service to others, devotion to an ideal (e.g. truth, art) or a cause (e.g. social justice, environmentalism, the pursuit of science, a religious faith) and/or a desire to be united with what is perceived as transcendent or divine (Koltko-Rivera 2006, 303).

Indeed, Maslow's hierarchy and his consideration of self-actualization and self-transcendence provide compelling arguments for the committed pursuit of the 'spiritual' in design. Investigations into the "growing trend of place-breaking" due in part to climate change and political/civil strife have led others to suggest that

> it may indeed prove both valuable and timely to engage in critical conversations around the potential for the spiritual to inform and inspire city planning, architectural design, place-making, and space-making (Sinclair 2011, 4).

In the modern world the places we inhabit, be they private or public, are the vessels through which our needs as humans are nurtured and satisfied. It is fairly easy to see how cities can meet physiological and safety needs, and proponents of greater attention to the social of life cities, such as Jane Jacobs, argue for cities that meet the needs of love and esteem. The ways in which the built environment address the needs of self-actualization and self-transcendence becomes much harder to identify, operationalize, and address. The inherent subjectivity and abstruse nature of spirituality, particularly in the context of modern design leads to a challenging, controversial discussion, but it is exactly these qualities and challenges that the author's contend make the discussion worthwhile.

1.2. A definition of spirituality

In order to develop an approach to the spiritual nature of design it is first useful to define what we mean by spirituality, in particular the spiritual experience vis-à-vis the built environment. Although one could turn to a nearly infinite number of sources from literature, art, and music to sacred texts and philosophical treatises, there have in fact been a number of psychological investigations into what constitutes a 'spiritual experience' (Maslow 1961; Pahnke and Richards 1966). Maslow identified 15 characteristics of people who were motivated by peak experience as it related to self-transcendence (Maslow 1961):

Feelings of integration, unity, whole, organized
Feeling fused with the world; becoming ego-less
Using all capacities at their best and fullest; fully functioning
Effortlessness in functioning (flow, 'in the groove')
Feeling responsible, active, being the creating centre of activities; being a prime mover, self-determined

Feeling free of blocks, inhibitions, cautions, fears, doubts, controls, reservations and self-criticisms
Spontaneous, expressive, innocently behaving (guileless, naive, honest, candid, ingenuous, childlike), more natural (simple, relaxed, unhesitant, unaffected, immediate), more controlled and freely flowing outward
Creative
Uniqueness, individuality, idiosyncratic
Here now; free of the past and future
Being a “pure-psyche” living under ones own laws; less of thing of the world and more a pure self
Non-striving, non-needing
Expression and communication become poetic, mythical and rhapsodic
A Sense of completeness, authenticity, catharsis
Gratitude towards a higher power, humility, feeling fortunate

With these characteristics in mind it is possible to develop an idea of what a ‘spiritual experience’ might look like for someone engaging in their surroundings. The question then becomes: How does architecture and urban design connect to an individual in a way that facilitates and/or compliments peak experiences, thereby fulfilling the higher order human need of self-transcendence?

2.0 AN EASTERN PERSPECTIVE

It is not difficult to see the parallels between Maslow’s description of peak experience and Buddhist and Taoist thinking. The idea of “letting one’s mind alone and trusting it to follow its own nature” (Watts 1989, 89) speaks of spontaneous, childlike, more natural behavior. Zen Buddhists often speak of transcendence (Sasaki 1954) and concepts such as unity and agelessness (Maslow 1961, 255) are reiterated within the Buddhist idea of “subjective isolation” where

> the knower no longer feels himself to be independent of the known; the experiencer no longer feels himself to stand apart from the experience (Watts 1989, 120).

This Eastern line of thinking, however, also has implications for the physical world. Beyond the psychogenic connection between a person and their environment, there are concepts that provide insights for the built environment. Concepts such as unity, organization, creativity, uniqueness, expression, poetry, and authenticity are just as easily related to the physical realm as they are to peak experience and transcendence. Certainly, balance, harmony, and nature can be associated with form, space, and order. Zen rock gardens provide one example of the physical manifestations of Buddhist and Taoist thought. The relationship between Eastern thought and aesthetics, design, architecture is not a new line of inquiry (Tanizaki 1977; Koren 2008). By appertaining to the idea of self-transcendence (spirituality) and having implications for the design of the built environment, Buddhism and Taoism provide a unique and valuable approach in connecting the two.

The following subsections explore a few central concepts drawn from Buddhist and Taoist thought, that the authors believe have implications for design and spirituality. By no means exhaustive, this list provides a starting point for connecting spirituality and place and helps to lay the groundwork for developing a framework.

Figures 1 + 2: Rock garden and temple garden, Kyoto, Japan. Source: (Birch, 2005)

2.1. Impermanence

The Buddhist concept of impermanence (anitya) suggests that change and flow are a natural part of the world around us, and to resist this change is like chasing “one’s own shadow, the faster one pursues it, the faster it flees” (Watts 1989, 46). It evokes the “transiency” of Pahnke’s mythical consciousness (Pahnke and Richards 1966, 8) as

> to the mind which lets go and moves with the flow of change, which becomes, in Zen Buddhist imagery, like a ball in a mountain stream, the sense of transience or emptiness becomes a kind of ecstasy (Watts 1989, 42).

The implications impermanence has for the built environment could manifest in various ways. For example, the use of lighting and shadow evoke a kind of ephemeral connection to fleeting nature of sunlight. As is described, the mythical, poetic quality of a space often "depends on a variation of shadows, heavy shadows against light shadows - it has nothing else" (Tanizaki 1977, 29). There are also social implications derived from the concept of impermenence. Flexibility in program of space (i.e. supporting a variety of uses) or encouraging user engagement in design also echoes a certain impermanent quality.

Figure 3: Floating village in Vietnam evokes a sense of impermanence, flexibility, and adaptability in its design. Source: (Birch, 2006)

2.2. The Way (Tao)

Arguably a difficult concept to define, the Tao nevertheless has significant implications for the world of design, particularly in the context of nature and sustainability. As Watts defines it

> the Taoist mentality makes, or forces, nothing but 'grows' everything. When human reason is seen to be an expression of the same spontaneous balance of yang and yin as the natural universe, man's action upon his environment is not felt as a conflict (Watts 1989, 176).

Emphasising the spontaneous, natural, balanced approach to the world, this description echoes the characteristics of the peak experience. In this way, using the concept of Tao, design upon the built environment should not be forced, should fit within the larger social, cultural, environmental contexts, and should respect the natural landscape rather than exploit it. The value of finding a path of harmony and balance, in a gentle and receptive manner, as opposed to forcing issues, is paramount.

2.3. Wabi-sabi

Another concept, equally hard to define, that has significant implications for design is that of wabi-sabi. 'Rustic' is the closest representation of wabi-sabi in a single word, but a larger explanation defines it as

> a 'comprehensive' aesthetic system...It provides an integrated approach to the ultimate nature of existence (metaphysics), sacred knowledge (spirituality), emotional well-being (state of mind), behavior (morality), and the look and feel of things (materiality) (Koren 2008, 41).

Fundamentally the concept of wabi-sabi embodies the imperfect, impermanent, and incomplete nature of the world and appreciates a close attention to the natural order of things. In this way wabi-sabi consolidates many of the preceding (and following) concepts as they relate to design. It serves to bring the spiritual element of consciousness and tune it to the material, aesthetic, world. The allowance for imperfection and authenticity in the design of places begins to evoke spiritual experiences as users are permitted to relate in a unique, individual, and idiosyncratic way. In our modern world the artificial and contrived often overshadow the genuine and the authentic – the authors argue for a more meaningful resonance with user needs and greater willingness to embrace the unrefined, the unpolished and the imperfect.

Figure 4: The imperfections and rustic quality of the material are evocative of wabi-sabi. Source: (Birch, 2005)

3.0 A FRAMEWORK FOR EXPLORING SPIRITUALITY IN THE BUILT ENVIRONMENT

Referring to the characteristics of peak experience and considering how specific concepts of Buddhism and Taoism have implications for design, we identify three conceptual areas which serve to facilitate the built environment in addressing self-transcendence, and provide some examples of each. Our framework evolves from an idea of connecting an individual to his/her environment (sustainability), his/her social/cultural world (humanity), and to his/her intimate self (sensuality). It is hoped that by addressing these three inter-related areas architecture, planning, and design can facilitate more meaningful experiences. We use the framework to consider how elements of the built environment (i.e., architecture, public space, landscape, program) contribute to various experiences characteristic of spiritual engagement through the concepts of humanity, sensuality, and sustainability. Figure 4 offers a graphic representation of our framework.

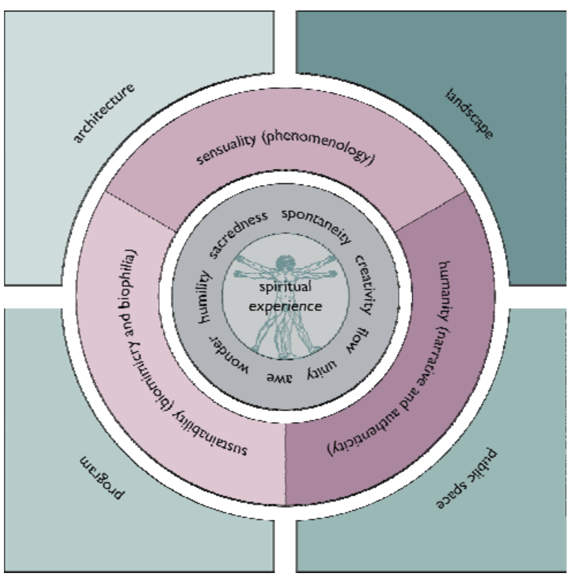


Figure 5: Framework for Spirituality in Place

3.1. Humanity (narrative and authenticity)

The places and spaces we inhabit as users communicate – they live, talk, and interact. Our challenge is to listen. They speak a language that tells us how we are meant to engage with a site; they relate a history and allow us to place ourselves as individuals within in that history; they convey the social and cultural context through which we experience that place; and they reflect a set of values and ideals that may or may not align with our own. When these places and spaces connect to us successfully on such levels, when the values they convey align with our own, and when we are knowledgeable of and recognize our place in the larger social context, the built environment attunes to a sense of humanity. It is through a legible and accessible narrative that this sense of humanity is conveyed. Drawing on some of the characteristics of Maslow's peak experiences and Pahnke's mythical consciousness, humanity in this sense is evocative of a sense of completeness, authenticity, sacredness, and conjures awe and wonder within a person. The sacredness of a place derives from the significance attached to it through history, which ties intimately to the sense of authenticity of that place. Truth plays an important role in design as Robert Grudin postulates "because our designs convey solid meaning, and because they interface between us and the world, they must tell us the truth about the world and the world the truth about us" (Grudin 2010, 9). This statement embodies the essence of a connection to the world and to ourselves and suggests that these connections are 'two-way'. We must connect to the world and the world must connect to us. Expanding on this notion we can add that not only must design convey truth about the world, but truth about ourselves. The truths we understand, as conveyed to us through the built environment, relate to habitation, occupation, activity, and places in which we conduct our lives, and these truths will speak profoundly upon the nature of our journey, our spirituality, and our essence. Additionally, design conveying a truth about us to the world has implications for sustainability and our recognition of our impact upon the world. Our place in the world can be honest or dishonest, living harmoniously with nature or working to exploit it.

A building's narrative and its perceived authenticity can be conveyed through many channels. For example the use of weathered material (or material that will weather over time), implies a certain history or narrative of time as people observe and experience that material. Monuments provide another way in which a narrative is communicated to the user. Providing that monuments act as significant references to particular social and cultural phenomena, they contribute to the narrative of a place and add depth and richness to the language that places speak. Buddhist stupas are one example of significant monuments that serve to remind a person of their place in the social and cultural fabric to which they belong. It would be worthwhile to consider what monuments we in the west have which comparatively act (not necessarily from a religious perspective) to remind us of our place within the world.

Figures 6 + 7: Stupa 'monument' as symbol, signifier & narrative of place. Source: (Sinclair, 2013)

3.2. Sensuality (phenomenology)

Juhani Pallasmaa in his book, The Eyes of the Skin, alluded to an historical, anthropological context for focus on hearing, smelling, touching, tasting, and oral communication. The disconnect between a person and his/her surroundings that Pallasmaa refers to when he speaks of the "hegemony of the eye" (Pallasmaa 2005, 25) gives reason for a focus on the senses and their potentially profound impact on the spiritual experience. This reinforces the need for spirituality in our built environment and reiterates the pertinence of engaging all of the senses in re-establishing those connections evident in Maslow's description of the individual that is

> fully functioning… using all of his capacities at their best and fullest… feels more intelligent, more perceptive, wittier, stronger, more graceful than at other times (Maslow 1961, 255-256)

By employing full sensual engagement in design, the built environment encourages a focus on the present, a “here-now” mindset, “free of past and future… most all there in experience” (Maslow 1961, 256) reminiscent of the Buddhist concept of mindfulness. Creating through design a fuller, richer sensual experience creates an awareness (conscious or subconscious) of one’s surroundings and takes steps along a path toward an awakening (satori) (Watts 1989, 83). The connection between the senses, the physical (built) realm, and the spiritual experience are echoed by the idea that “human experience is determined as much by the nature of the mind and the structure of its senses as by the external objects whose presence the mind reveals” (Watts 1989, 119). As architect Peter Zumthor suggests it’s not enough to simply engage the senses and use materials, textures, light at a base level, but to do so in a way that is authentic and truthful to the observer.

> The sense that I try to instill into materials is beyond all rules of composition, and their tangibility, smell, and acoustic qualities are merely elements of the language that we are obliged to use. Sense emerges when I succeed in bringing out the specific meanings of certain materials in my buildings, meanings that can only be perceived in just this way in this one building (Zumthor 2010, 10)

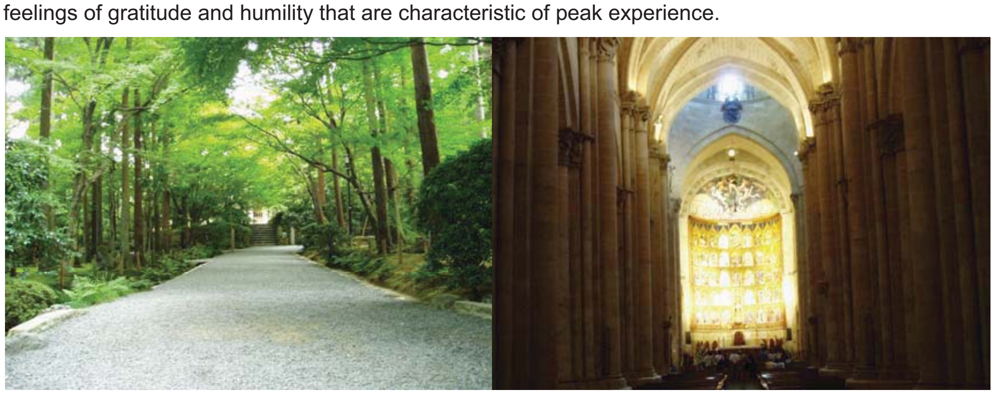
Figures 8 + 9: Source: (Birch, 2006)

3.3. Sustainability (biophilia and biomimicry)

The concept of biomimicry uses nature as a “mentor”, nature as a “measure”, and nature as a “model” (Benyus 1998). Through authentic or truthful replication or integration of natural harmony and order, the built environment has an opportunity to appeal to the feelings of being integrated, unified, organized, and whole that is characteristic of peak experience. Biomimicry presents a unique channel through which an individual can sense fusion with the world and move toward an egoless, self-transcendent perspective. This oneness with the world echoes the sentiments of both peak experience and the expression of the Tao is working in tune with the natural world rather than exploiting it. The concept of biophilia argues that human beings have an inherent need to be close to and integrated with nature (Kellert and Wilson 1993). It therefore seems intuitive that both biophilia and biomimicry would be important in establishing an experience of feeling unified and whole. Biophilia also plays a role in engaging all the senses as part of the experience of place as

> biophilic cities seek to counterbalance the ocular or visual bias by emphasizing the importance of sounds and hearing in the city… as modes of connection with the natural world and as therapeutic and pleasurable aspects of urban living (Beatley 2011).

The humility displayed in biophilia and biomimicry by harnessing the wisdom of the natural world echoes of feelings of gratitude and humility that are characteristic of peak experience.



Figures 10 + 11: Sacred space in both landscape and architecture. Source: left (Birch, 2005) right (Birch, 2004)

CONCLUSION

"The task contemporary architecture confronts is how to escape from binomial oppositions and dualism to allow regional and international, past and present, and the identities of topos and the universe to exist in symbiosis."
Kisho Kurokawa

As the world today struggles with the consequences brought about by climate change, political conflict, population growth and other means by which people are displaced, and urban settings are built and re-built, it becomes increasingly important to consider how we, as designers, architects, and planners might infuse places with richer meaning, poetics, atmosphere and strive for the spiritual essence of space. By establishing a definition derived from characteristics of peak experience, we can begin to translate the ethereal notion of spirituality to a form that has demonstrable implications for the built environment. The concepts rooted in Buddhist and Taoist philosophy, having connotations in both the spiritual and aesthetic realm, provide a unique and valuable vehicle through which this translation can be made. The result is a unique framework, which offers an approach to design that considers elements of humanity, sensuality, and sustainability and how they might engender a more meaningful, thoughtful and intense spiritual experience of place. Our framework is by no means concrete and definitive --there are many associated concepts, such as memory and monument, which, though not elaborately discussed here, would hopefully find relevance within the notions of humanity, sensuality, or sustainability. Recommendations for future work in this area would consider a more detailed and rigorous application of the framework to real-world examples in addition to further elaboration of the three facets of the framework. As a starting point, the framework lays the groundwork for considering spirituality in place and offers opportunity for exceptional, challenging and long overdue dialogue around this timely topic.

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Making Visible Alternative Futures on Mine-Scarred Lands in Appalachia

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ABSTRACT: The Southern Coalfields of West Virginia is a region undergoing extraordinary levels of change through the practice of mountaintop removal mining (Todd 2008). At the core of the disturbance is northern McDowell County in deep southern West Virginia, an economically and ecologically compromised area long dependent on extractive industries, and a venue of ongoing degradation. Mountaintop removal involves the excavation of a coal seam from the top down, rather than traditional tunnel mining. As 'developable' flat land, the remnant landscape is perceived to provide economic development opportunities for local communities. The 'site' (6000 acres) of this project is a reclaimed surface mine north of the town of Welch WV and on the border between Wyoming and McDowell Counties including the Indian Ridge Industrial Park (600 acres). This project proposes the positive reuse of the landscape through the installation of alternative energy infrastructure: biomass, wind and solar; and a phased plan for integration of mixed-use development.

In visualizing change within the project area researchers created a three-dimensional digital model of the site using ground-based static and aerial LiDAR (Light Detection and Ranging). The model provides a very recent (2012) portrait of the landscape and its components: bare-earth topography; drainage systems installed as a part of the reclamation mitigation; groundcover, shrub layer, sub-canopy and canopy vegetation; infrastructure, roads, and buildings. The lone resident buildings on the site are components of a Federal Correctional Institution (FCI-McDowell). Designing within the model allowed researchers to test a variety of planning scenarios and create visualizations that captured the phasing of the project, and expressed the aspirations of the community. Visualization phases included: 1.Biomass, Solar, Wind and Recreation; 2.Expressway Development and Interchange Zone; 3.Residential; 4.Commercial and Industrial; and 5.Stormwater Infrastructure, Green Infrastructure and Bioremediation. Local participation ensured that the project addressed local needs in becoming a model project for the region promoting sustainable development approaches to heavily impacted landscapes.

KEYWORDS: visualization, participation, LiDAR, renewable energy, mixed-use, mine-scarred lands

INTRODUCTION

SOCIAL/ENVIRONMENTAL/CULTURAL CONTEXT

McDowell County is deep in the steep mountains of southern West Virginia. Once the leading coal producer in the country (Myers 2008), during 'coal boom' times in the 1950s, the population of the county was near 100,000 with burgeoning towns and bustling rails feeding the Norfolk and Western Railroad's Ohio Branch and Norfolk Southern line. Post World War II the companies that were able to mechanize did so, and the others closed shop leaving thousands that had depended on coal without work. Today the population has fallen to below 20,000 and the once brimming towns are emptying. Statistics from the 2010 census are staggering. Only 39.9% of the population graduated from high school or equivalent (US Census 2011). Poverty is rampant with 59.9% of families with children under five living below the poverty line (US Census 2011). The county has the highest rate of child abuse and neglect in West Virginia; and high rates of welfare dollars; drug use; and teen pregnancy (State Journal 2012). The economy that long depended on coal has been 'deindustrialized' through consolidation and disinvestment, drawing jobs away from the area. The disinvestment did not include liquidation of land. Non-resident corporations now own over 80% of McDowell County, holding lands until the timber is ready for another harvest or the costs of extracting more coal balances with the benefits. So the people with an ingrained sense of commitment to corporate coal are left without work and without lands to develop. Residents have been said to suffer from "mountaineers' fatalism" (Myers 2008) or mental and cultural isolation- "mountain isolation" (Myers 2008). The region has been termed an "internal colony" (Myers 2008) which is reflected in a lack of home rule for many unincorporated communities. The wealth has been, and continues to be, extracted from the region with little to no benefit for the local economy.

The coal in McDowell County is some of the most valuable in the world. Under the surface and revealed in deep cut stream valleys, lies the Pocahontas No. 3 seam which covers nearly nine hundred square miles in Mercer, Wyoming, and McDowell counties in West Virginia, and neighboring Tazewell County, Virginia. Extracted first through 'backyard' pick and shovel mining to the now over-scaled machinery the coal is so valuable that removing the mountaintop overburden for a twelve-inch seam is economically viable in some cases. The low-volatile, low-sulfur, ''smokeless'' coal originated during the Lower and Middle Pennsylvanian Period and is older and better than most coal found elsewhere in the world. It was the US Navy's chosen fuel for powering steamboats (McGehee 2012). It is estimated that of the original three billion tons in the field, some 900 million remain. Cities that were created in relation to coal reserves include: Bluefield, Bramwell, Keystone, Northfork, Kimball, Welch, and Gary with many unincorporated coal company towns following river drainages and hollows. These towns attracted settlement from all over the region in the late 19th and early 20th century with 20% immigrants and 33% African American (McGehee 2012).

McDowell County is found within the Central Appalachian Ecoregion, stretching from central Pennsylvania to northern Tennessee. The geology includes a highly dissected landscape of ridges and valleys cut from an ancient seabed plateau. The bedrock is sandstone, shale, conglomerate, and coal. A mixed Mesophytic forest cover dominates with rugged oaks and hardwoods. The soils are thin and poor and limit agricultural development. Coal and timber have been the predominant industries since settlement (Omernik 2007). Straight pipe sewage systems, mining and forestry practices have compromised hundreds of miles of streams in the county with over 90% of the Tug River Watershed, within which this project is found, considered 'impaired' (EPA 1998). Primary pollutants are tied to mining: aluminium, iron, and manganese.

Without a new vision for this region, communities, landscapes, ecologies and economies are destined for further diminution. Imagining alternative futures has been underway since the time that Appalachia was rediscovered and brought to light during the Kennedy administration in the 1960s, creating the Kennedy Task Force. Efforts to integrate the region with the nation included many federal programs (Appalachian Regional Commission, Volunteers in Service to America, the War on Poverty, etc.) and projects that sought to 'fix' the people and the place. Recently, John Todd, in a report to the Lewis Foundation, 'A new shared economy for Appalachia: an economy built upon environmental restoration, carbon sequestration, renewable energy and ecological design' (Todd 2008) presented another strategy towards sustainable development. Todd's vision promotes technologies that "tap into the dynamics of the natural world to self-organize, self-design, self-repair and self-replicate" (Todd 2008, 7). He has proven the effectiveness of passive, nature-based systems approaches with his 'living machine' for sewage treatment at a smaller scale. Though at a larger scale, a landscape scale, the method calls for the ecological design and management of "biomass and forest ecosystems, agro-forests, and farms that integrate traditional and ecological values" (Todd 2008, 9) that is focused on soil building, or rebuilding in the case of the reclaimed surface mine where soil and stone are so compacted that promoting plant growth requires extensive inputs. The goal of carbon sequestration as an economic development strategy seeks to cultivate a sustainable market-based transformation. Encouraging and supporting, almost choreographing, succession is a core premise in Todd's healing process. This is accomplished through the introduction of both mineral and ecological elements towards building a natural resource base including forestry, biomass forestry, agro-forestry, and ecological agriculture (Todd 2008). These new products would thus create new industries and cooperative markets.

Peter Del Tredici, a biologist, asks planners and designers to consider two central models for the approach to reclaiming mined landscapes towards a productive second life. Del Tredici suggests reclamation and restoration. Reclamation allows that there is not a strong potential for returning the landscape to its previous pre-mining state, and that the "ecological clock cannot be turned back to a previous time" (Del Tredici 2008, 13). More realistic goals would be to minimize the negative impacts that the site may have on the surrounding environment and to maximize its aesthetic and ecological functionality. Functionality is the key component of this model and containing the impacts of the mining activity and subsequent redevelopment so as not to negatively impact downstream resources, or adjacent landscapes. Succession, encouraged by intervention, is the main process by which the land revitalization process may occur. Del Tredici proposes four steps to ecologically sound mine reclamation: 1. establish an appropriate substrate and soil that can support the growth of plants. 2. begin a re-vegetation strategy that makes an effort to enrich the degraded land with the organic matter of the local pre-existing plants, so that it jump starts the soil forming process, increases water capacity, and allows for the growth of Mycorrhizal fungi. 3. select plants that are native to the area and thus can best withstand the local climates and microclimates and those that produce shoots from their roots in a short period of time, or branching from the base of their trucks after being traumatized. 4. acknowledge and accept a long-term process of maintenance and care. This means that the design must coincide with local support and monetary constraints.

As the beginning point of this research/design project the various social, cultural and environmental contexts were central to the planning process. An understanding of the complex fragmented local ecology was established. A participatory process was designed to tap into local populations and engage them in visualizing change. The now well-documented (though still elusive in definition) culture of McDowell County played a role in forming the model for change. The driving force behind the research/design project is to provide some relief and generative momentum for the economic conditions at the local level and to provide a new model for reintegrating surface mined landscapes across the region.

1.1. Creating the three-dimensional digital model: Aerial LiDAR

In order to better communicate and perform the inventory/analysis, design, planning, and potential of a Sustainable Energy Park in McDowell County researchers constructed a digital three-dimensional model of the approximately 6000 acre site. LiDAR (Light Detection and Ranging) has become an established method for collecting very dense and accurate elevation values and subsequent modelling of large scale environments. This active remote sensing technique is analogous to RADAR but uses light pulses instead of radio waves to measure travel times. The location and elevation of the reflecting surface are derived from: 1.the time difference between the laser pulse being emitted and returned; 2.the angle that the pulse was 'fired' at; and 3.the location and height of the aircraft (i.e. sensor location). Unlike RADAR, LiDAR cannot penetrate clouds, rain, or dense haze and must be flown during fair weather.

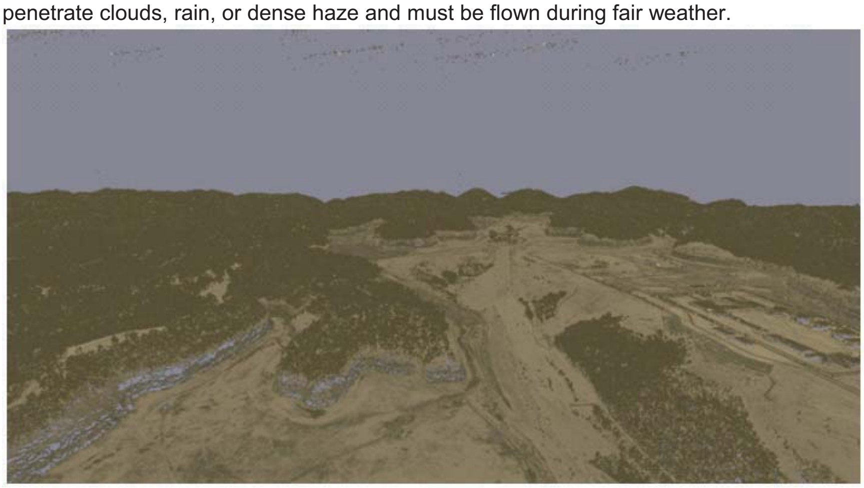

Figure 1: A bird's eye view of the Indian Ridge Industrial Park site in McDowell County, WV. This image was created in Pointools® and shows the raw pointcloud with a sepia tone elevation gradient. Source: (Butler 2012)

Collected pointclouds create an accurate depiction of overall landscape characteristics, topography, elevation, vegetation and site hydrology. The model then serves as a base for the rendering of design alternatives and for tracking change over time, and as an immersive environment for design visualization. The resulting pointcloud model (Figure 1) was exported to Pointools® software that allows planners and designers to work with very large data sets through linkages with design software (Google SketchUp®, AutoCAD®, 3D Studio Max®, Rhinoceros®, etc.).

The research team performed a review of the spatial requirements (physical, structural, infrastructural needs, etc.) in state of the art and practice alternative energy facilities. Investigations included the collection of case studies of completed projects throughout the United States. These projects provided detailed information in the physical needs for site suitability and feasibility of alternative energy facility development. Structural elements included the dimensions of specific facilities and forms. Facilities and structures were modeled three-dimensionally at scale so that they could be placed within the 3D digital model for visualization.

1.2. Pointools®, Rhinoceros®, and ESRI ArcMap®

The primary design software used to create visualizations was Rhinoceros®. Geographic Information Systems (GIS) data provided alignments for the Coalfields Expressway (north/south) and the King Coal Expressway (east/west) which are planned to intersect on the northern border of the project boundary. With the existing pointcloud researchers were able to model the future expressways planned for the area. Researchers also modeled the existing prison, FCI-McDowell, in the three-dimensional digital model.

A detailed inventory and analysis was performed using the LiDAR data. One example of the use of the model in performing site inventory and analysis is the creation of very detailed topographic data allowing researchers to create a map of site hydrology (Figure 2). Site hydrology information was then applied to the development of green infrastructure design focused on stormwater management. Vegetation for the approximately 6000 acres was also modeled showing areas of canopy, sub-canopy, shrub layer, grasses and bare earth. When combined the layers create an accurate depiction of overall landscape characteristics.

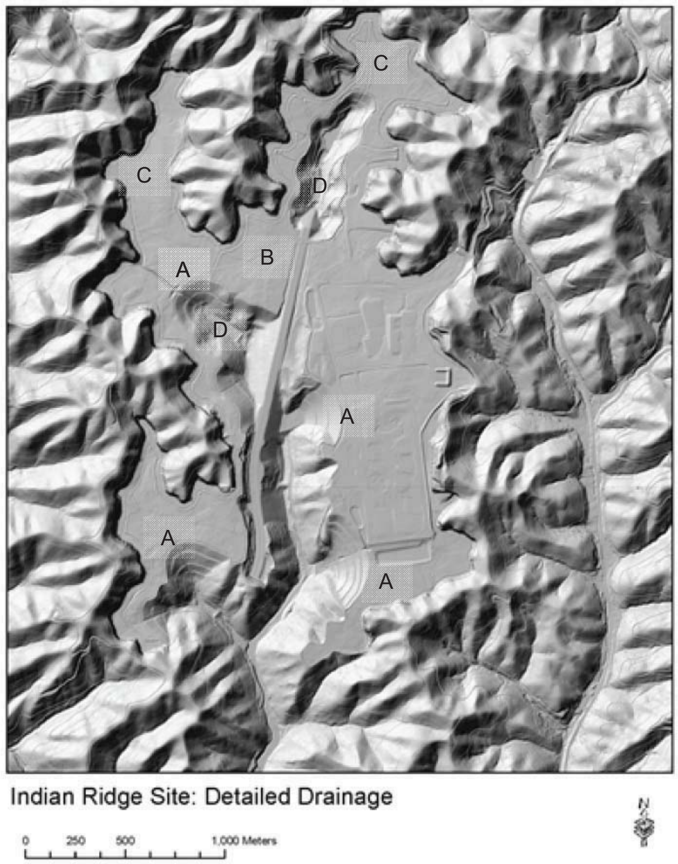

Figure 2: The LiDAR pointcloud was processed in ESRI ArcMap to create a hillshade image of the site revealing A. valley fills; B. new expressway alignments; C. existing post reclamation drainage features; D. large scale water retention areas. With the use of LiDAR and the creation of a hillshade image for site topography, a highly detailed inventory of drainage patterns is possible. The drainage plan post-surface mine reclamation includes swales that follow along the edges of highwalls. The swales bring stormwater runoff to two very large detention ponds. Also visible in the model is the planned and graded alignment for expressway development. Source: (Natural Resource Analysis Center, Jackie Strager & Aaron Maxwell 2012)

1.3. Visualization: Participation and Gaming

The LiDAR model was also used as a mode of communication and interaction in administering participatory design processes. In order to address questions and concerns of local youth an event was scheduled at the McDowell and Wyoming County 4-H camp with a self-selected student group. The digital model, now exported to and enhanced using Rhinoceros® software, became a gaming environment (Mayer 2005) for participation. The model was rendered in a ‘cartoonish’ style to appeal to the youth, and used to educate participants on the suitable siting of alternative energy infrastructure and as an environment for visualization and planning. Students were provided a ‘kit of parts’ including a wind turbine, perennial grasses, a solar array, an industrial building, suburban type housing, high density apartment style housing, high income detached housing, and single family detached low density housing. After an introduction to the siting suitability of the three alternative energy elements, the students were able to move elements around, multiply them, and create a vision of the sustainable energy park (Figure 3).

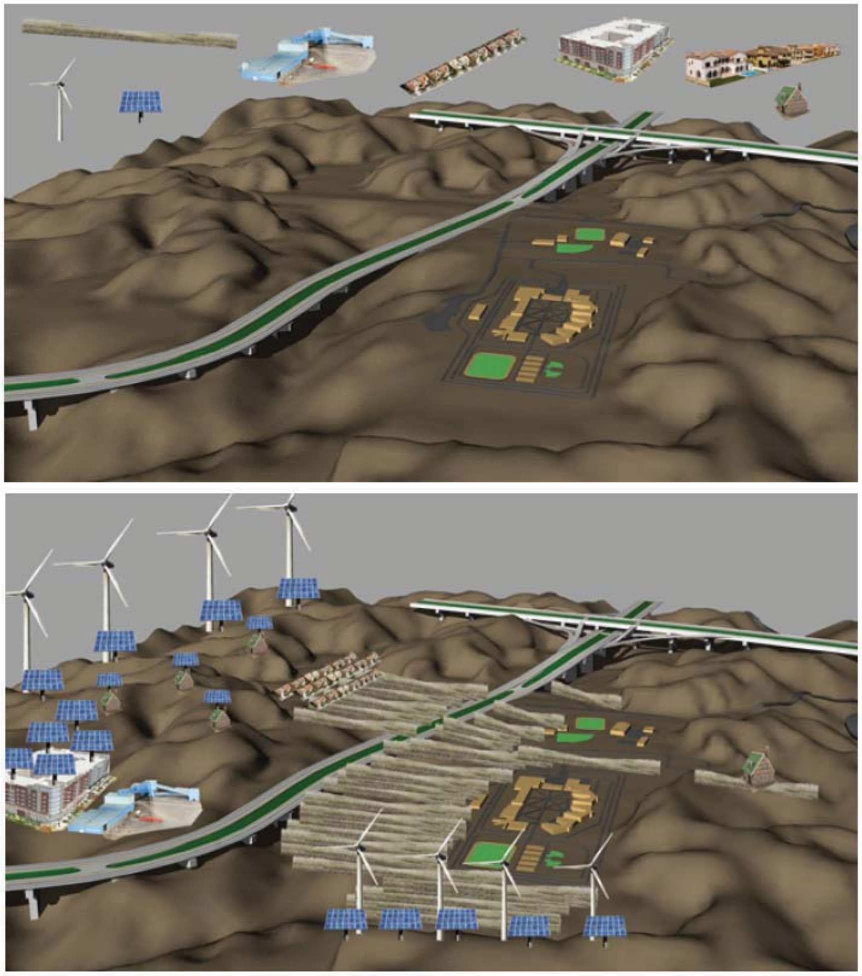

Figure 3: depicts a three-dimensional digital site model and the 'kit of parts' that students were able to use in designing the site. The prison, FCI-McDowell, property is also shown, as are the planned expressways. The second image shows one of the three mixed use and alternative energy development scenarios developed by students. Source: (Chu and Butler 2012)

2.0. SITE SCALE PLANNING

Developing a digital model of the new mixed use and alternative energy facilities was the next step. After integrating all of the previously described information and defining areas for specific land uses within the Indian Ridge Industrial Park through masterplanning a model was created. Guidance in identifying needed land uses was gained through local participation. Identified needs included: industrial, commercial, recreational and residential. Alternative energy suitability modeling allowed researchers to site these facilities in the most appropriate locations. The land use masterplan for the Indian Ridge Industrial Park attempted to satisfy the community needs for developable land and provide for spaces to integrate alternative energy generating facilities. The topography of the existing stormwater infrastructure created limitations in siting facilities. Other primary limiting factors were the planned expressway corridors which require a buffer. Leaving these areas open for future road construction by planting biomass/switchgrass in the corridor allowed for transitioning the area at a later date. Industrial uses were placed adjacent to the main highway interchange, while residential development was proposed in the south and east of the site. Locating residential development here provided for a sense of seclusion from the highway. Solar infrastructure was located close to FCI-McDowell so that the facility could take advantage of nearby energy production. This location, with its full southern exposure was identified as the most efficient in solar collection. Commercial development was included in an 'Interchange' zone, providing needed services that were identified as desirable by participants. Areas of biomass were located in marginal settings- areas lacking the spatial requirements of other land uses or in close proximity to areas of sensory disturbance, i.e. highways and industrial development. The integration of alternative energy elements (wind, solar, and biomass), on a smaller scale, was interwoven with necessary infrastructure and building prototype design. Green infrastructure design of stormwater systems was also interwoven within the overall pattern of the masterplan.

2.1. Planning and design visualization: energy systems

Phasing development of the Indian Ridge Industrial Site allowed for a marketing effort with designated areas of future development. The 'Interchange Zone' would not be a suitable land use until the expressways are constructed so using the land temporarily in producing biomass through perennial planting and soil building strategies creates a placeholder for change. Additionally, lands designated for residential/commercial development and industrial development can support biomass production through planting or encouraged succession while waiting for investment. Solar infrastructure would necessarily be permanent, however, so designating the area adjacent to FCI-McDowell as a future 'new energy' gateway element into the industrial park created a sense of character for the overall site and defined a powerful entry experience. Switchgrass, or other grasses, to be used for biomass production are very rugged species- drought-tolerant and fast growing. The soils on site are currently compacted and require specific additions to be productive. Necessary soil amendments for creating a positive growing medium were calculated for the site. Locations and character of alternative energy installations are seen in Figure 4.

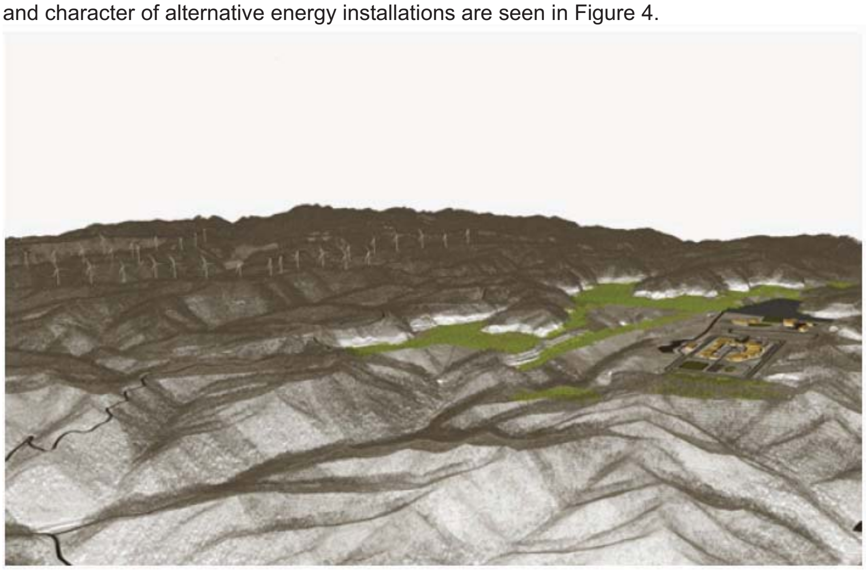

Figure 4: Three-dimensional digital site model with integrated wind, biomass and solar facilities (view from southeast). Source: (Chu and Butler 2012)

2.2. Mixed use development

Focus group participants guided the research team in identifying new land uses for the Indian Ridge Industrial Park site. The participants saw a need for a tourism visitor center on the site as a gateway into the region and the adjacent National Coal Heritage Trail (US 16). They also identified a need for housing. Many local employees commute long distances from other states to workplaces in the county, especially FCI-McDowell and local schools. Focus group participants envisioned different businesses and services that could be a part of the Indian Ridge site development that were lacking in the area. Throughout the visioning process, participants voiced their hope that this development could spur entrepreneurial spirit in the area. New expressway and utility development were seen as necessary elements in the development of the region creating better access into and out of the area. Roads and railroads would help to counter loss of population trends and enhance local school investment and quality, a perceived barrier to in-migration. Fulfilling all of these needs within the scope of this planning project was not possible though the appropriate location for siting of facilities, determining circulation patterns and connections, and integrating alternative energy and green infrastructure that would accommodate new development was completed. The overarching goals of healing the scarred landscape, making it productive and functional, and minimizing new development's impact on adjacent landscapes were central to the visualization of mixed use development.

2.3. Green infrastructure interventions in creating public space and connective tissue

The community's identity as formed during past mining operations, created a need in planning for alternative futures, to reflect on the scars of former surface mining operations; while recognizing the successional landscape within new development. All of the community groups that engaged in the planning process asked that the mining history be acknowledged, celebrated, and interpreted. The form of the design responds to the orderly frames of development, mining and mine land reclamation, interrupted by the chaos of biological patterns. These patterns are recognized through natural processes such as stormwater movement and forest development that organically weave through the site. Green infrastructure (Benedict 2002) and open space areas heal the landscape, filtering water and collecting sediments, and are linked through pedestrian greenways creating connections that seek to reconnect local peoples to the site (Figure 5). Core areas connect varying land uses and serve as spaces for reflection of historical landscape patterns. The valley fill ponds reflect both pre-mining vegetative forest cover and new orderly topographic tiers and linear streams resulting from mining operations. These areas are designed to be experienced from multiple elevations, further referencing succession. The reflective spaces can be intimately experienced at the base valley fill, explored through the valley fill climb, serve as a gateway at the development level or be viewed from the proposed freeway above. The visitor's comprehension of the landscape constraints associated with former landuse is a necessary component towards successional landscape healing. Community and ecology bond to create the energy to drive this process forward.

Figure 5: Illustration of stormwater infrastructure and public space design. Source: (Campbell 2012)

CONCLUSION

The vision of a renewed Appalachia through the creation of new economies related to alternative energy and ecological mine reclamation holds potential. At the Indian Ridge site, the reclamation process strives not to obscure the extractive industry, but rather apply the past setting as precedent for the ecological development of the future (Barnett 2008). Focusing the healing on stormwater management and soil-building adds value by building ecological function (Dickson 2003) into the landscape. The designed spaces provide a mutually supportive habitat; considering people, wildlife and plant communities. This holistic approach to place-making inspires people to experience nature while improving their ecological literacy (Lister 2009). Through the use of three-dimensional digital models and visualization, these values are communicated revealing links between nature, science and art.

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Global Cultures and Architecture Education: The Case of the India Initiative

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Figure 1: India Initiative exhibit 2012: student reading of seven cities

ABSTRACT: How is architectural education enriched by the seemingly peripheral voices of diverse global cultures? How does the process of creating design propositions within unfamiliar cultures and sites unknown encourage students to question their own assumptions and methods? In order to explore these questions, a research project methodology was created to shift the normative architecture studio pedagogical structure, content and location to specifically examine transformations in student learning. Several theoretical concepts support this work, including spatial dislocation, experiential learning and the bodily senses, reflection, and constructed knowledge. University of Virginia Professors Phoebe Crisman and Peter Waldman established the India Initiative as an interdisciplinary research and teaching program to study environments constructed by the diverse cultures of India and develop sustainable strategies for future development. A complex mix of religions, ethnicities, languages, geographies, arts and architecture, India is a crucial location for the contemporary study of architecture and urban sustainability. India is the world's largest democracy with a burgeoning population experiencing massive rural to urban migration and growing economic disparity. Widespread environmental degradation and natural resource depletion plague the country. Nevertheless, there is much to be learned from a close study of effective practices that have emerged from a combination of necessity and ingenuity in the Indian built environment. Each year of the five-year study will focus on one of Hindu elements or *panchabhuta*: earth, water, air, fire and ether. From the enduring village to the emergent megacity, and across scales from city to the architectural detail, the research seeks a deep and synthetic understanding of sustainable approaches to infrastructure systems, landscapes and architecture. The long-term research goal is a study of the intertwined aspects of environmental design and social equity. This paper formulates findings from the first year of the India Initiative.

KEYWORDS: culture, education, India, sustainability, dislocation

INTRODUCTION

How is architectural education enriched by the seemingly peripheral voices of diverse global cultures? How does the process of creating design propositions within unfamiliar cultures and sites unknown encourage students to question their own assumptions and methods? In order to explore these questions, a research project methodology was created to shift the normative architectural studio pedagogical structure, content and location in order to examine the effect on student learning. Professors Phoebe Crisman and Peter Waldman established the India Initiative at the University of Virginia as an innovative research and teaching program that examines the physical environments constructed by the diverse cultures of India and develops sustainable strategies for future development. The long-term goal of this research is to develop a deeper understanding of the intertwined aspects of environmental design and social equity. Several theoretical concepts support this work, including the educational value of spatial dislocation, experiential learning that engages the bodily senses, reflection, constructed knowledge and other ways of knowing. A research methodology was created that intentionally shifts the normative architectural studio pedagogical structure, content and location to examine the effect on architectural education.

1.0 RESEARCH QUESTIONS AND METHODOLOGY

1.1 Why India

In seeking a rich and relevant place to study global sustainability issues in architecture and urbanism, India emerged as the ideal location for several reasons. The complex mix of religions, ethnicities, languages, geographies, arts and architecture of India produces hybrid and rapidly transforming cultural conditions. India, as the world's largest democracy with the second largest national population, is experiencing massive rural to urban migration and growing economic disparity. Widespread environmental degradation, pollution, deforestation, a declining and contaminated groundwater supply and natural resource depletion plague the country. There is much to be learned from a close study of locally developed sustainable practices that have emerged from a combination of necessity and ingenuity in the Indian built environment. For instance, the natural cooling systems of the medieval Indian settlement of Jaisalmer keep residents comfortable in the scorching Thar Desert summers. Several urban and architectural strategies are combined to achieve this outcome: arranging buildings in dense clusters, orienting buildings to reduce solar income, creating ornamental stone fenestration to cool sunlit surfaces, using massive stone construction for roof and walls to absorb heat, and providing cross-ventilation with complex courtyard configurations. (Gupta 1985) The exquisite fountains and water channels found throughout the arid states of Rajastan and Gujarat use intelligent evaporative cooling strategies to create pleasant microclimates in the courtyards of both civic and residential buildings. These are just a few examples of sustainable strategies for infrastructure, landscapes and buildings that the India Initiative research seeks to understand in a deep and synthetic way.

1.2 Content and Structure

A design research methodology was developed to immerse both undergraduate and graduate architecture students in the diverse cultures and places of India at two scales of dwelling—the enduring village and the emergent megacity. Directed by University of Virginia Architecture Professors Phoebe Crisman and Peter Waldman, each year of the five-year study focuses on one of the five Hindu elements or *panchabhuta*: earth, water, air, fire and ether or space. The first year (2012) focused on water as a spatial generator of highly particular forms of infrastructure and architecture that support the occupancy of water itself and those that use it. The research team studied the formal, material and cultural significance of enduring and contemporary water architecture in India, while proposing new design strategies. The second year (2013) will consider fire—the most sacred of the five physical forces according to Vedic philosophy. Fire is associated with the Sun as the primary source of life and energy. Fire represents light, heat and energy manifest in architecture through spatial configurations and places of gathering, symbolism, materials, and apertures that regulate light and heat. Shade and shadow, days and nights, enthusiasm, passion and mental energy are all qualities of the force of fire. As we have done in the first year, each year the India Initiative will produce an exhibit and publication of research findings and speculative projects that will establish an important body of work. This paper formulates findings from the first year of India-based research, as well as written student reflections gathered six months after completion of our travels and coursework.

1.3 Pedagogy

The India Initiative builds on several years of pedagogical experimentation structuring design research studios to explore individual agency in challenging places and with underserved populations. (Crisman 2010) That research focused on the revitalization of contaminated and underutilized industrial sites in Eastern seaboard cities of the United States. (Crisman 2007) By critically engaging students with social and ethical considerations in difficult *real world* places, those studios provided students with hands-on experiences with architectural agency. In the past two years this research has expanded to include the global sustainability challenges for Indian cultures and built environments. The India Initiative emerged as a multi-faceted research investigation that includes my own theoretical and praxiological research, as well as three intertwined courses co-taught with Prof. Waldman. Students in the spring *India Research Seminar* begin to engage Indian culture by exploring literary, historical and philosophical foundations through a diverse selection of historic and contemporary Indian texts, films, art and architecture. They also develop a research proposal that will guide their independent summer research. During six summer weeks of intense travel and immersive learning, students are enrolled in the *India Summer Studio* and an *Independent Research Seminar* that provides a unique lens for their work, while enriching the shared studio investigation. For instance, the fourteen independent research projects in 2012 expanded the focus on Water as a Spatial Generator to the symbolism of water in India, microclimates created with evaporative cooling and more. In this way, both the individual and the collective research are furthered by reciprocal exchange and critique.

This format differs from most *home-based* studios, where students are either enrolled in a studio with a prescribed focus defined by the instructor or left to develop their own thesis or independent research with limited group interaction and instructor guidance. This pedagogical experiment combines the benefits of both models and develops synergy between them. Compared to most study abroad programs in the School that are based in one location for a four or six-week period, the India Summer Studio studies several diverse urban and rural locations using a comparative method that also values the spatial act of travel.

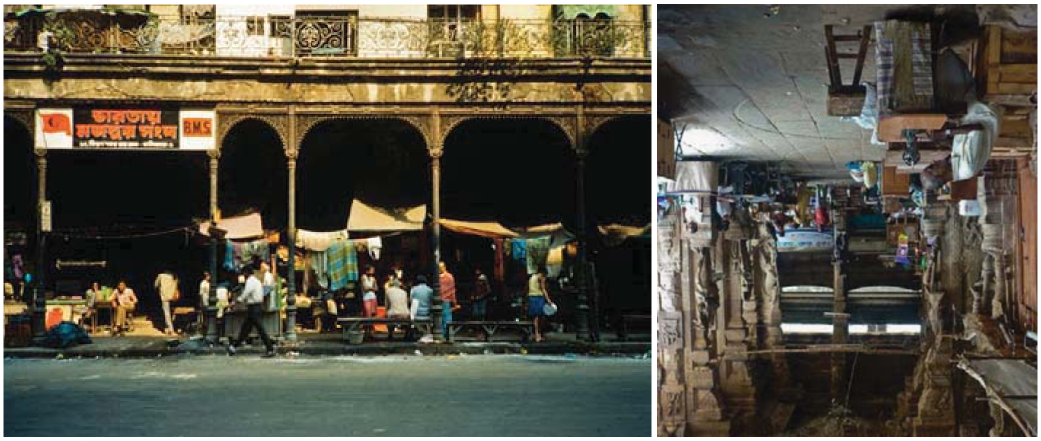

Figure 2: Public microclimates for work and respite

2.0 THEORETICAL CONCEPTS

2.1 Travel and Spatial Dislocation

What is the role of travel and spatial dislocation in the construction of both architectural knowledge and self-knowledge? Many architecture study abroad programs often occupy their own permanent facilities or those of a host university in a city such as Rome or Paris. For instance, graduate student Catharine Killien had participated in a twelve-week study abroad program based in Rome that she described as “much like a typical architecture studio that I would have back home.” Reflecting on how it differed from her India experience, she realized that “the design I developed for that [Rome] studio did not necessarily have anything to do with the Roman context or the peculiarities of that site. I had relied on design strategies and representation technique strategies I already knew.” Unlike these programs, a significant amount of travel is essential to the India Initiative. Testing the value of travel as extreme dislocation requires a different pedagogy and program structure. Student Sarah Buchholz described her India studio experience this way.

> Instead of just researching sites from books and using computer tools to analyze spaces, the India studio gave me a firsthand experience of the site, culture, people, and traditions. It allowed to me to observe how people use spaces and how architecture influences daily routines and rituals. Being in such a foreign place also affected my way of learning as I suddenly became much more aware of the types of spaces I was in and how architecture has such a huge affect on all senses. The intense summer heat combined with a variety of smells and sounds changed the way I think about spaces and environments and how they are created.

Scholars such as Theology Professor Frederick Ruf have focused on the multiple values of travel. In his book *Bewildered Travel: The Sacred Quest for Confusion,* he argues that we often travel to unlearn, to challenge and rupture the surface of the known and expected. Ruf recounts poet Mary Oliver’s use of particular disruptions and difficult memories obtained while traveling to remind her “you can creep out of your own life and become someone else.” (Ruf 2007, 16) Dislocation that challenges our thinking and our very being is quite useful to learning about global culture, architecture and nearly anything else. Georges Van Den Abbeele’s metaphor of travel to thought is relevant as well.

> When one thinks of travel, one most often thinks of the interest and excitement that comes from seeing exotic places and cultures. Likewise, the application of the metaphor of travel to thought conjures up the image of an innovative mind that explores new ways of looking at things or which opens up new horizons. That mind is a critical one to the extent that its moving beyond a given set of preconceptions or values also undermines those assumptions. Indeed, to call an existing order (whether epistemological, aesthetic,

or political) into question by placing oneself 'outside' that order, by taking a 'critical distance' from it, is implicitly to invoke the metaphor of travel. (Van Den Abbeele 1992, xiii)

In addition to comparing of the different types of study abroad programs that she had experienced, Catharine Killien reflected on spatial dislocation and studying architecture in an unfamiliar place.

> In some sense, spatial dislocation isn't just about physically being somewhere outside of the familiar; it's a complete breaking of the way you typically do things. You give up your schedule and daily routine and the way you typically do work. You find new ways to represent new experiences, and can't rely on techniques and design strategies you typically rely on in the past.

Figure 3: Working while spatially dislocated

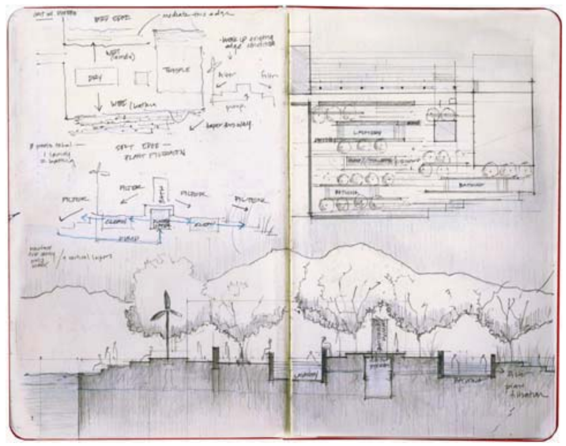

Figure 4: Sketchbook (Catharine Killien)

Both students emphasized how spatial dislocation changed their experiences of place and also their work. The book *Travel, Space, Architecture* raises relevant issues of how "physical and metaphorical dislocation affect spatio-architectural practices, and how these conditions redefine the parallel notions of place, culture and identity." (Traganou 2009, 2) This dislocation may be the result of travel, immigration or other types of forced and self-initiated movement in space. The author argues that architecture theory and practice seen through the lens of travel can "move beyond the centrality of static, place-bound principles into an understanding of more open-ended networks of relationships (or subjects and sites)." (Traganou 2009, 3) This is a powerful argument for conceiving of travel as an essential element of architectural education. While scholars in anthropology, geography and religious studies have theorized travel within their disciplines, architectural education lags behind.

2.2 Experiential Learning and the Bodily Senses

When experiencing spatial dislocation our bodily senses are heightened as well. This is an ideal time to learn as we see, hear, smell, touch and taste new things. Travel stimulates us with places, people and images that generate new ideas. During the India studio, students see and experience by making drawings and collage, photographs, sound sampling, video and journaling. Student Nicholas Knodt noted: "The spectacularly layered Indian cities and villages present juxtapositions between a variety of cultural, historical and architectural influences. Only through on-site drawing, mapping, recording and observation were we able to fully analyze these incredible relationships." Several other students commented on the importance of sketching. When asked "what was your favorite design project and why," student Rebecca Hora replied:

> Each city introduced a new and exciting milieu to draw from and build on. Rather than one specific project, it was the overall process and culmination of sketches that most intrigued me. Designing from only my sketchbook and found materials meant expanding beyond superficial solutions and examining more contextual and site-specific considerations.

The students were fully aware of the complex cultural, formal, spatial and constructional Indian context as they designed. Sensory engagement and experiential learning predominated over the abstract analysis that occupies so much of their time in studio at home. In her essay "Unpacking the Suitcase: Travel as Process and Paradigm in Constructing Architectural Knowledge," Kay Bea Jones noted that "experiential means of learning are underdeveloped compared to studio fabrications and representational inventions developed in isolated school environments." (Jones 2001, 128) She refers to the prevailing objectification and production focus of many architecture schools. Although students travel abroad to study architecture, few faculty have theorized the educational value of these excursions or adequately examined how they are structured. Active learning and "site-based travel pedagogy" are essential to the India Initiative approach, which concurs with the claim that "by observing primary site, architects can use original insights built on past knowledge to inform critical new thinking." (Jones 2001, 146) Traveling to fully engage buildings and places is more crucial than ever for architecture students, as they are bombarded by slick digital images of global architecture rarely shown in its broader context. Student Liz Kneller reflected on how a heightened awareness of the senses provoked her new design research focus the following semester.

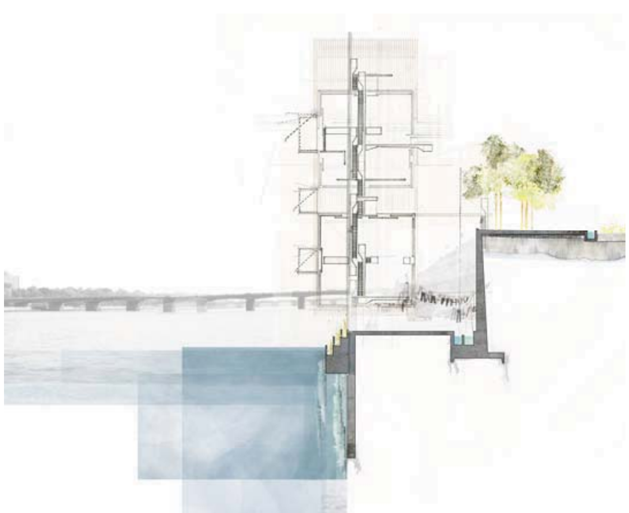

Figure 5: Sketch (Rebecca Hora)

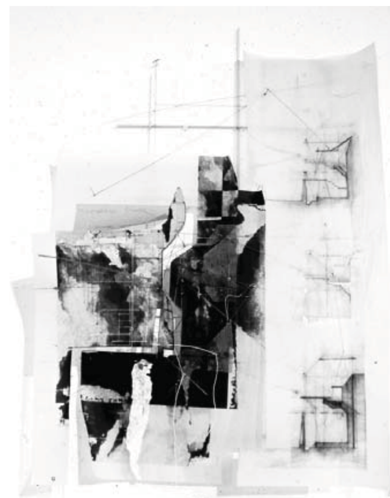

Figure 6: Sketch (Whitney Newton)

> While in India, my most profound experiences were those that engaged all five of my senses, particularly that of touch. While I was previously interested in sustainability, I never knew how to incorporate that notion into my own work, and found that the focus of my studio projects was too often based solely on aesthetic concerns. In India, climate extremes require material, spatial, and geometric knowledge to create comfortable environments without the extensive equipment of typical modern mechanical systems. I was particularly struck by the wind tower at Fatehpur Sikri, the jharokhas of Udaipur, and Le Corbusier's brise soleil on the Millowner's Association. The firsthand experience of a cool breeze or shaded alcove in the midst of a hot Indian summer convinced me to rediscover the importance of designing explicitly for place. This led to a semester of research into how to design a building in my own climate that rejects energy consuming modern mechanical systems for passive systems that use less energy while providing greater thermal comfort to inhabitants through appropriate fluctuations in interior conditions.

The imprecise knowledge gained in a "shaded alcove in the midst of a hot Indian summer" is quite different than the systematic knowledge acquired through abstract analysis, quantification and mapping. Rather than study buildings as isolated artifacts, they see architecture as part of a larger cultural context and construct knowledge through exploration. By emphasizing constructed knowledge[1] in combination with Paulo Freire's theory of critical pedagogy, the goal is to educate future agents of change that understand the inextricable connection between the social and the environmental as a crucial consideration of architecture.[2]

2.3 Slowness and Reflection

Taking time to experience a place cultivates our ability for careful observation and contemplation. Through the concept of slowness and the possibilities for reflection that it provides, writer Rebecca Solnit critiques efficiency, convenience, profitability and security as she considers those things that cannot be measured.

> The conundrum is that the language to describe the ineffable splendors and possibilities of our lives takes time to master, takes a certain unhurried engagement with the tasks of description, assessment, critique, and conversation; that to speak this slow language you must slow down, and to slow down you must have some inkling of what you will gain by doing so… Ultimately, I believe that slowness is an act of resistance, not because slowness is a good in itself but because of all that it makes room for, the things that don't get measured and can't be bought. (Solnit 2007)

Figure 7: Taking time

This way of working and understanding the world embraces the differences between the normative classroom or studio and what can and must happen differently abroad and in the field. Traveling and learning in sites unknown frees students from these constraints and provides time to experience, to absorb, to understand and then to make. Student Catharine Killien noted: “You tend to remember a place far more if you draw it than if you photograph it. Drawing makes you slow down and truly see and experience the space you are trying to record. I remember making every drawing from India—I certainly don’t remember every photograph.” Students described how their understanding of *studio* changed because of their experience in India or how they were able to learn in a different way.

> Learning about architecture in India expanded the definition of my education. It meant that studio was not only a place were everyone has their headphones in and are building perfect 3D models in Rhino. But rather studio, and learning about architecture, is everywhere. Anywhere can be a place of learning and you don't need a desk and fancy tools to create inspired designs. (Phoebe Harris)
>
> Even though I’ve spent nearly my entire waking life inside of them, I don’t believe the key to learning lies in classrooms. My most memorable and breakthrough academic experiences have been on the road. I believe that the best way to learn is to push us outside of our comfort zones… In architecture school (and I've attended three of them by now) we're forced to sit in a chair indoors and go through the motions in front of a computer for hours on end. We can’t help but get stuck and churn out projects that go nowhere. The India studio is a catalyst, and it was the best thing that’s ever happened to me. (Christopher Barker)

2.4 Constructed Knowledge and Other Ways of Knowing

The India Initiative pedagogy builds on Jones’ compelling argument for an epistemology of constructed knowledge as it relates to travel and teaching methods.

> If we accept that constructed knowledge offers an important alternative approach that is uniquely characterized by intuition, cross-disciplinary preferences, collaborations, ambiguity, integration, personal and social values, and historic contingencies, we can then consider observation of everyday life within the agency of travel. Traditional pedagogical practices deserve reconsideration, since travel radically alters the conditions of the classroom, the laboratory, and the studio… Teaching methods abroad can substitute techniques of observation and group discussion for typical ‘objective’ examination of learning. Collaborative inquiry strategically located allows subjects to reveal diverse aspects of themselves. Participants who are then equipped to debate differing interpretations provide a model preferable to the usual subordination to definitive authorities or studio masters. (Jones 2001, 153)

Several students noted changes in how they constructed knowledge and their design process. Amidst increasing quantitative analysis in architecture schools, the students have a new appreciation for their own perceptions, abilities to synthesize, and the importance of the self, subjectivity and the social. Sarah Buchholz’ reflection on her transformed design process is an example of these tendencies.

> One of the most prominent ways that India affected my design thinking was through attention to detail, specifically materiality, apertures, and awareness of local context and climate. I had never before realized how subtle changes in materiality can change the feelings of spaces. In Chandigarh, the concrete space below the Open Hand Monument was one of the most exposed and hottest spaces I've experienced,

> while in Golconde every small aperture was well thought out to provide ventilation. In Udaipur, the sudden change in materials and openness along the water's edge created a space vastly different to the chaotic, crowded city streets. Overall, my method of designing now has changed in that instead of relying on computer programs and preconceived ideas about sites, I tend to sketch and work more with my hands to force me to think more about materials and context, and my designs are constantly adapting as a result of personal experiences, senses, and emotions, rather than being fixed and inflexible.

CONCLUSION

The India Initiative seeks to study how student learning might be transformed by strategically shifting the typical architecture studio pedagogical structure, content and location. Though it is too early to evaluate the outcome of the planned five-year research program, there is much to be gleaned from the students' projects and written reflections how the India experience affected their design work after the first year.

> Surroundings play a critical role in the development of design, and it is only through exposure of various surroundings that we have the opportunity to know, understand, and relate. The unfamiliar becomes a source of inspiration and curiosity—fueling innovative design. My experience in India allowed me to revolutionize my understanding of the implications of design, and to challenge myself to go beyond my known boundaries. I look forward to stretching my parameters and reconfiguring ideas; vacillating between them and adapting to each encountered environment. (Rebecca Hora)
>
> Half a year after studying with the India Initiative I am still being challenged by lessons learned throughout our travels. The process of confronting preconceptions about culture and the built environment through the lens of India has enriched my design thinking, effectively adding complexity to my understanding about how life is lived through architecture. (Nicholas Knodt)

By providing the opportunity for architecture students to question their own assumptions, ways of knowing and personal design processes within unfamiliar cultures and places, their projects were quite different than they would have been in the studio back home. The students were less convinced of the correctness of their assumptions and their design work was more layered and holistically conceived across scales. As they constructed their own knowledge and understanding of the richness of difference and hybridity in these sites out of mind, their preconceptions fell away and new ideas emerged.

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ENDNOTES

[1] See J.E. Hartman (1991) "Telling Stories: The Construction of Women's Agency." In *(En)Gendering Knowledge: Feminists in Academe* and M. Belenky (1986) *Women's Ways of Knowing: The Development of Self, Voice, and Mind.*

[2] For more on critical pedagogy, see Paulo Freire (1985) *The Politics of Education: Culture, Power, and Liberation* and (1998) *Pedagogy of Freedom: Ethics, Democracy, and Civic Courage.* For a discussion of critical pedagogy in architecture education, see Thomas Dutton, (1996) ‘Cultural Studies and Critical Pedagogy: Cultural Pedagogy and Architecture’, in *Reconstructing Architecture. Critical Discourses and Social Practices.*

Making the Marginal Visible: Microenterprise and Urban Space in London

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ABSTRACT: A research project in London is focused on the following question: Can the morphology of cities, and the typology of urban buildings, help support grassroots economic development and the assimilation of new participants into the urban economy?

We have surveyed over 2000 buildings in three London districts that have large immigrant populations, gentrification, and an active mix of shops, street markets, warehouses, and new, community-based space for start-up businesses. These surveys are resulting in maps that show the distribution of different attributes of building types, uses and businesses. We have simultaneously conducted about 120 interviews with business owners and employees, concerning the advantages of locations, building transformations, and history of the business. Combining the maps with the interviews leads to understandings of how physical factors of building type and location interact with the development and success of very small businesses.

Our results show the following:

- Small businesses are established within a wide variety of building types.
- Most of these types allow subdivision that maintains the continuation of the public realm into the building.
- Synergies exist between nearby businesses of different sizes, types and status with respect to gentrification.
- A strong hierarchy of streets, alleys and quasi-public space supports a variety of locations and rents.
- Although gentrification is not necessarily seen as negative by local business owners, it results in the loss of "back-of-house" space that is useful to small vendors and local businesses.

Our findings shed light on the fine-grained dynamics of urban structure, and help re-connect physical urban design to urban policy.

The findings are intended to be useful to local organizations of merchants and micro-enterprises in their efforts at self-advocacy; to local authorities which support and regulate business activity including micro-enterprise; and to investors and developers who want to include space for start-up businesses in their projects.

KEYWORDS: building typology, London, microenterprise, urban ethnography, urban structure

INTRODUCTION

For the last several years my research group has been investigating the idea that there is a relationship between the form of the city, the design of small urban buildings and the ability of the city to support economic development at the grassroots. Our investigations are part of a larger concern with the inclusive city—the idea that in socially and economically successful cities, there is a symbiotic mixture of people: rich and poor, immigrants and longer-term residents, young and old, black and white. The nature of this mixture allows for exchange that supports positive economic evolution of people as well as of the city itself. The city has a dynamic relationship between stability and change—and therefore needs to be understood not in the static terms that are characteristic of many urban design studies, but instead in terms of the decisions that are made by individual players in the city, that ultimately affect the city's growth and transformation.

Our interest is in "microurbanism" –apatial structure and relationships at the scale of individual buildings, streets and neighborhoods—and in particular the conditions in local areas that allow for small-scale enterprise to establish and maintain itself. This is of course more than an academic question. Most of the world's population growth is happening in cities, and a good part of urban growth is with the "informal economy," based on individuals and individual families that are trying to make their way with tiny businesses that often happen "under the radar." Government policy with respect to this phenomenon, particularly in South America but also to some extent in southeast Asia, is beginning to change, with an acceptance of informal urban settlement and the institution of new initiatives that recognize the permanence and validity of this kind of urbanization.

But this issue is not important only in the so-called "developing world." As the economy and employment patterns change in the developed world as well, as the relationship between the central city and the suburbs changes in the United States, and as the idea of sustainable cities begins to incorporate social and economic sustainability as well as issues of energy and land use, the question of how the city can best support small-scale, self-initiated business is also important. In planning, over the last several decades, there has been a widening gap between physical planning and urban policy, often resulting in urban design practice that is rightfully criticized for often being overly scenographic and visual. One way of bringing together design with meaningful policy that is based on economic issues is by looking at the fine-grained dynamics of neighborhoods and buildings themselves, in an attempt to understand relationships, between the urban morphology of districts, the typology of their buildings, and the possible ways in which those physical factors support economic development at the grassroots.

The work has two origins:

First, the development of my book LIVING OVER THE STORE, in which I looked at the common urban building that combines commercial and residential uses, and which I came to see as a microcosm of a local urban system that has synergies between different uses and that is flexible in its use and transformation. This building is a cross-cultural phenomenon, strongly linked to aspects of urban geography, and in which commonalities across cultures provide a beginning insight into the larger question of the relationships between architectural form and economic life.

Second, work in Guangzhou, China, in which we looked at buildings constructed before the end of the Qing dynasty (in other words, before 1912) and how they maintained their flexibility over decades of radical political and economic change in China. We began this work with a strong bias toward the traditional, densely-packed urban fabric of two-, three-, and four-story shophouses. We showed not only that these buildings maintained their flexibility partly because of one or two simple architectural attributes, but also that their collective FAR efficiency is as great as that of high-rise buildings up to about twenty stories in height, given how buildings are actually disposed on the ground.

We moved from these studies, focused mostly on individual buildings, to investigations of urban districts, also in Guangzhou. That work took place in 2010. For the last two years we have been working in London, in three areas that are characterized both by a high percentage of immigrants and in two out of the three cases, gentrification.

Within these districts, we have been using an approach that combines two methodologies: geographic mapping and ethnography. These combined methodologies are intended to reinforce each other, as the human stories help to explain the impact of geographic distributions and architectural type.

The first area of investigation is Whitechapel and the adjacent neighborhood of Spitalfields, which are adjacent to the City of London, now one of the two major financial districts in London (the other being the Docklands). This area has been a harbor for immigrants for over four hundred years: Hugenots in the early eighteenth century, followed by Irish, Jews and most recently Bangadeshis. Although many Bangadeshis have moved from Whitechapel to other places in London and the UK, they still regard Whitechapel as their cultural hub, marked by the East London Mosque, one of the largest mosques in the UK. Although Bangladeshi businesses are still being newly established here, change is afoot, with a major expansion of the Royal London Hospital, a new station for Crossrail (a major new transportation line), and the ongoing gentrification of Spitalfields.

The second area is Upton Park, about seven Underground stops to the east of Whitechapel, past the site of the Olympic Park. Here, large numbers of Bangladeshis established residences and businesses as they moved east from Whitechapel toward Essex--and numerous people have businesses in both places. Commercial life is centered on Green Street, a long north-south artery lined with ground-floor commercial spaces, with streets of two-story terraced houses perpendicular to it. The streets' businesses include necessities such as groceries, pharmacies and ordinary clothing stores, as well as upscale businesses in clothing and jewelry that bring people in from beyond the neighborhood. Near the Overground station is Queen's Market, a public market with dozens of stalls selling food, clothing and dry goods.

The third area is Dalston, a few Overground stops to the north of Whitechapel. Dalston has a large West African population, and is gentrifying as new coffee houses, art galleries and craftspeople are becoming established in the area. We chose Dalston partly because of a relatively new initiative in which tiny prefabricated shops intended for microbusinesses were located around a new public square. (Fig. 1.) Like other areas, Dalston has a great variety of spatial types that accommodate businesses within a relatively small area. These include a major outdoor street market, an indoor shopping center, as well as many shops that directly front the street.

Figure 1. Gillett Square in Dalston. The picture shows renovated terraced houses and prefabricated structures for microbusinesses. Source: (Author 2012)

Our work in London happened over two years, with each year's fieldwork combining the two methodologies mentioned earlier.

We began with an extensive building –by-building survey in each district, ultimately including about two thousand buildings. This was a visual survey, in which each building was recorded according to attributes including building type, number and location of businesses, presence of microbusinesses, building height, building uses including kind of business, and similar factors that could be directly observed.

The second phase involved over a hundred interviews with business owners, employees, residents of the area and people who worked for local government and local organizations. With these interviews, we tried to understand people's own stories and their perceptions of how local geography and architecture were affecting their business and its prospects. We talked about the advantages and disadvantages of particular locations people's origins, where they lived relative to their businesses, where their customers came from, the origin of their goods, as well as the history and transformations of the buildings themselves.

From a methodological point of view, the ethnography and the geographic analysis were intended to reinforce each other. The individual perceptions that people had might be borne out by the overall patterns observed in the survey; and likewise, the geography would be shown to have an impact on particular lives and particular businesses. This combination of geographic and ethnographic investigations has been central to the work.''

Our methodology has advanced from a technical point of view, as well. In 2010, when we first carried out the geographic survey in China, we recorded the various attributes for each building directly onto the maps. We then spent months transcribing that data onto spreadsheets that could be imported into the GIS database that produced the analytic maps. The following year, we recorded data directly into matrices that were subsequently converted into GIS-friendly spreadsheets. But even here, that process was time consuming, with a substantial gap between data collection and seeing the results.

So last year, we made a further advance allowing for an increase in the speed and accuracy of data collecting. With the use of smartphones to record data, we used an interface originally invented for community-based mapping in developing countries in connection with ArcGIS—allowing us to visualize our results almost instantly and to easily find geographic correlations among different attributes. This system allowed us to budget between two and three minutes per building, including a photograph taken on the smartphone. And because the data recording was based on a series of questions to be answered with selections from drop-down menus, there was much more of a chance that all questions would be answered, and in a consistent way.

Although each neighborhood is different, our results show the following common features:

a) Small, new businesses are established within a wide variety of building types.

There is a great variety of kinds of buildings within which businesses are established, and physical transformations they undergo in order to accommodate those businesses. (Fig.2.)

Figure 2. The variety of building types in a portion of Whitechapel. Source: (Author 2011)

These building types included the following:

- Terraced houses that started out as residences, parts of which were later converted to commercial use
- Free-standing market stalls that are erected and broken down each day. These stalls are pretty much exactly the same size, as they each fill an identically-sized pitch, the corners of which are permanently laid out on the pavement with metal markers
- Permanent market shops at the edge of a train yard
- Purpose-built buildings of different sizes used for retail, wholesale and manufacturing purposes
- Purpose-built public markets.
- Arches in railway viaducts converted into retail and wholesale shops
- Private supermarket converted into an indoor bazaar
- A movie theatre converted into retail use
- A brewery converted into a marketplace with many shops and residences
- Retail shops converted into mini-shopping malls
- Prefabricated metal buildings specially built for microenterprise
- Temporary metal sheds used for storage facilities

- Jerry-built wooden and metal structures used for retail shops
- A mosque complex that includes retail shops at its base

Some of the spaces are as small as about fifty square feet and allow just enough room for a single person to work and sell; some are just the width of a single doorway; some have direct street frontage and others are known only because of a sign that can be seen from the street.

This variety of spatial types, all in the service of different commercial uses, points to a complex relationship between form and function, and to the flexibility of buildings in the face of local economic change. Some of the examples seem to run counter to the idea that fine grain is necessary for flexibility. They show that fine grain can be readily created out of larger entities—and as I will show later, that ability may be as important as building type itself in setting up positive conditions for business and entrepreneurship.

b) Many of these building types allow for physical subdivision that maintains the continuation of the public realm to serve new businesses, even if the businesses are deep inside the building.

This physical subdivision happened in both large and small buildings.

The London terraced house, versions of which were built from the eighteenth century through the early twentieth century in all three neighborhoods, easily lends itself to this kind of subdivision, largely because of the side passage that allows access to all rooms and which may act as a quasi-public space even though it is of course privately owned. The conversion of these buildings allowed for businesses mostly at the ground floor but also floors above and sometimes below.

But we also saw the conversion of a large Tesco supermarket, into a shopping bazaar served by several corridors perpendicular to the street, along which were tiny stalls occupied by tailors, various kinds of music businesses, food businesses, and at least one businesswoman who grew up in London, became a registered nurse in New York, and then returned to London to take care of her ailing mother and then became a missionary of the Seventh-Day Adventist Church which occupation she practices out of a stall in the middle of the former supermarket.

Another phenomenon we saw in all three neighborhoods, consisted of the division of a single shopfront, no more than about sixteen or eighteen feet wide, into a tiny shopping mall, accessed by a central corridor and lined with very small stalls that were no more than about six feet deep.

In Spitalfields, the conversion of an old brewery is allowing for space that incorporates start-up businesses as well as restaurants, and in all three neighborhoods, tiny businesses, which often have to do with sales of cell phones and SIM cards, were easily established as part of existing shopfronts. In Whitechapel Road, a small supermarket was divided to include a fried chicken shop, and a phone card shop on the ground floor, with upper floor space rented to an accountant, and the basement space rented to a restaurant. An old pickle factory in Heneage Street became a brewery, then a clothing factory, and has now been subdivided into studios and galleries. In the Kingsland High Street in Dalston, offfice space that was rented by a Turkish television studio is being converted into residential space that has already been rented by a local housing association.

Most of the examples we saw during the fieldwork, have to do with the differentiation of space rather than the consolidation of space. In these neighborhoods, the push toward the establishment of new businesses seems to require small spaces rather than large ones. The available buildings lend themselves to subdivision in different ways, allowing for a variety of kinds of small spaces, and a variety of relationships between those spaces and the public realm.

c) Synergies exist between adjacent and nearby businesses of different sizes, types and status with respect to gentrification.

For example, the former supermarket was itself adjacent to the Ridley Road Market, an old street market in Dalston, This adjacency was important for two reasons. First, the intense pedestrian traffic in the market helped support the business in the old supermarket; it was clear from observations and from interviews that the street market was the engine without which there would be little business in the old supermarket. But second, rents for spaces in the old supermarket were low enough so that some of the spaces could be used for storage, rented by stallholders in the market. It turned out that gradually-rising rents in the area were a problem, as it meant that those storage spaces in the former supermarket were turning over to retail uses.

In Whitechapel, there is a strong relationship between the outdoor stalls in the market that lines Whitechapel Road, and the permanent shops that are opposite those stalls. (Fig. 3) This was somewhat counterintuitive, as we might have expected that the shopkeepers would feel that the stallholders were taking away their business. But in fact the situation was the reverse—the shopkeepers felt that their own businesses depended on the market stalls. People moving between the Whitechapel Underground station and the Royal London Hospital across the street shop at the outdoor stalls, and incidentally find the fixed shops. The shopkeepers felt that without the outdoor stalls, their business would be much less.

Figure 3. Whitechapel Road, showing fixed shops at right and temporary stalls at left. In the background is 30 St. Mary Axe (the “Gherkin”) designed by Norman Foster, indicating the proximity of this area to the City of London. Source: (Author 2011)

Other, specific relationships Include the following, among many others. The owner of a shop in Whitechapel selling Islamic religious items reports that his business is helped by the presence both of a Halal poultry shop and a religious school on the same block. A food truck provides prepared food for many of the merchants and employees in the Queens Market, in Upton Park, and another takeaway food business in the same place sources its food from other food vendors in the market. A tailor in one of the tiny prefabricated shops in Gillett Square in Dalston says that his customers can have coffee and food in the other shops while they are waiting for him to work on their clothes.

d) A strong hierarchy of streets, alleys and quasi-public space supports a variety of locations and rents.

Each of the three neighborhoods is characterized by a strong hierarchy of different kinds of streets, alleys and quasi-public space (which is defined as space that functionally acts as public space even if it is actually privately owned). These public spaces of access support a rich variety of uses, with the distribution a result of both the persistence of historical pattern and the variations of rent that come from different levels of visibility and accessibility.

This variety of public spaces may be formally described by a typology that is analogous to the typology of buildings. For example, in Dalston, this typology includes the following elements:

- the main north-south artery of Kingsland Road
- side streets such as Birkbeck Mews, Sandringham Road, Bradbury Street
- the narrow pedestrian paths that serve the individual stalls in the Ridley Road Market
- Gillett Square

- the outdoor galleries allowing access to rooms in the old terraced houses that have been converted into offices for local community organizations
- the corridors in the converted Tesco supermarket that provide access to the individual stalls
- corridors in retail shops that have been converted into mini-shopping malls
- the passages in the Dalston Cross shopping centre

In Whitechapel/Spitalfields and in Upton Park, there are equivalent typologies and hierarchies, ranging from major through-arteries like Whitechapel Road or Green Street, down to tertiary streets and alleys, and private spaces that allow for public access.

These hierarchies, and the variety of rents that they support, allow for choice, and for new businesses to establish themselves in the neighborhood but off the most expensive and highly-trafficked streets. This allowed a new café owner to put his business on a side street, near but not directly on the main street in Dalston; it allowed the seller of Islamic religious goods to put his business next to other businesses oriented toward the Islamic population of Whitechapel, but off the main streets; ii allowed recent Ghanaian immigrants to establish small businesses in an informally-organized outdoor mall at the quiet end of the Ridley Road market in Dalston.

e) Gentrification is not necessarily seen as negative by local business owners. But it results in the loss of “back-of-house” space that is useful to small vendors and local businesses.

In many cases, we heard longtime owners of businesses say that they welcomed gentrification, because they felt that new businesses and new people would make their own businesses more viable. These owners tended to be welcoming of economic change but wary of social change. People we talked to who were most negative toward different ethnic groups tended not to be business owners but instead long-time residents of neighborhoods who dealt with other people at arm’s length rather than in direct economic interactions. The business owners were more balanced in their views. A wine merchant in Kingsland Road changes his stock on a regular basis to serve a changing clientele. A takeaway food vendor is the Queens Market has developed a new item to bridge the gap between cultures—an English pasty filled with Caribbean stuffing and spices.

But in addition, the increase in rents that comes along with the influx of new businesses into the neighborhoods began to eliminate uses that depended on cheap rents. In the Dalston neighborhood, for example, some of the street vendors who operated stalls in the Ridley Road Market relied on spaces in the converted Tesco supermarket for after-hours storage of their wares. Some of this storage space was converted into retail space as rents began to increase. And this in turn put pressure on the owners of the market stalls, who either had to pay more rent for their storage space or increase their storage costs buy paying more for transport from locations with cheaper rent.

•••

Most of what we looked at can be characterized as “organic” urban growth—development happening business-by-business, within a physical structure of buildings that were themselves changing slowly over time. From one point of view, our project is intended to show the structure of this kind of organic growth, linking economic issues to physical ones.

But in one case, a single community initiative showed that these kinds of “natural synergies” might be successfully designed from scratch. In Dalston, a local NGO called Hackney Community Development developed a new project relatively near one of the Overground stations just off the high street. This project consisted of several adjacent and interrelated parts:

- a new public square near the principal street, carved out of a previously-existing parking lot
- the conversion and re-use of a row of dilapidated terraced houses at one edge of the square. The ground floors of these houses had shops, facing away from the square, and were converted into spaces for start up retail businesses. The upper floors, previously with dwellings, were converted into spaces for local community organizations and arts groups, accessed by new outdoor galleries overlooking the square.
- the construction of a new jazz club and café at the west edge of the square
- and finally, the installation of ten prefabricated metal buildings, no more than about 80 square feet each, for microbusinesses, right on the edge between the terraced houses and the square. At the time we visited, these microbusinesses included a tailor, a recording studio, a coffee and juice bar, a cell phone store, a money exchange office, and others.

The variety of businesses in this initiative, working alongside existing businesses, helped support a vibrant place with an active mix of uses. The square was busy all day, and was occupied by people using and hanging out at the microbusinesses, homeless people who occupied a shady place at one end of the square, local business people patronizing the café during the day and people from farther afield coming to the jazz club at night. This included mothers who brought their children to toddlers' jazz classes in the morning, a car-washing service for people who left their cars to be clearned at what was left of the old parking lot, children using play equipment brought into the square in the afternoon. On the adjacent street, facing away from the square, were new businesses in the renovated spaces of the terraced houses, and across the street, in different properties altogether, including an upscale restaurant and a café opened in the last year by a former lighting designer from New Zealand.

This iniitiative is a complex design that happens to incorporate many of the principles that seem to be the result of our research. It has a variety of spatial types; it makes use of the transformation of old terraced houses; it puts businesses of the gentrifying economy next to those of people who have been in the neighborhood for a long time. It raises the question of the extent to which the economic diversity of cities, to the extent that such diversity is supported by spatial configurations, can actually be planned for. Indeed, I would suggest that the value of our research is partly in the insight it gives into the complex spatial/economic dynamics of urban neighborhoods, but also in the ways it might suggest principles for policy and design.

The first part of the title of this paper, "Making the Marginal Visible," speaks to both the content and the dual methodologies of our work. Our observations and interviews indicate a wide variety of spatial types that accommodate an equally wide variety of business functions; the ability of spaces to easily transform; and strong functional relationships between different uses. This complex variety, within small geographic areas, is the context for economic mobility, allowing people of little means a spatial and economic armature within which their own efforts are supported. Combining the spatial survey with the interviews has allowed us to detect and confirm these relationships.

As mentioned at the beginning, this work is part of a larger effort that is more generally concerned with the question of urban inclusion. This effort is incorporating historical studies as well as investigations of design and policy initiatives that are intended to legitimize and support what is often considered to be marginal and objectionable activity. There are implicit assumptions in our current work—that urban inclusion will lead to a more resilient and stable economy. Those assumptions themselves need to be tested with further investigations into the literature of urban economics and its relationships to social mix.

We conjecture that making this kind of activity visible, and beginning to understand its spatial structure, is a first step toward its legitimization and toward the understanding of how designers, developers and policy-makers might support the inclusive city.

Territorial Assessment of the Urban Peripheries Fragmentation in Fez, Morocco

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ABSTRACT: The paper discusses the problematic of the urban fragmentation at the level of the peripheries of Fez, Morocco. The paper aims at dealing with complex urban issues namely: How can we nowadays assess territorially the scales of the urban in this large city, based on the observation of the urban peripheries fragmentation, which are so sensitive and strategic, with a plural and complex reality, interactive and in full motion? On what basis and according to which criteria can we define the degrees of this fragmentation quite visible spatially from its peripheral extensions?

There are two main objectives in this study. First, we shall demonstrate if this spatial fragmentation regenerates any social fragmentation. In this sense, we have to master the indicators allowing us to evaluate the presence of this fragmentation. This approach allowed us to manage its meaning in terms of urban integration and/or exclusion. Second, we shall identify the diversity of peripheral scales according to how the inhabitants themselves visualise their territories.

At the level of methodology, we adopt two complementary qualitative approaches based on an extensive and long fieldwork. The "renewed" typological approach adopted in the first part has been completed in the second-level by the "axiological" approach, essentially qualitative.

The analysis of the issue refutes clearly any correlation between mechanical spatial fragmentation and social fragmentation. It follows from the in-depth analysis that the "non-regulatory city» is not at all "another city", it has similarities and articulations with the conventional city. On the other hand, our research confirms the importance and size of these different forms of adherence, symbolic and real, to the urban, through the individual and collective access to products and services of the "Urban," tangible or intangible. These results call for a critical examination of the fragmentation connotations as a shared and irreversible process at the core, related to an advanced and desirable urbanization.

KEYWORDS: Peripheries, fragmentation, integration, urbanization pace, territorial assessment.

INTRODUCTION

This article discusses the issue of the socio territorial assessment related to the urban fragmentation through the "reproduction" scales of our peripheries at the time of globalization in a big Moroccan city, Fez.

Questioning this reality is done in our research through the various scales and socio-territorial manifestations of the "creation" and urban practices process. Indeed, our field work, undertaken since the middle of the 90s, focuses on new forms of territoriality and the new ways to make the “urban” today in accordance with different strategies. These strategies are facilitated by multiple actors who actively participate in the process. In this presentation the focus is on the "ordinary" actors long neglected, though largely at the heart of the making and practices of the city in the urban peripheries of Fez.

At a first level, it is a question of applying a multi-criteria approach in assessing the spatial fragmentation of urban peripheries of Fez, with the intent of demystifying the thresholds of the socio-territorial diversity which generate four geographically distinct scales. This level of analysis has been accompanied by a minute and intense methodological approach in terms of mapping, reporting milestones and research results. Taking into account the normative requirements, only the overall findings will be analysed with the synthesis map in this paper.

At a second level, it is a question of deepening the socio territorial assessment and urban fragmentation through social practices of appropriation and reconfiguration of peripheral territories. This time the analysis of urban residential practices reverse the posture of the approach, starting from inside and focusing on the "micro" scale: from the district housing towards the periphery.

The "renewed" typological approach adopted for the assessment of this urban fragmentation in the first part has been completed in this second-level by the "axiological" approach, essentially qualitative, of the alternative process, made of social forces "against- fragmentation". And beyond the observation that confirms whether the dynamics of articulation actually or symbolically describe these peripheries, it is a matter of using the new scales and new ways to create the "integration" of the urban and territorial qualification in our Southern Mediterranean countries, today and tomorrow, at the time of globalization.

1.0 IMPLEMENTATION OF THE MULTI-CRITERIA APPROACH IN ASSESSING THE SOCIO SPATIAL FRAGMENTATION: DIVERSITY OF THE "GEO-TYPES"

1.1. The assessment background: Complexity of the peripherical urbanization processes and stakes

In the urban peripheries of Fez, and following the example of the major Moroccan cities, the internal "national" transfers, in their relation to the international dynamics of globalization, are asserted and articulated par excellence. It is in these peripheries that the future of our cities is asserted because numerous stakes are concentrated and articulated there.

Indeed, demographic issues related to the horizontal extension of the urban area is at the heart of this fragmentation, and Fez city is characterized by a growing population. The population has passed from 100.000 at the beginning of the 20^{th} century to around one million a century later, becoming the second largest city of Morocco. During two decades,1970-1980 and 1980-1990, the population's growing rate was due mainly to a migration flux from the rural areas and the nearby cities. Faced with the impossibility to intensify the historic urban fabric that has reached a "saturation" level, and the lack of access to nearby property opportunities, housing demand has shifted massively since the 70s to the "non-urbanized" margins. The choice of households is usually directed towards sites topographically rugged and private land: on the slopes associated with the Pre-Rif hills in the northern peripheries; slopes related to "Oued Boufekrane" in the North Eastern and South Eastern peripheries, on the agricultural plains where groundwater is near the surface due to the proximity of "Oued Fez" in the lower part of the South Western peripheries.

Thus, the unregulated solid housing market encompassed until the early 90s about 25,000 plots of land, approximately 180,000 inhabitants, 30% of the city of Fez, that is three times the national average. Hence the beneficial contribution of this market to mitigate the housing crisis and the economic dynamism that ensued, Meanwhile, the regulatory market had seized from the mid 80's a fairly consistent land reserve inherited from colonial urbanism. The latter is located in the peripheries of the South West part of the city. It consists of areas of land belonging to the State, which is approximately half of the total area of this periphery with 45.7%. Indeed, it is this reserve that has allowed the State to conduct its programmes of rehousing slum dwellers as well as all its social housing projects, in the short and medium term, on large surfaces and intensively. But the weakness of this reserve land, given the number of plots - with only 17.3% of the total - has helped to reduce the potential for long-term action. Hence the observation of current trends related to the extensions of the non-regulatory habitat to the south of the city in the rural commune "Ouled Tayeb". It is a new generation of peripheries that reproduces the process of a massive re-urbanization while awaiting its urban status and the official release of the new urbanism document. This new process of urban upgrading has the same logic that conditioned the making of the first generation of South West peripheries, but with a difference that lies at the level of very complex status and property stakes: The lands are governed by a special traditional status of joint ownership "J'moue" because they belong to rightful owners.

In this sense, a question is raised about the worrying delay that the new Master Plan for Urban Planning and Development of the city has known. Indeed, it should be recalled that under the pressure of strong socio-political issues, driven by irrational management of public land reserve over forty years, two major decisions and guidelines of Urban Planning and Development alternate. This is on the one hand related to urban policy governed by the technical institutional logic. The latter generates essentially a process of formal urbanization conditioned by questioning the planning tools so as to make habitat production processes more flexible and to reduce unregulated space (conservation, permissions ...). On the other hand, it is a question of directions governed by essentially political logic. The goal is to accept the fait accompli and proceed with the restructuring of informal settlements in order to grant it public recognition. This is in spite of the consequences generated in terms of financing infrastructure projects and various pressures. In principle, and in a context of concerted planning, these two processes should be complementary. But in reality the past decades reflect the alternation of the two processes following the national and international contexts. On the one hand, the causes can be external, ie the pressure of international financial organizations. This corresponds for example to the eighties with the implementation of the Structural Adjustment Programme - financed by the World Bank - hence the regeneration of the first process.

It is this context to which belongs the unfinished experiment of the Master Plan for Urban Planning and Development of 1980. On the one hand, the plan was distinguished by the orientation of the development of the city to the east, with the backdrop of the rehabilitation of the historic medina. On the other hand, it was characterized by the adoption of quality management in the restructuring of the peripheral areas most integrated to the city. This in parallel to the adoption of a policy of demolishing the remaining peripheral areas located in areas deemed dangerous and inadequate to the standards of urban planning. But on the other hand, the causes may be internal, in which case they appear in the form of urban unrest triggered from the South West peripheries of the city of Fez in 1990. The last Master Plan and Urban Planning of Fez represents since 1991 the political will to integrate into the urban area all the peripheries and to direct the development of the city to the South West. This trend was criticized by the conservative elites because it recalled the colonial model planning based on the principle of "spatial separation" between the historic and the modern city. In this sense a new administrative division of the city territory was adopted, and The “Zouagha Commune” was one of the fifth new Communes. But the strong social base of the new players in power from these same peripheries strengthens legitimacy of action. It is essentially about the "Zouagha Commune president" elected in 1993. Thus, mass qualification actions of the peripheries during a rather sensitive period, 1992-1997, which affected 48.4% of the population of the city, were accompanied by this new powerful actor. This has been a decisive factor in his promotion and election as mayor of the city since 2003, after the introduction of the new model of governance, which reset the principle of "unity" of the city.

1.2. Methodological approach

The conception/building of our approach makes use of specific databases and new principles regarding the design and optimization of field work. Components adopted are as follows:

- Combine and synthesize different data and approaches where intersect the quantitative with the qualitative: institutional quantitative data, qualitative data from institutional self-assessment. In this sense, institutions focus attention on the technical data about slams projects. However, when it comes to interventions in substandard solid housing, data becomes scattered, partial and lack precision. And to fill this gap our own field surveys have been incorporated.
- Investment of data from personal interviews and discussions with institutional actors.
- Capitalization of references and technical data from legal public debate on the definition of standards regulating the production of social housing.
- Exploitation of qualitative data from fieldwork relating directly or indirectly to the concept of habitat and / or neighbourhood "socially acceptable". These data were released from the dwellers' assessment of their experienced territories. This way we have combined the technical evaluation with the satisfaction rate of periphery dwellers against each of the indicators and generate an average of both. The rule adopted is as follows: The rating increases gradually following the increase in the average of the two percentages.
- Definition and selection of the reference note for each indicator and for any category of fragmentation indicators with a consideration of some equation between the thresholds and standards of "technically feasible" urbanism and those of a "socially acceptable" one.
- Generally, the criteria for evaluating the physical and morphological fragmentation are based on three indicator categories: indicators related to unity fragmentation (discontinuity, isolation ... etc), indicators of articulation (dependent on adequate and adapted transportation) and morphological indicators (fabric, density ... etc).
- On the criteria and indicators of equipment side, we have grouped them into three broad categories: "infrastructure" through the assessment of the technical work and the social use (accessibility), integrating the average rate of infrastructure connection and the rate of satisfaction. The "economic facilities," conditioned by the influence/opening criterion related to public amenities outside the narrow limits of the district or residential unit. The "social facilities and public services," treated similarly to the previous one.
- Concerning the criteria for assessing social fragmentation thresholds, they rely on a combination of indicators: socio-cultural (urban or rural origin, level of education), socio-professionals (by sector and skill level) and social (three major classes distributed into strata).

1.3. Assessment of the socio spatial fragmentation in the peripheries of the city of Fez: Synthesis map (Figure 1)

The general observation confirms results as follows:

- Presence of complex and composite indices, useful for understanding this fragmentation and the determination of its thresholds and scales, its justification and its backdrops.
- Emergence of a fundamental relationship between the socio economic situation and the current spatial studied units, both are evolutionary consequences of complex mechanisms,
- positive transformation of these spaces with the development pace of urbanization and the gradual integration to the urbanization process,
- Differentiation of scales and peripheral territorial units: the analysis allowed to identify four types of units interacting with the pace of urbanization.

In order to structure the findings of the assessment, a closer analysis has allowed to identify a classification of socio-spatial units studied on the basis of four geographic scales which correspond to four thresholds. These thresholds correspond to four separate peripheral models, some sort of "peri geo-types": namely the South West periphery located at the lower than average threshold, as opposed to the Northern periphery model corresponding to the higher threshold above the average, the North East periphery located in a central position, and at the bottom scale the South East periphery:

- First threshold corresponding to the socio-spatial potentialities above average, represented by the northern periphery of Fez: This "peri geo-type" is representative of a relatively positive situation in relation with the fragmentation/cohesion equation. This equation has led to a relative balance between a spatial fragmentation relatively low due to the relative concentration of equipment (despite pressure from the morpho-physical fragmentation) combined with social potential relatively positive (presence of positive socio cultural indicators and more meaningful involvement in the formal economy). This is parallel to a representative balance in the social composition of this periphery. In sum, this positive situation is both the result of early commitment in the process of urbanization, and the opportunity of appropriate location near the old Medina of Fez.
- Second threshold corresponding to the socio-spatial potentialities relatively average, represented by North East periphery: This "peri geo-type" reflects the positive effects of localization economies near the Medina. In this case, follow one another, almost equally, breakup forces and cohesive forces. This results on the one hand, in the spatial fragmentation which is situated in the average threshold. The development of economic facilities, related to the convenience of location near the Medina, helps reduce the effects of these spatial constraints. This balance justifies the presence of relatively positive social dynamics: significant representativeness of middle class, positive socio-cultural and socio-professional mixing. .
- Third threshold corresponding to the socio-spatial potentialities below average, it is represented by the South West peripheries. This "geo type" expresses socially negative pressure forces, which act in the direction of social exclusion: political choice to direct the growth of the city to this peripheries hence the concentration of state projects for relocation of slums of the city in this periphery. Hypertrophy of the lower class represented by its different strata reflects the direct consequence of this trend. Despite this, the South West peripheries include positive dynamics. This has to do with spatial potentialities adequate for urban planning, reflected on the one hand by fragmentation values relatively moderate, and on the other hand by a positive social mixing in the case of districts producing non-regulatory planning. This is expressed mainly by a stronger representation of the middle social class in the non-regulatory areas of production. This reflects the role of "non-regulatory planning" in the disparities regulation and in recreating alternative balance, allowing some "catching up" of urbanity.
- The deepening of territorial analysis at the level of neighbourhoods on the peripheries of the South West leads us to conclude that the main elements of analysis are as follows:
  - This is to confirm that the non-regulatory areas of production are not "another city" isolated from the regulations. This is all the more true that the oldest core of these districts, especially High Zouagha, play a vital role in the integration of new adjacent neighbourhoods. Moreover, these are at the top of the hierarchy.
  - Concerning the districts resulting from intervention in the slum, they meet the following classification rule: the more precocious these districts are part of the urbanization process, the more there is an increase of cohesion and urban integration forces: the case of "Ben Souda" and "N'zalet Faraji" are significant in this sense. By contrast, opportunities for integration of relatively new districts are reduced, mainly represented by the relocation of the slum district named "Al Massira," located at the southern end of the South West

- In opposition to all this, these opportunities dwindle completely in the case of precarious habitat districts, consisting of "pockets" of slums scattered around non-regulated housing, "pockets" not yet part of the urbanization process.

- The fourth and final threshold, corresponding to relatively low socio-spatial potentialities, is represented geographically by the South East periphery. This "geo type" expresses the pressure exerted by the spatial fragmentation forces due to the combination of three negative factors: namely the constraints of uneven topography, lack of equipment and a low level of articulation with the rest of the city. Despite the presence of relatively positive social indicators, physical constraints pressure remains strong.

To conclude, the factors that explain the spatial fragmentation do not automatically fit the simple socio-economic elements and exceed the static and recurring ones. The fragmented or discontinuous urban pattern, differential according to typo morphology and differences in equipment and services, correspond to the perpetuation of the process of exclusion and integration. This proves that the issue of fragmentation is beyond mere mechanical and simplistic reading of spatial and social components. It requires the integration of elements of urban living, along with the monitoring and evaluation of projects. This requires to go beyond this level of analysis and to switch to a direct questioning of the socio-spatial fragmentation from "below", meaning the actual experience of urban projects redevelopment.

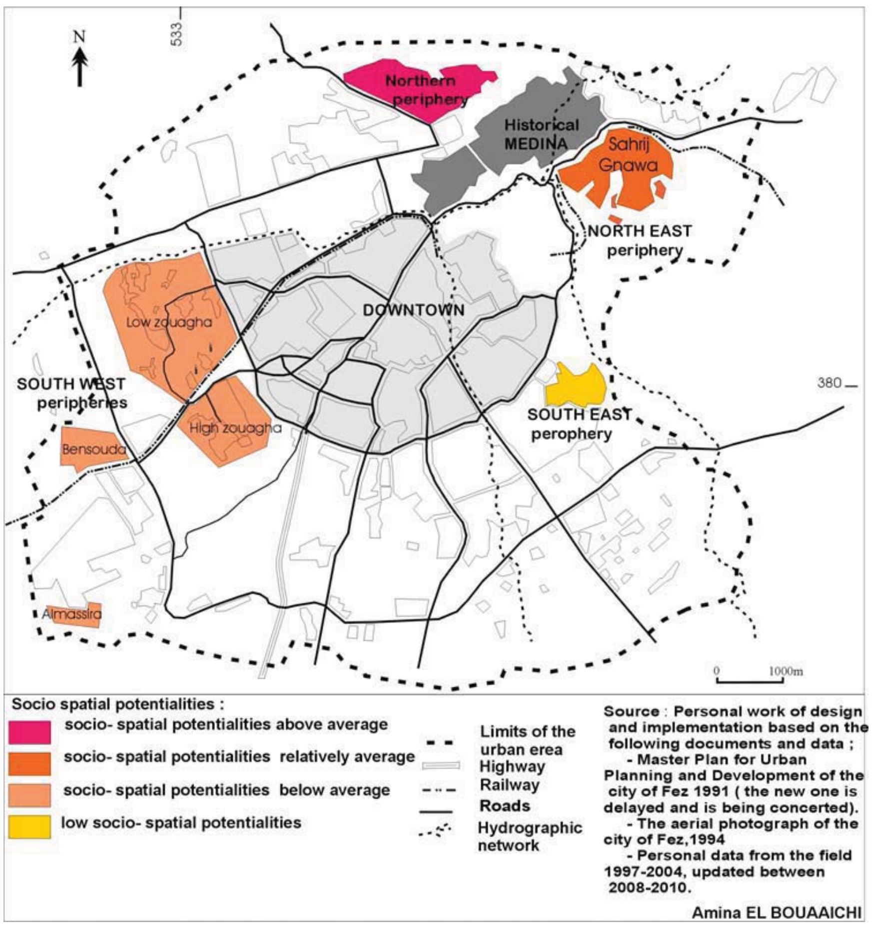

Fig 1: The socio-spatial fragmentation in the outskirts of Fez city. Source: (Amina El Bouaaichi, 2004)

2.0 MODES OF TERRITORIAL APPROPRIATION ACROSS THE DISTRICTS ON THE SOUTH WEST PERIPHERIES

The in-depth interviews carried with the inhabitants has shown the importance of territorial models reformulated in residential areas of the South West peripheries of the city, used for the needs of micro analysis. This is because they express the practices and strategies used by people in the process of access to "socially acceptable" housing. In this sense, several constants and variants determine the production, accumulation and control of the residential territorial capital, and thus determine the configuration and reformulation of the experienced housing models.

2.1 The constants in the residents' capitalization on territorial "resource"

The models of housing experienced by all people, irrespective of the type of housing and neighbourhoods studied, highlight on the one hand, the desire to acquire an independent property and reflect, on the other hand, the criteria and conditions that underlie socio territorial housing / building "socially acceptable".
The desire to access an independent urban land is considered as an ultimate objective, "an ideal" for the general population in all districts. The results of the analysis confirm that approximately two thirds of the households interviewed have concluded their residential process through the establishment of completely independent housing. The low mobility combined with the dwelling seniority are there to explain these gains. Thus the semi-independent housing becomes an alternative for about a third of the mobile population and of recent residence (with the exception of pockets of slums). Whereas the formula for collective housing is almost nonexistent, in fact, it is restricted to the nuclei of small households and / or recent constitution. Independent urban housing or semi-independent is considered a socio territorial gain which may materialize the conditions to create "adequate" habitat according to the population.
"Sufficient" surface area and "independent" or individual entry are two decisive factors that contribute to the projection of the "desirable housing" model. This model is based on the reference model of the traditional habitat. The "separation" space between the internal spaces, loaded with intimacy, and the external reception areas, charged with social representation, constitute one of the most significant expressions of this model. Besides the advantage that this independent housing model allows, through expanding the margin of freedom (formulation of desirable housing model), this quasi-independent housing also generates additional income for the household through the exploitation of the ground floor business and / or renting a portion of the house. All this to substitute for the lack of stability in employment and lack of social security (pension, health care insurance ... etc).

2.2. Variants conditioning the reformulation of residential models at the level of the South West peripheries districts of Fez

The processing and in-depth analysis of field qualitative data show a set of variables that interact to define the degree of ownership of residential territories and reformulate housing models. These variants are considered as "resources" that feed the territorial capital in a continuous process of accumulation and valorisation of the latter. It is these variants that determine ultimately – downstream/the later process to the making of residential territory- the "winning" categories of population who managed to accumulate an "optimal" residential capital and the opposite, "losing" categories of population who have not been able and / or did not know how to seize the opportunities that underlie these "resources". These are the thresholds and degrees of socio territorial expertise which condition the acquired aftermath/outcome by these categories: we mean by this expertise the input in time and space of the territorial experiences and social skills accumulated and used to control the residential territory by the "ordinary" actors.

The identification and analysis of the variants in question offer the following outcomes:

- **Mobilization of family and relational capital**: This mobilization is diverse and combines more when it comes to producing non-regulated areas. In these areas, in addition to family mobilizing, a fairly specific mobilization stands out: This is the mobilization of socio-political networks of local intermediaries. However, in the districts resulting from intervention in the slum, the relational capital is concentrated on the mobilization of the entire "household unit". As for the pockets of slums, the mobilization is restricted to the family network.
- **Diversity of residential areas**: social fragmentation in large spatial peripheries, the South West, and the diversity of its suburbs have been used by people in the formulation of appropriation strategies and territorial mastering in the sense of generating the best possible residential opportunities. The diversity of the districts in this periphery expands the degree of people’s freedom to act. The districts resulting from intervention in the slum also participate in this sense: they offer a new market in product diversification "socially acceptable habitat» in these South West peripheries.
- The strong and average ownership of residential territory has been brought out as a lived experience even in the case of "pockets" of slums. This high and medium residential appropriation is based on the "acquisition" of the "right of occupation" of land, for cheaper available land on the

market, and pending valorisation of this capital through the passage from the "precarious residential territorial capital " to "conventional residential territorial capital" and with the perspective of the restructuring of these slum pockets on site. In this sense, the "market" of "Nouala" or "shed" becomes a buoyant market for exchange value, thus fulfilling the law of supply and demand, just as is the case for other non-precarious districts.

- **Policies and public interventions in the peripheral territories in the south west of the city of Fez:** The impact exerted by these public interventions on the process of appropriation of residential land has been highlighted from two angles of analysis**:**
  - Ahead of the process of residential appropriation, these interventions allow people to mobilize and direct their residential projects with the ultimate goal of accessing a "suitable" residential formula.
  - The post process of residential ownership allows these public interventions to affect differently the strengthening or weakening of territorial capital and thus the "catching up" or not of urban integration.

Urban policies that affect directly the process of territorial appropriation are represented by: intervention programs in the slums and intervention programs in non-regulatory restructuring neighbourhoods.

- **The level of intervention policy on the slum**: These programs are seen as good opportunities for suitable independent regulatory housing affordability. This finding reinforces stability in the pockets of slums, especially since the actual engaging (since early 90s) in "restructuring" projects allows to multiply the chances to benefit from a plot of land to build and accelerates the rate of home-ownership. In this race to "catch up" urbanity and the accumulation of this territorial capital, it has been a question of going further and create new slum pockets, parallel to the urban density of existing pockets.
- **At** t**he level of regularizing illegal plots**: The "restructuring" of the non-regulatory areas has become a major socio political stake used by the public actor as a "game" election. But on the other hand, this issue has been recovered as a "fundamentalist gain" from the groups that represent dissidence in situ in these peripheries. These groups frame these populations. This fact has an obvious effect on the area, but it is cyclical. This established fact results in the reproduction of a non-regulated housing market (solid and precarious).
  - However, the negative effects of the "restructuring" policy have been brought out through the pressure of the building cessation over a decade (technical constraints, groundwater close to the soil surface) on the dynamics of territorial reconfiguration.

CONCLUSION

A review of the issue of urban fragmentation across the peripheries of Fez refutes clearly any correlation between mechanical spatial fragmentation and social fragmentation. It follows from the in-depth analysis that the "non-regulatory city" is not at all "another city". It has similarities and articulations with the conventional city. On the other hand, our research confirms the importance and size of these different forms of adherence, symbolic and real, to the urban. This adherence is done through the individual and collective access to products and services of the "Urban," tangible or intangible.

In this sense, we find harmony between the orientation noticed in Fez and the result of the studied reality carried out in cities of the Maghreb. However, the comparison with parallel studies of the urban realities of various areas in other sites (Latin American cities in particular), prompts us to ask some questions about what might be considered a merely temporary balance due to a particular composition:

- The idea of "achieving urbanity" reflects a strong positive socio-spatial mixing, which is one of the features of "urbanity" in the context of the current situation. In this sense, the position of the population about achieving urbanization is based on references prior to public action, given its strong presence in the population’s memory. These references are projects / models from which residential areas and segments of the urban community have benefited, in the same city and in other cities.
- The outcome of our field research unequivocally confirms that the future of the socio-political regimes is vital for our cities, given the importance of the implicit "Community Charter" enhanced recently by the Arabic spring.
- Abandoning the implicit "Social Charter" recreates the formula of unconventional "urbanity"; through the re-employment of illegal production of the urban area as a way to control the rarity and disparity of the socio-spatial capital. Therefore, the illegal "urbanization" could become a means to “catch up with” urbanity.
- In this context, we propose a national dialogue that may be held on extending the debate on the intersections that may be drawn and implemented between on the one hand, the public formula of "technically acceptable" models in the control and requalification of the urban area, and on the other hand

the “socially acceptable” population formula in adapting urban space values to the socio- cultural references and values.

The most meaningful results of the research clearly demonstrate that the ways of action carry some likeness; they materialize themselves notably in the general references that use the "lodging" in multiple intervention formulas to widen and recreate the socio political and socio technical legitimacies. In this sense the analysis demonstrates the importance of the models of living as witnessed in the southwest peripheries of the city. These models reflect the strategies and the practices implemented by the population to reach the "socially acceptable lodging" in the limit of "technically feasible formulas ". This analysis also shows the influence of these strategies and practices on the dynamics of construction, reconfiguration and private planning of the residential areas.

The assessment of socio-spatial indicators of fragmentation in the urban areas and districts under study, at the level of their relational composition and their horizontal and external systemic connections, confirms the presence of compound indications that help us to understand this fragmentation and determine its limits, justifications and dimensions, in addition to their significant background. This perception has important practical dimensions, both at the level of theoretical assimilation, and at the level of developing appropriate strategies to overcome problems. The consequence is the emergence of an intrinsic relationship between the socio-economic structure and the current field situation of the units under study. Both of them constitute an evolutionary outcome of complex mechanisms, given their multiple connections and dimensions, whether social, economic, of real estate, legal or other. It may have a direct impact that is soon embodied in field manifestation, and it might in other cases have an indirect influence, constantly working implicitly to adapt the situation to the regulatory requirements.

However, the positive transformation of these areas with the gradual engagement in the rapid progress of urbanization - in time and place – reflects the strong presence of cohesion and integration forces. The weight of these forces is identical with the weight of the forces of fragmentation. In this sense, the outcome of the research proves that the peripheral areas vary with different levels in their socio-spatial components and the tempo of urbanization. This itself reflects the disparity between cohesion and integration forces and the rest of the urban areas. In order to restructure the practical conclusions drawn from the socio-spatial fragmentation, the hierarchy of the field units under study was devised on the basis of four levels of assessment, according to their particularities and practical projections.

The results in general call for critical examination, on an international, national and local level, of the meanings of fragmentation. On this basis, we can use the specifics of fragmentation, its composition and its levels in Fez in the context of putting forward a set of questions and assumptions, that seem to be pending, as follows:
- The absence of extreme manifestations of fragmentation, similar to the districts of South American cities isolated from the urban "whole", is linked to the time and the current pace of urbanization,
- Questioning the time and the pace of integration into the global economy and the process of globalization,
- Reading the process of field and social mobility in some Latin American cities, as a significant model in the eighties, provides important similarities and differences with the condition of our major cities in the nineties,
- This fact prompts us to question the nature of the future process, and the possible impacts of the current dynamics - in the socio-spatial restructuring – supporting a number of phenomena, including the phenomenon of "metropolisation", economic restructuring, developing state institutions and urban governance.

I would like to end up with these ideas/questions to explore:
The Study lays a number of new questions that remain pending until today, and constitute a fertile field of thought and social, geographical and socio-political research,
- What are the determinants of socio-territorial "unity" for the urban of today?
- How can we separate the socio-territorial "unity" and distinguish it from the unity of the urban “regime” / "system"?

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Digital Diffusion of Research: Ongoing Studies & Potentials

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ABSTRACT: In the study of vernacular architecture, verification of physical space and understanding social, cultural, and economic contexts are of central importance. Today the challenge is to create new ways to share findings and invite dialogue. Our studies of early wooden structures in the Balkans have yielded publications and exhibitions on regions and buildings as well as our drawings and photographs.
Today the Internet includes an increasing number of sites with images of vernacular buildings that survive or are being restored. A number of preservation institutes and other organizations are developing websites to reveal these cultural treasures. Within this context, we are working to produce an open access site with a flexible format to provide information that crosses national and cultural borders, that in some cases are more rigid as countries in the Balkans reinterpret their cultural heritage and their artifacts. This shift in presentation media and transformation in historical interpretations demand that we revisit our research and the way it is disseminated.
This paper focuses on two aspects. First, it will present examples of misinformation created as national entities begin to redefine their identities. These include situations where historians, scholars, politicians and journalists have created views that are more fantasy than actual. Second, we will show strategies that we are implementing in our website to allow others to view a database with bibliographic notes of Balkan vernacular architectural artifacts that cover the period from the 17th through the last part of the 20th century. The website describes visited and studied buildings, locates these geographically, and will include an interactive database to allow access to images and information about similar building types across the Balkan peninsula, and will allow others to contribute.

KEYWORDS: Vernacular architecture, digital dissemination, Balkan

INTRODUCTION

The original focus of our studies began with a goal to explore the early wooden structures of Yugoslavia in an effort to reveal the variety of structural, formal, spatial and detail expressions generated by the craftsmen in the highly charged cross-cultural setting. In 1987, little had been published or shared beyond the borders of Yugoslavia. The exploration involved the study of archived information as well as direct observation of dwellings, farm buildings, religious sanctuaries or other economic structures that remained functional and part of the occupants' everyday lives. The information collected was catalogued and entered into a simple database, and shared over the last two decades, through the generation and display of photographs, and drawings, and through presentation of academic papers (e.g. Fig.1).

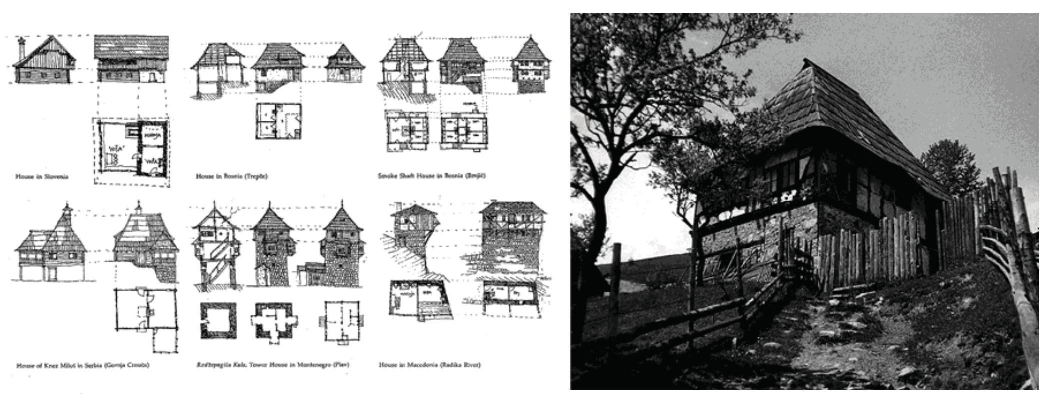


Figure 1: Sketches and photograph. Source: (Authors 1993)

These studies expanded to other countries on the Balkan Peninsula and beyond as we sought to find additional roots of the architecture of the South Slavs. We included investigations of the architecture of adjacent countries, as well as previous politically dominant centers that brought both immigrants and cultural influences to the Balkans. The study has extended historically to the earliest evidences of Hittite, Persian, Greek and Roman incursions.

1.0 Rewriting History, Shifting Interpretations

The conflicts among the countries of former Yugoslavia and the desire of their peoples to build a different future have had deleterious effects upon many of these historical buildings and settings. Numerous architectural artifacts were destroyed or allowed to decay because of new priorities. Our studies include records from on-site observations and interviews with those who occupied these sites during the years of 1987-91. In the case of sites in Bosnia and Herzegovina, Bulgaria and Turkey the time frame extended into the period from 1996-2004. Our most recent visit to selected sites (in Slovenia, Croatia, Serbia, Bosnia and Herzegovina, and Macedonia) occurred in the summer of 2008.

The formation of new countries in the Balkans, over the last two decades, has in some instances resulted in removal of architectural artifacts as well as the displacement of people. The changes, in some cases, brought genocide to both people and their cultural expressions. An important goal of the dissemination of these materials is to expose examples of buildings and settings that were important parts of social and physical landscapes that no longer exist, and in many cases are being denied as having existed by current populations or politicians. Three examples are worth noting: the first is an important mosque in the city of Foča, the second a Han in Počitelj, and the third a Roman Catholic Church in Petrinja.

The central mosque (Aladža Džamija, erected in 1550[1]) in Foča, Bosnia and Herzegovina, was completely destroyed during the 1992-95 war for independence. In a discussion with Dr. Michael Sells of Haverford College in Pennsylvania in 1994, I was informed that the mayor of Foča told Professor Sells that there was no such mosque in Foča, nor had there been one in recent history. I was able to inform him about the Aladža mosque, that I had seen and taken photographs of it in 1987, and possessed Preservation Institute publications presenting information on the mosque and its decorative elements.

During the 1991-95 Croatian War for Independence from Yugoslavia a number of Catholic churches were destroyed and totally razed in the town of Petrinja. During our visit to Petrinja in 1996, we visited one of these sites with a Croatian colleague, Davor Salopek[2], who explained that the masonry walls of the church were reduced to rubble and moved to a fortification where the stones were used as a barrier to protect Yugoslav army fighters from the attacks of local fighters. We stood on the site of the church and could barely make out the foundation perimeter; the land had been bulldozed over to cover any hint of a building. In this case the Croatian inhabitants subsequently built a new church to serve the surviving congregation.

In Počitelj, Bosnia and Herzegovina, a small crescent shaped village nestled in a rock formation, the local Han was appropriated in 1997 to become a Catholic religious center for the Croatian Bosnian population that took over this area. The term Han describes a building complex used to house travelers and merchants who were traveling to major trade centers with their goods. The Šišman Ibrahim Pašin Han in Počitelj dates back to the sixteenth century, an important building in this historic village complex. Prior to the war the village population had been decreasing and a number of its dwellings had been deserted. The town had become an artists' colony and a number of the old dwellings turned into a hotel. In 1988 and in 1991 we stayed in restored dwelling units within the revitalized town. In those pre-war years the Han served as a café and restoration work was in progress. In 1996 we drove from the Croatian coast through Počitelj on our way to Mostar and briefly saw the level of destruction in the town. In 1997 the new town officials working on the conversion of the Han complex into a new religious center, denied the Han's historical function or importance.

Historians often differ regarding the importance of physical settings and social positions but it was saddening to see such rapid rewriting of history in the face of physical evidence or historic records. Unfortunately the few examples above are not unique in our experience and moved us forward in seeking a way to present our own records for a large audience. The erasure of architectural artifacts in the heat of wars can serve many purposes, the voids can memorialize that which is lost or they can deny what has existed. It is not our goal to proselytize the importance of what was, rather to document what we saw.

2.0 Basic Resources and Initial Methodology

Our initial research was funded through a Fulbright grant that allowed us to spend a year in Yugoslavia. We were assigned a contact colleague, Dr. Zoran Petrović, a scholar of vernacular architecture and professor at the University of Belgrade. We spent our first five months studying the available resources noting buildings of special interest, their construction types, location, age (when given), and creating small sketches of each building, indexing its book or article source. We began to form itineraries to visit the best examples. In the fall and winter months, we also traveled to visit promising sites, universities and preservation institutes in the each of the former Yugoslav republics. This allowed us to expand our collection of publications as well as to form relationships with other scholars and gain access to preservation institute materials.

At the end our first five months, we set off to visit the six republics of Yugoslavia for one month each, to visit the most promising sites, to gather information from local institutes, and to observe the buildings in their current context. We also visited Vienna, Venice, Budapest, Plovdiv, and Istanbul to gather information that focused upon vernacular architecture of the larger region.

In our travels during that first year we traveled over thirty thousand kilometers by auto to visit sites, took over four thousand photographs (slides and black & white), and collected over one hundred books and articles. Each photograph was entered into a daily log that recorded the place (one grided map book was used), the name of the structure, and date if possible. Each roll of film was numbered for future cataloguing. The sketches generated during the initial archive studies served us well to illustrate to local villagers and towns people buildings we wished to find when our language skills failed us. In the formation of our studies we considered a number of approaches but decided to use the methods put forth by Ronald W. Brunskill as a beginning point and modified our methods to respond to those found in the preservation institutes in Yugoslavia and in keeping with the types of information that available across the region.

In the ensuing years (fall 1988 - spring 1991) we created more detailed databases of collected materials. The photographs were entered into a database that identified the town or village, republic, building type (dwelling, church, chapel, mosque, stable, shade structure, granary, etc.), construction (masonry, wood, thresh, straw, half-timber, combinations), notes on age, location of town in our gridded index map book, and number of the photograph (roll and frame number). In a similar way all of our collected publications and drawings were entered into a database. In the spring of 1991, with a preliminary manuscript in hand, we again traveled to Yugoslavia and revisited numerous sites and colleagues. This research trip was cut short by the beginning of the war when Slovenia seceded from Yugoslavia.

3.0 Initial Dissemination Approaches

The original intention for the project was to create a book about early wooden architecture in Yugoslavia that would illustrate and describe selected buildings and their details, within the context of the cultures in which they were created. That intention evolved since we began to find that the great volume of information and goals established made it impossible to disseminate findings quickly, and we recognized that all of the materials gathered should be housed in one archive. Along with drafting a manuscript, we decided to present papers at conferences that focused on selected building themes. This was followed by creation of an exhibition that included approximately fifty buildings that demonstrated important aspects of the vernacular architecture in the regions of our interest. Our exhibitions (e.g. Fig.2) were accompanied by gallery lectures and at subsequent venues grew to include more examples (approximately one hundred panels). The majority of the goals of the study remained only schematically addressed since true analysis was unattainable given the pressures of everyday university teaching obligations.

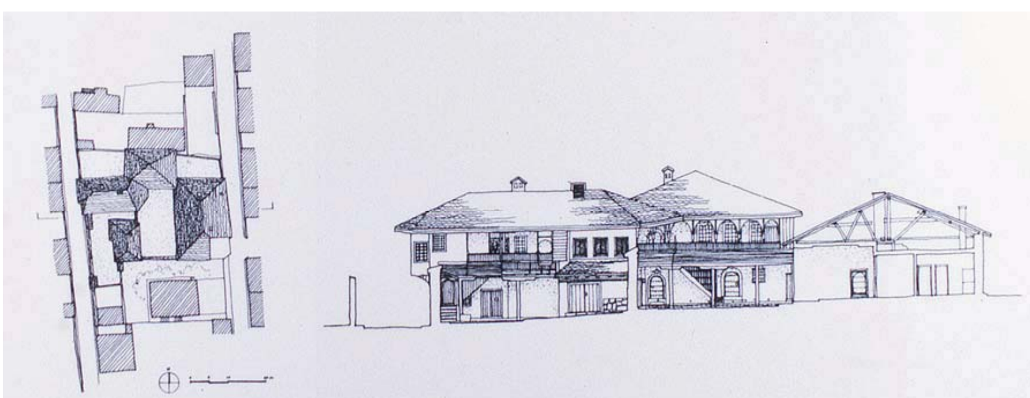


Figure 2: Exhibited sketches of Kuća Svrzina (Source: Author 1993)

4.0 The Condition of the Research Archive

As one would expect, elements of such research materials are vulnerable to deterioration. Our large archive of photographic slides, (diapositives), are now over twenty years old and some are showing signs of organic matter attachment, while the black & white negatives are in good condition. Photocopied materials are on standard paper of the time, diazo blueprints of preservation drawings and have been kept away from light, but the images need to be transferred to a more stable medium, and the books and journals are aging. These are normal concerns that all archival materials face. The exhibition materials were prepared on acid-free papers and stored in acid-free archival boxes; approximately half of these were exhibited most recently in 2012.

5.0 Current Dissemination Goals

With the changes in political ideologies and boundaries in the Balkans, the proper place for our findings is in the public realm, with access to the greatest audience. Our goal is the dissemination of materials more appropriately through the photographic images, drawings of the building configurations (plans, sections, elevations) and site or situation plans, and accompanied with a brief description and a bibliography of sources used and acquired to date.

When one defines goals, it is important to know what items, activities, and issues are not included as goals. One aspect that has not been pursued, originally or today, is to assign authorship to any particular individuals or ethnic groups for the design or details of buildings. Vernacular architectural studies sometimes attempt this task but the complex overlay of cultures in the Balkans makes this impossible and has led to much speculation and controversy.

6.0 Selection of a medium for dissemination

Our decision was to create a website to allow the greatest dissemination of our archives and findings. With the growth of the Internet it is increasingly easy to disseminate information to a wide range of people. Accuracy and honesty, however, are more difficult to guarantee in this medium. In the academic setting one expects that the words and images presented have been thoroughly researched using scholarly protocols and methods. This is not always the case with information found on the Internet. Yet it is unjustified to presume that information is any more accurate, honest, or scholarly because a more conventional medium or approach has been used. One can find many conventional documents and images that contain erroneous, deceptive, or misleading presentations.

At first our efforts were directed toward a search for primary sources and development of academic (scholarly) papers. Our ability to work towards a comparative study now seems more distant. Instead the rapid rate of disappearing vernacular artifacts and the inaccessibility of our collected works forced us to re-evaluate our goals and approaches to the research. The medium selected was not defined by the process of submission, review and production but by our ability to reach those with an interest in the content. The Internet allows the ability to share information and to expand and adjust the materials available in a way that other more conventional modes of dissemination do not allow (e.g. Fig.3).

Figure 3. Website entry page with key (Source: Authors 2012)

7.0 Positioning of Research Content

Vernacular architecture in the area of the Balkans is becoming more prevalent in travel books and on the Internet for those interested in cultural tourism. A number of websites provide isolated images of the wooden buildings that are representative of rural and village life from the end of the eighteenth century to recent times. Each selected building is typically shown only in a single view, without accompanying plans, sections and site information. It is the study of these buildings in the context of one another that can bring a richer knowledge of the variety of forms, textures and spatial orders.

Vernacular architecture of a region, on a more scholarly level, is typically studied as a complex of inter-related social, cultural and economic issues that are present at a particular time or over a particular period. Most of the studies that we have found were produced during a time when a particular building or site was important as the site of an historical event or individual's home. Furthermore the documentation and publication of most examples were produced in the local languages and in very small quantities so that the information was not available to a wide audience. The formal and spatial aspects were normally expressed as resultant conclusions to these influences and little weight or value was given to the craft and creative expressions present in the building as an individual work of art.

We are working to provide a set of more contemporary illustrations of a large number of the vernacular buildings of the Balkan peninsula that have survived over the last two centuries (e.g. Fig.4). The notion is not to provide historical context of the buildings and settings but rather to include bibliographic references for access to the content that others have developed. This approach is taken for two reasons; first there are a number of recognized scholars who have already put forth historical frameworks and contextual theories; and second many of the structures are defined in nationalistic ways that can neither be totally confirmed nor refuted. In whatever historical framework the selected buildings sit, it is our belief that the buildings and settings themselves are of notable value as worthwhile examples of the sensibility of their authors and builders. There are many scholars who wish to assign building authorship to specific nationalities, ethnic groups, or local families; this is contrary to our goals and works against the development of the materials that we wish to disseminate. We prefer to allow the audience to view the materials in ways to promote comparisons of individual settings, buildings, structural or spatial orders, and detail expressions.

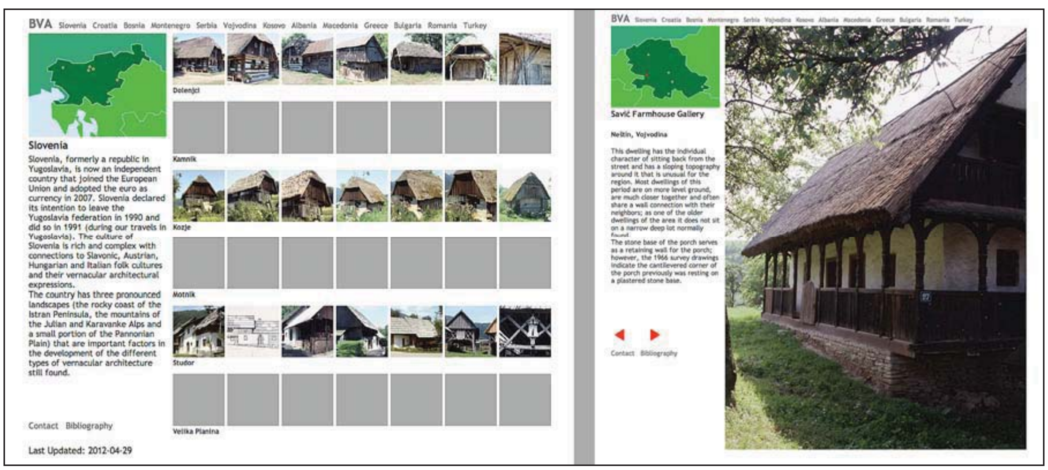


Figure 4: Two web pages in current state under construction (Source: Authors 2012)

8.0 Website Implementation

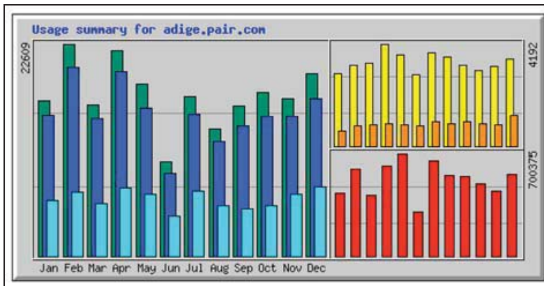
Although creating an Internet archive appears to be an inexpensive and efficient way to disseminate our research results, it is highly labor intensive in its design and implementation. The ultimate goal is the dissemination of our findings and materials to the widest audience possible, and we believe that the Internet allows this. The design of the website is developed to recognize and function for a wide variety of web browsers currently available and constructed to allow those with the most economical and rudimentary software and power to have access. Although Internet programs and applications offer many effects and capabilities, many people with the greatest interest and cultural investment in the study of these buildings may not have the applications that we take for granted. For this reason the size of graphic files and choices for usable applications have led us to building the website for the simplest applications possible. In line with this goal, the portal for the website has been developed to provide access to pages and images that contain information about the places and buildings that we have studied directly. This first phase presents the site as interactive in the simplest terms since it only allows visitors to make self-guided tours of the site.

A future iteration of the site will allow connections through the portal to a community, blog and fully developed and detailed bibliography. The website design will have an administrative side that will control metrics, to observe who is visiting the site and how they are observing it (currently this occurs through our hosting service). This function is helpful to understand who is visiting, what browsers are being used and where members of the audience are geographically located.

Since the study has been developed with the aid of many colleagues from numerous countries, one of the goals will be to establish an Internet community section that will allow linking together these scholars and eventually to other Internet sites and scholars. The Blog portion of the site (to be initiated in the second phase) will initially be established in a 'Push Content' format to disseminate content to the community and visitors; eventually this will be changed to a Social Media format to allow the interchange of information.
The initial browsers that are being used as test vehicles are Safari, Mozilla, Internet Explorer, and Netscape, and more sophisticated webpage techniques are being avoided. In order to make the information available to a larger audience this list will be expanded to include Lynx, and OLPC (one Laptop per Child) Internet applications. Additionally a database of photographs and drawings will be created through MySQL to allow a crossover of information so that one will be able to call up specific building types with similar types of construction and architectural elements.

The community that will be created in the future will aid to grow the knowledge base and aid in the work of maintaining the site. One long-range goal is to reach out to social networks and others interested in the expansion of this knowledge base and relevant issues.

The most effective presentation of the bibliographic information and academic papers produced by the authors of the site is still under study. At this point a simple list of source materials is included in the entry webpage. This overall bibliography, when completed, will be used to create a separate bibliography for each of the geographic areas covered by the study.



Summary by Month

Month	Daily Avg				Monthly Totals					
	Hits	Files	Pages	Visits	Sites	KBytes	Visits	Pages	Files	Hits
Dec 2012	627	541	240	114	1271	560351	3551	7444	16788	19453
Nov 2012	557	497	221	109	891	449871	3284	6636	14914	16715
Oct 2012	560	479	175	99	914	495032	3096	5455	14852	17390
Sep 2012	532	460	167	110	1006	549592	3316	5030	13812	15979
Aug 2012	438	393	174	118	925	554053	3675	5400	12200	13584
Jul 2012	546	488	225	123	1000	654959	3835	6976	15144	16935
Jun 2012	336	293	143	97	824	304832	2924	4303	8817	10104
May 2012	592	508	212	120	884	700375	3730	6595	15770	18356
Apr 2012	727	653	241	139	941	616322	4192	7256	19616	21838
Mar 2012	518	472	181	109	872	415556	3409	5619	14652	16069
Feb 2012	779	692	234	114	818	597483	3323	6813	20073	22609
Jan 2012	535	483	192	96	624	431899	2993	5976	14983	16592
Totals						**6330325**	**41328**	**73503**	**181621**	**205624**

Figure 5: Summary of website visits over year (Source: hosting service 'webalizer_reports', Pair networks)

9.0 Ongoing observations & Potentials
The development of the portal and website described above has already yielded a series of questions and issues to be addressed. First, the portal itself is very simple, tame, and restrained (given the materials) relative to more advertisement-oriented presentations that are available on the Internet. This brings into question at what level one wants to engage visitors and whether the goal is to *grab* an audience, or is the content presented more as an academic or scholarly archive. The level of involvement on the Internet by preservation and conservation groups in the Balkans is ever increasing and provides additional information[3]. This also demands that anything currently on our website, or being uploaded, be reviewed and information cross-checked.

To insure that others can track information on our website we always date the entry of information and images. We also have found that a number of historic buildings have been modified for new uses and in a few cases destroyed by fires in very recent years. It is rewarding that our website has become a resource for others, even in its incompleteness. From the 'webalizer_reports' and the use of IP address location applications we find that approximately 900 separate sites visit our website each month (e.g. Fig.5) and by checking the IP addresses have found that our visitors are from all around the globe. The ‘webalizer_reports’ demonstrate that the site is not only used to observe images but also to check our bibliography. As we continue the work on building the website we hope to find a home for our original archives that are too extensive to completely upload onto the Internet.

Our change to this form of dissemination of research, we believe, is valid. The potentials and opportunities of the Internet method allow great exposure, links to others, entry of fresh content, allows immediate expansion, and is economical for the audience. We also have to admit that there are certain limitations and concerns that remain these include a lack of permanence, a realization that software applications can transform to antiquate web-design formats, is labor-intensiveness to generate entries, and demands the management of communications.

ENDNOTES

[1] Pasic, Amir , Islamic Architecture in Bosnia and Hercegovina, IRCICA, Istanbul 1994, p58-59
[2] Davor Salopek is a noted Croatian author of several books on the early wooden buildings in the region near Zagreb
[3] There are a number of preservation institutes that have documents providing information about architectural artifacts that were designated as culturally important. One such website is ‘Bosna i Hercegovina Komisija/Povjerenstvo za Očuvanje Nacionalnih Spomenika <http://www.kons.gov.ba>. There are also sites that tie together historic pathways across Eastern Europe; one such website is ‘Cultural Corridors of South East Europe’ <http://seecorridors.eu>.

Making Evidence Visible: Using Mock-ups in Healthcare Design

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ABSTRACT: While the healthcare design community has increasingly focused on using research evidence in design decision-making and on using collaborative practices, there has been very little research into how interdisciplinary design teams operate in the real world and especially how they communicate and attempt to integrate evidence from different sources into architectural practice. This paper reports on one focus within a long term ethnographic study of the design of a community hospital. It explores how physical mock-ups allowed multidisciplinary teams to collectively experiment and to gain shared understanding of affordances and constraints within the design of the patient room, and particularly how the teams explored the impact of design on visibility within the patient room within the context of new models of distributed nursing.

In our systematic observations, mock-ups emerged as key media to represent actual spaces to facilitate and support interdisciplinary decision-making. The 'interactional expertise' of project architects combined with interactive properties of mock-up rooms, which acted as 'boundary objects' among participants with different disciplinary backgrounds, helped this particular community to conduct a local research activity in order to generate first-hand evidence with regards to the design of patient rooms.

KEYWORDS: Healthcare design, ethnography, mock-ups.

INTRODUCTION

Real-world architectural practice is complex, with multiple stakeholders, numerous constraints and ongoing invention. Healthcare design is particularly multifaceted. In addition to the routine complexities such as budget and time constraints or specific programmatic requirements, there have been recent calls to employ integrated methods of project delivery in healthcare design and to base design on research evidence (Zimring and Bosch 2008). However, there has been very little academic investigation into how these interdisciplinary teams operate in the real world and especially how they communicate and attempt to integrate evidence coming from different sources into the final architectural design. This paper relies on ethnographic systematic observations of a healthcare design project *in situ,* with the aim of developing an enhanced understanding of actual collaborative healthcare design practice.

The specific focus of this paper is on the use of physical mock-ups, which were intended to facilitate crucial discussions and negotiations among participants including architects, planners, engineers, managers, physicians and nurses. Mock-ups have long been used within the healthcare design community and have been shown to be effective in testing key spaces (King, Marans, and Solomon 1982; Pietroforte, Tombesi, and Lebiedz 2012). One important feature of mock-ups is that they embody and make visible affordances and constraints that are only implicit in drawings. In this paper we are particularly interested in the potential of mock-ups in making design ideas from the research literature and local design experiments visible. These design ideas are intended to engage participants with a variety of disciplinary backgrounds.

Rather than viewing mock-ups as yet another form of representation utilized in design processes, we aim at accounting for the unique contributions of mock-ups in local design experiments and in generating first-hand evidence to be translated into design work. In a broader sense, the paper aims at contributing to the developing literature between design and research.

1.0 CONCEPTUALIZATION

It is necessary to clarify the use some of key terms. Many of these are not well defined in the literature or have multiple interpretations.

‘Research’ in this study means not only academic research presented in reports or refereed journals, but all the activities encompassing the systematic search for knowledge to be utilized in practice. The term ‘evidence’ is used in this study refers to the types of information in various representational forms (i.e., documented or anecdotal) providing a basis for belief about a phenomenon, which, in turn, are used to support or challenge design decisions. In that sense, evidence encompasses information emerging from scientific research, expert opinion, or even the anecdotal stories of individuals. This can include, for example, users who actively engage with the phenomena on daily basis. Furthermore, evidence can be embodied in publications, physical mock-up exercises, current or precedent practices, anecdotes, or regulatory documents. ‘Information’, on the other hand, refers to facts provided or learned about something or someone, whether or not it is used to support or challenge a theory or a design decision. In that sense, information is an encompassing term, and includes evidence as a subset. Within the user group meetings observed in this study, for example, the designers had extracted information with regards to spaces, devices, and processes within environments of care, a sub-set of which were then utilized and presented as evidence in subsequent interactions.

2.0 METHODS

This research adopts long-term ethnographic inquiry to provide a description of the practices of an interdisciplinary healthcare design team. These practices occur in situated contexts that include systems of people, tools, and representations. Ethnography is defined as “sustained, explicit, methodical observation and paraphrasing of social situations in relation to their naturally occurring contexts” (Weick 1985, 568). Rather than starting with a theory or a preconception, this research aims at observing emergent phenomena related to our broad research questions concerning the nature and use of evidence in healthcare design. The goal is not to test a hypothesis, but to better understand webs of significance in studied practice. Rather than generalizing from our limited analysis, our concern is to describe the properties of the emergent phenomena observed, and to determine significant findings that have the potential to transfer across situations.

With regard to the unit of analysis, this study focuses on a larger system, involving people, tools, and representations, to pursue the research questions. The research adopts ethnographic field strategies, observations, open- and semi-structured interviews (Spradley 1979) as methods to capture interdisciplinary problem solving *in situ*. We have conducted 145 hours of observation, audio-recorded 31 interviews with 16 participants, and video-recorded 15 meetings with an average duration of two hours. We also have accessed project documents including drawings, meeting notes, memos and online exchanges between participants.

In the analysis phase, the research adhered to “grounded theory” (Strauss and Corbin 1990) procedures involving inductively developing a theory that was grounded directly in the empirical data collected. The typical steps of the grounded theory method, namely open, axial and selective coding, was employed in analysis of our qualitative data set. To achieve higher levels of reliability and validity, the research followed two strategies including triangulation and inter-rater reliability exercises.

2.1. Context

The hospital project observed in this research is part of a larger expansion project initiated by a Private Health System (PHS) in the U.S.[1] In 2010, the board of directors of the PHS decided to allocate approximately 140 million dollars to replace one of the hospitals within the system. The replacement hospital (PHSP) will include a 112-bed, state-of-the-art hospital with enhanced services and programs to be developed around specialty lines. In total, there will be eight floors which will make the hospital the tallest building in the county. All patient rooms will be same-handed, meaning each have identical layouts, and will provide a space to accommodate visitors staying overnight. As stated in the initial vision for the new hospital, there are two other significant features to be adopted; distributed nursing stations and extensive IT support to increase bedside time for nurses.

Firm A, a local architectural design firm, received the design commission for the hospital in December 2010, and engaged in steering committee meetings which were already being held for over a year. Although there was a certain circulation in human resources within Firm A, three members of the design team, D1, lead designer, D2, intern architect, and P1, programming and space planning consultant remained as the key members of the design team. On the other hand, O4, the president of the hospital, and O3, the vice president and chief nursing officer, were the client representatives who sustained a close relationship with the architects throughout the project.

Figure 1: Key actors involved in developing patient rooms.

3.0 EMERGENT ISSUES: DISTRIBUTED NURSING AND VISUAL ACCESS

The critical need for providing visual access emerged as one of the major issues on many occasions throughout the project. The design group revisited layouts in order to make sure that the design provided good visibility to people, spaces, equipment. Enhanced visual access was seen as important at multiple scales, such as across the nursing floor and within the patient room. In many exchanges involving designers, consultants, client representatives and staff members, the value of providing a better line of sight was repeatedly emphasized. The emerging narratives to emphasize the need for better visibility, which were provided by all engaging parties, clearly suggested the value of the concept which was deeply embedded and prioritized in care culture:

> ***O3*** *Uhmm, you can have as much technology that you can around the bedside, but observation, being able to see the patient is the best skill that a nurse can have, looking at their color, looking at their respirations, looking at how they are feeling to their overall environment. Many times we know that a patient is in pain by the expressions on their face, the movement, and their sleep, before they actually complain their pain…*

Starting from the very early meetings, the project group had embraced several concepts to enhance the observation of the patient. Introduced as one of the principal features to bring nurses close to patients, the idea of distributed nursing stations, for example, was adopted by the committee during visioning, and maintained throughout the project. We have not recorded any resistance against the idea of distributed nursing.

A distributed (or decentralized) model of nursing care has been one of the hottest topics within healthcare design community. Different from the traditional unit configurations with central nurses' stations, this relatively new concept proposes distributing resources across patient care units. This concept seeks to improve monitoring of patients by clinical staff and reduce walking distance. The impact of distributed nursing has been documented in the research literature (Hendrich et al 2004, 41). Alongside novel care protocols to be adopted, the model introduced a set of design interventions to achieve an effective, efficient, and safe care process. One design implication is to incorporate individual work stations outside each patient room which "increases the time available for meeting patients' needs and decreases the time and distance nurses must travel to help patients" (Hendrich et al 2004, 41).

In addition, the question of universal "same-handed" rooms and inboard-versus-outboard bathrooms are currently being debated in healthcare practice. Universal same-handed rooms are identical with the patient always in the same orientation to the door. (In this case, to the right as you enter the room.) This increases cost because a common wall cannot be used for utilities for the headwalls of two rooms but is argued to reduce error during emergencies because each room is identical, similar to airplane cockpits (Pati et al. 2010). Outboard toilets are on the outside window wall rather than the corridor wall of a room. This allows for a more transparent corridor wall to be used for visibility and other purposes but the toilet on the outside wall can reduce the size of windows.

4.0 CONDUCTING VISIBLE RESEARCH

The client representatives were exposed to details of the idea earlier in the process through formal and informal presentations, and site visits which enabled them to see distributed nursing model in action. Our interviews with both O3 and O4 revealed that the client representatives were well aware of positives and negatives with this new model, which was a different process from what was utilized in the old hospital. They were also aware of the fact that the staff, at all levels, needed to be continuously informed and educated about the new model, which required a “shift in SHSP’s care culture.” Throughout our field observations, we observed both O3 and P1 patiently and simply explain the set of new processes and design implications to staff members in each engagement.

Having all these initial principles and ideas at hand alongside budget and schedule constraints, the task for the project architects was to come up with a satisficing design for patient rooms. Particularly the design for the corridor wall of the room, which was expected to accommodate a nurse server, a hand-washing sink, a convenient entrance, and a nurse work station, consumed vast amounts of hours before arriving at a proper design solution. When it was the time to delve into details of the patient room, the project architects produced countless sketches to synthesize initial ideas (Figure 2).

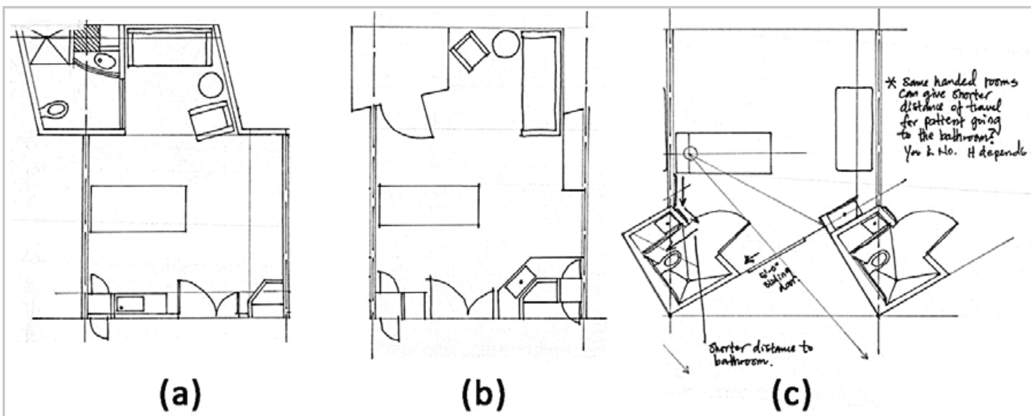

Figure 2: Developing the patient room.

Following comments from client representatives during late schematic design phase, the architects had narrowed down their attention to configurations with outboard patient toilets, which reduced the number of elements to be integrated into corridor walls. Another clear direction which came out of meetings with client representatives was the utilization of same-handed rooms which eliminated alternatives with a shared headwall.

One of the most striking attempts to shape the patient room corridor wall had emerged during these exchanges with client representatives. We were able to identify several sketches dated in the schematic design phase which introduced an angled corridor wall (e.g. Figure 2c). In these series of sketches, the designers had indicated lines of sight which intersected at a circle representing a patient’s head. These lines, through which the designers had studied visual access to patients, were generally extended to corridor space, and to nurse stations.

The designers had entertained the angled wall idea through many sketches, each providing another reconfiguration of elements, including doors, sinks, nurse servers, and nurse work stations. These studies were not immediately translated into CAD drawings in the schematic design phase, but archived in the form of sketches, though it was not clear who first sketched the angled corridor wall.

The corridor wall angle in these sketches displayed a great variety, ranging from very tight ones (~5 degrees) to open ones (~30 degrees). The architects did not arrive at a final decision with regards to the particular configuration of corridor walls, as the team approached the deadline for schematic design. The plan was to continue developing the room design in both layouts and in mock-ups until they were refined as appropriate and acceptable by the steering committee. The angled wall option was suspended for a while until the team started developing plans for mock-ups during design development phase. The versions of patient rooms included in the schematic design package did not communicate any of the experiments with the corridor wall.

As the team developed the strategy for mock-up rooms later in the design development phase, the architects focused their attention back to details of the patient room of the future hospital. P1 was the key person to develop mock-up exercises, which were based on a build-review-rebuild model in order to accommodate input from all participants. D2, who was tasked with developing the drawing for mock-up exercises, returned a set of drawings which included a series of features (e.g. outboard toilet, angled wall, charting alcove) integrated into room design (Figure 3).

The drawing below was adopted by the construction consultants to develop mock-ups, which initially consisted of constructing movable walls to define the room perimeter. The expectation was to engage in a conversation with a larger group involving a collective exercise utilizing movable walls, and, eventually, finalize the evolving geometry of the room.

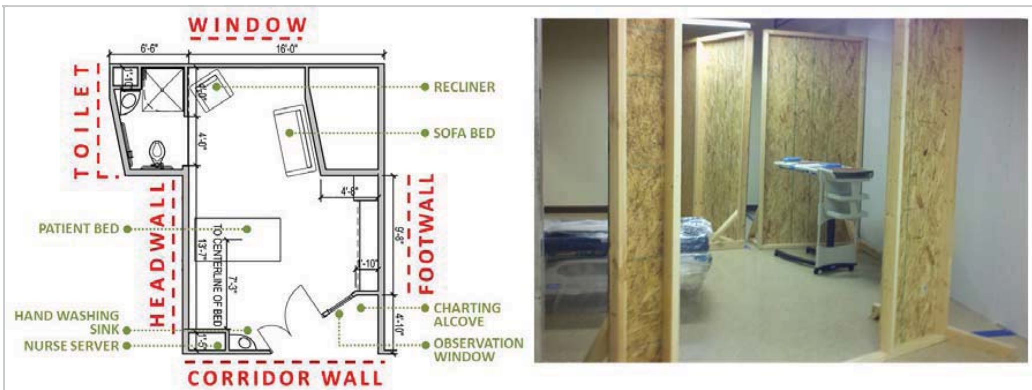

Figure 3: The layout diagram utilized in mock-up studies (left) and movable walls utilized in the first phase (right).

Even though the hospital staff was presented with computer renderings and the layouts of the rooms prior to their visits to mock-ups, they were amazed by the size of the room, which was significantly larger than the patient rooms of the old hospital. For the first mock-up exercise, the staff members' comments were limited, since there was very little to talk about other than the overall size, dimensions, and clearances around certain elements within the room perimeter defined by bare walls. In a later visit, however, a group expressed their concerns with regards to limited visibility to patient heads from workstations just outside of rooms. This comment, which was raised only once in a series of visits by staff members had significant consequences for the room dimensions and the angle of the corridor wall:

D2 *The visibility issue found the charting niche to the patient head, uhh, we have a very unique design at that door to the patient room and the angle of that wall was prohibiting a nurse from standing at the charting niche and seeing directly to the patient head. You can see the majority of the bed, but you couldn't see their face very well unless you lean down very awkwardly, so we increase the angle a little bit so they…*

I *On the mock-up?*

D2 *Yes, on mock-up. They are working on it now actually.*

I *All right. So how did you decide on the angle in the first place?*

D2 *We, uhhh. Just in the computer actually, and then sketch up, and in modeling programs, kind of taking some views from there. Looking at the floor plans and getting view angles, and looking at perspective views and so that's how we put the original. We knew there was gonna be some tweaking. And this is actually the third tweak of that particular angle that we are doing just, you know just to get it exactly perfect. So that no one is leaning or turning in an awkward way, we want to be as natural as possible.*

As D2 emphasized the architects "knew there was going to be some tweaking" following mock-up exercises, and they were expecting staff input "to get it perfect." By having actual staff members seated at charting alcoves and letting them check visual access to hypothetical patients lying on beds in mock-up rooms, the architects were able to test patient visibility which was initially studied by drawing sight lines on layout drawings (see for example Figure 2c), and by three dimensional renderings which provided views to patient beds.

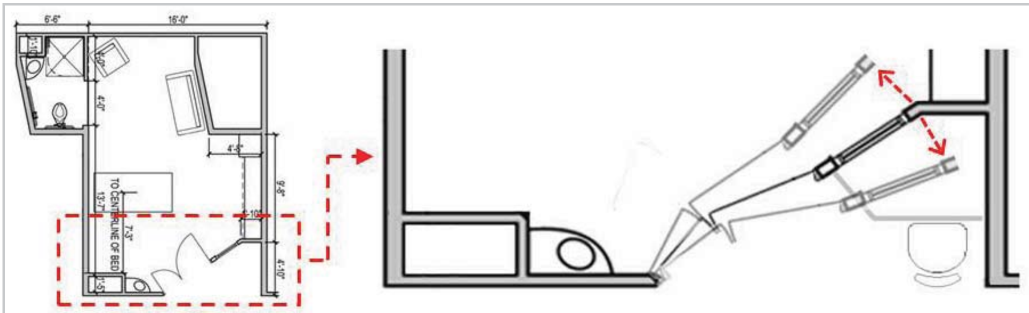

Figure 4: Finding the right angle for the corridor wall.

As opposed to other media, the mock-ups exercises were collective experiments, which led to generation of first-hand evidence involving actual staff members enacting their everyday practices in physical space. The comments with regards to the angle of the corridor wall were evaluated and re-evaluated by the architects (“*this is actually the third tweak of that particular angle”*) by using movable walls before the “right” angle was translated into drawings. Without updating computer drawings after each “tweak” on mock-ups, in this particular case the architects’ strategy was to wait until the group arrived at a satisficing solution which provided better visual access to patients. Until the angle the corridor was re-reviewed and approved by staff members who communicated the issue earlier, the mock-up remained as the major representation to be manipulated.

I *So, how about discussing issues with users on the paper and on the mockups? I mean is there a difference or not?*

D2 *Yes there is a huge difference. I don't... I personally think users have a hard time with visualizing what the space is going to be like in plan. You show them the plan, and they have very hard time understand it unless they have experiences with building design before. And not many nurses have ever done design exercises, spatial recognition, I mean nothing. So you are trying to explain something to them, the only thing they have ever seen is, you know, the architectural digest, a plan of a house. So you are trying to explain very complex space such as a hospital to them, and a lot of times you can show them perspectives, and that helps some. But the mock-up has been irreplaceable in terms of that…*

D1 and P1, the senior architects of the team, were the individuals to negotiate the corridor wall angle with the users, whereas D2 was the one to keep track of the progress on mock-ups and translate the “perfect” angle into layout drawings. What D2 stressed in above quotation with regards to the differences in utilizing drawings versus mock-ups during design review meetings exemplifies design team’s view which was repeated by D1 and P1 in multiple interviews: Mock-up space was an “irreplaceable” medium which enhanced the crucial negotiations with users, which eventually, allowed architects to process and translate user input.

Briefly, the idea of introducing an angled corridor wall was developed and maintained in layout drawings before it was collectively reviewed within mock-up rooms. The anecdotal evidence emerging from conversations with users suggested a series of tweaks on mock-ups in order to improve visual access to patients. Furthermore, the mock-up enabled research in the form of in-house experimentation which, in this particular case, had a significant effect on the design decisions concerning visibility. The output of this in-house research activity was then captured within mock-up representations before they were translated into architectural drawings. The case presented in this paper epitomizes how a larger principle (provide better visibility) was collectively elaborated and grounded in fine-grained details through a series of experiments utilizing mock-ups.

CONCLUSIONS

In addition to typical challenges in any given architectural design project, a constant struggle in healthcare design is to meaningfully utilize emerging research-based findings and to satisfy critical requirements posed by the culture of patient care which is in constant transformation. The innovation-driven healthcare market requires architects to quickly adopt and implement research-based or evidence-based concepts such as distributed nursing stations. The design team in this study utilized mock-up spaces which allowed them to make visible and implement an emerging research-based feature while fine-tuning details through a series of tests involving participants with different backgrounds. In the case presented, the mock-up acted as a "boundary object" (Star and Griesemer 1989) to facilitate an interdisciplinary exchange between architects and healthcare workers. The architects in the project, who possessed interactive expertise (Collins and Evans 2002) to access nurses' practices and languages, utilized mock-ups to conduct a series of local experiments which made design decision making, to some extent, accessible to users. While making ideas visible for non-designer participants, the mock-ups aided architects in blending research-based evidence with local needs of users.

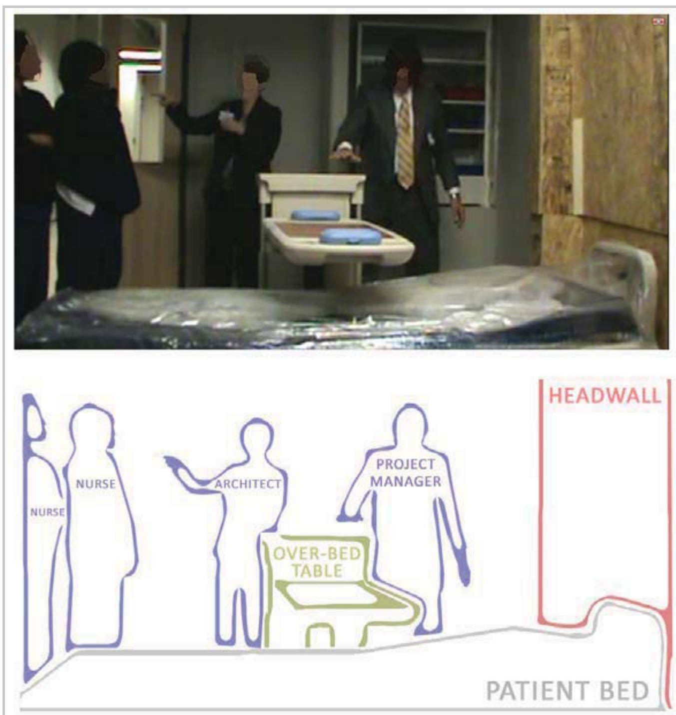

Figure 5: Negotiating in the mock-up.

With regard to visibility, the design intention, which was collectively formulated, was enacted and evaluated in mock-up space without any other form of mediation. Embodied experience of care activity animated, to some extent, people, equipment and processes in mock-ups which provided an ecology that was superior to other forms of representations –i.e. orthographic drawings or digital models– in deriving and generating evidence on use.

Emphasizing the role of architects in translation of evidence, the case presented in this paper provides a vivid example of how research, in forms of rigorous academic studies and in-house experimentation, shapes design of healthcare environments.

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ENDNOTES
[1] The names for the organization, the project, and people have been masked at the organization’s request.

Architectural Anamnesis

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ABSTRACT: This paper is concerned with how conceptual frameworks, disciplinary perspectives, and personal and cultural histories shape the available range of solutions to design problems. Two notions central to the argument relate directly to the conference theme: visibility and transparency. In both cases, the terms apply, not to physical or phenomenal conditions, but to the conceptual frameworks that guide design and research activity.

Grounding the visibility/transparency analogy are the related concepts of fitness landscapes and design space drawn from genetics and from evolved hardware. These terms designate the graph of all possible solutions and their degree of optimization with respect to certain criteria. Algorithms and organisms are seen to move across this landscape occupying more or less favorable positions.

In order to illustrate the notion of visibility, I use Thompson's experiments in evolving hardware using genetic algorithms. This allows a comparison of the solution space searched by the algorithm and that accessed by human circuit designers. I show that cultural frameworks, such as the concept of the 'digital', restrict the kinds of solutions that are available to human designers. Cultural frameworks outline the range of visibility into solution spaces.

Transparency is introduced in reference to the digital framework in circuit design as a specific case of a more general property of tools that have been long and successfully wielded. Disciplinary and cultural frameworks that have become transparent through extended use are most difficult to identify and transform, yet profoundly affect the kinds of solutions that can be 'seen'. The recovery and exposure of these invisible assumptions might be guided might be guided by the kinds of problems encountered. My intention, by making explicit the relation between frameworks and design solutions, is that designers will come to actively manage the frameworks they employ in solving design problems.

KEYWORDS: Design space, fitness landscapes, visibility, transparency, anamnesis

INTRODUCTION

Anamnesis, the recovery of memory, has a range of meanings specific to the disciplines that employ it. In medicine, it refers to the case history. In Philosophy, it references the Platonic idea that all knowledge resides in an immortal soul, and so cannot be sought, but must be remembered. Here, I use the term to mean bringing into awareness the underlying epistemological assumptions that guide ones work. I hope to show that this has importance for research and design by showing how underlying assumptions circumscribe the kinds of solutions that can be invented. Further, it is suggested, based on Agre's analysis of Artificial Intelligence, that the kinds difficulties encountered might provide a clue to the underlying tacit assumption that give rise to them.

1.0 FITNESS LANDSCAPES

Sewall Wright, a theoretical biologist, first employed the concept of a fitness landscape in 1932. Wright had been invited to give a relatively short and non-mathematical presentation of his 'shifting balance' theory, to the Sixth International Congress of Genetics. The theory was highly technical and involved a genotype space of 9000 dimensions. He invented the landscape metaphor as a diagrammatic representation of the field of all possible gene combinations, reducing them to two dimensions from thousands, and then using the vertical to represent adaptiveness (Wright 1932). Wright suggested that genetic combinations adjacent in genotype space would have a similar level of adaptiveness, and so, the graph might resemble a landscape with peaks of higher fitness, local optima, separated by relatively lower areas. Wright is then able to explain his theory of speciation in terms of the mechanisms whereby successive individuals move across the fitness landscape. Figure 1.

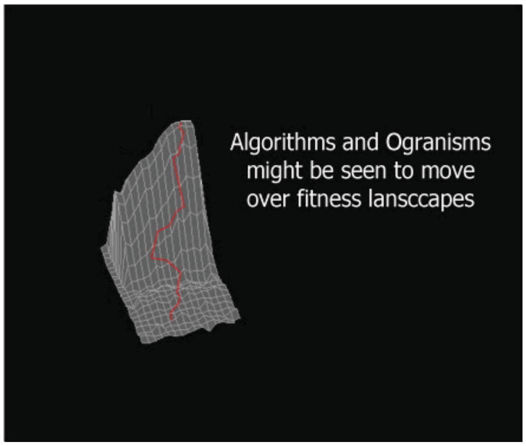

Figure 1. A generic Fitness Landscape

In the present context, I am less interested in the details of speciation than in the ability of the landscape metaphor to facilitate thought experiments, visualizations, and conversation about highly dimensional spaces. Indeed, others were as well. The metaphor was quickly taken up to describe the fitness of populations, adaptive landscapes, and the form organisms take, theoretical morphospaces (McGhee 2007). It has become a standard method of intuiting concepts in evolutionary biology (Kaplan 2008). Fitness of adaptive landscapes is described in terms of their ruggedness, granularity (Stadler 2002) and temporal transformations (Johnson 1999) as well as their topological characteristics. Landscape terms used to describe these topological features include peaks and valleys, holes, benches, plateaus, channels, and discontinuities. Beyond biology, the metaphor has found utility in visualizing how specific computational techniques sample an underlying solution space. In the technique known as simulated annealing, for example, a solution space is initially widely and randomly sampled, and thereafter, the volatility, metaphorically the 'temperature' of the sampling, is gradually reduced as better solutions are located and the sampling distribution is concentrated within these local and potentially more productive areas (Reidys 2002).

2.0 DESIGN SPACE

Design activity as implemented in a range of disciplines also operates within highly dimensional space. In addition, it seems to have some elements in common with biology. Highly optimized solutions, with respect to a single variable, are frequently brittle in the face of unforeseen or changing conditions and solutions that satisfy multiple constraints are often the most desirable and robust. In much design work, clusters of solutions of similar desirability can be imagined differing perhaps only in detail or material, suggesting a landscape of rolling hills rather than rugged peaks. Efforts to evolve hardware bridge the domains of design and biology (if only metaphorically), and provide valuable insights to certain aspects of design activity.

In a series of experiments, Adrian Thompson and colleagues demonstrate the application of evolutionary principles to the design of electronics hardware (Thompson 1999) using a Field Programmable Gate Array (FPGA). An FPGA is composed of generic logic gates that can be configured using software running on a host computer. FPGAs are often used build proprietary circuits that have too limited an application to justify producing custom chips. In other circumstances, the ability to configure and then reconfigure, within milliseconds, a fixed hardware resource to accomplish different computational tasks has value. In Thompson's case, a genetic algorithm controlled the repeated reconfiguration of the gates in a search for a circuit able to distinguish a 1kHz from a 10kHz square wave. In general this is not a difficult task for a human circuit designer, but becomes increasingly so as computational resources are constrained. Thompson allows the genetic algorithm to operate in an area of the FPGA comprising only 100 gates and further does not provide access to an external clock or resistor/capacitor oscillator to coordinate the timing and flow of signals.

Nevertheless, after 4100 generations the output changes from +5Vdc to 0V immediately and reliably as the input signal changes from 1kHz to 10kHz; a successful outcome of the experiment. While the algorithm runs for an additional 1,000 generations, no significant change is detected. Figure 2 shows the evolved circuit with all its connections. By inspection, many of the connections shown do not appear to participate in the circuit, those in the lower right, for example. Thompson and colleagues systematically test and eliminate useless gates and, in the end, find that the 32 shown in Figure 3 are required for the circuit to operate successfully.

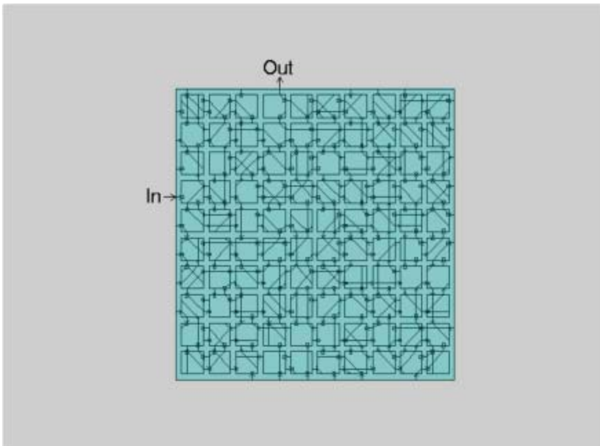

Figure 2. An Evolved Tone Discrimination Circuit (Thompson 1999)

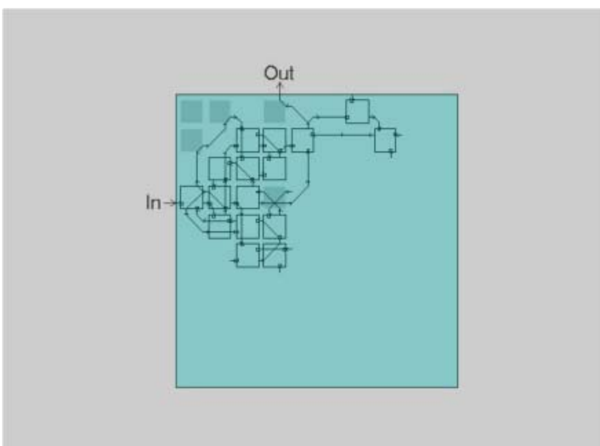

Figure 3. Evolved Circuit Pruned of Inactive Gates (Thompson 1999)

However, the circuit shown does not in any way resemble one crafted by a human designer. The principles on which it operates are not immediately legible. Of particular interest are the cells marked by a grey tone. Even though these cells are not connected to the circuit, it will not operate properly without them. While this result is surprising and intriguing it does not, however, suggest anything mysterious. The circuit operates wholly within the domain of semiconductor physics, but aside the principles of digital design. Thompson and colleagues argue that their evolutionary technique operates in domains of the design space of electronic devices that are not available to human circuit designers operating within the conventions of digital design.

Thompson notes that the genetic algorithms used in his experiments encode certain biases and so do not perform global searches across design space, what is privileged instead is the use of the algorithm to open up previously unrecognized domains of design space with practical value, or to illuminate techniques that are previously unknown and might be incorporated into the human circuit design lexicon. In this the approach is parallel to the objectives of Tom Ray's *Tierra* simulation software. In the 1990s, Ray solicited computer users to run the Tierra program on their desktop machines voluntarily donating unused CPU cycles to a distributed artificial life simulation. The project sought the development of new software ‘species’ that when recognized and ‘domesticated’ might produce new useful computational techniques (Ray 1997).

It is interesting to note that the fabrication of the FPGA, the standard methods of configuration, and the intended end use of the device are all predicated on the use of the digital framework. The operation of the genetic algorithm and its highly efficient solution to the tone discrimination problem illuminate the fact that the ‘digital’ is a cultural overlay atop a material substrate capable of complex and often subtle interactions. These interactions must be carefully controlled, avoided, or interpreted into the discrete binary logic that is the *lingua franca* of electronics. It is, however, exactly these logical assumptions that allow human designers to manage complex tasks. Clearly, by using binary logic, vast ranges of devices and techniques have been developed with extraordinary cultural consequences. So much so that it may seem that the ‘digital’ is inevitable. But, this is not the case.

3.0 VISIBILITY

Digital, analog, or evolutionary techniques each access different domains of design space. Each has a certain visibility into that design space (Figure 4) based on the assumptions it carries forward. At the same time, the solution space visible to one technique might be in a large measure invisible to another. In the example given, each technique illuminates a portion of design space that is unique or that has very limited overlap with other techniques. I believe that this is true for all design work. In many cases of design activity, assumptions may not result in completely autonomous domains, but rather in domains that differ in salient ways nevertheless, making some frameworks of assumptions more effective for certain tasks than others.

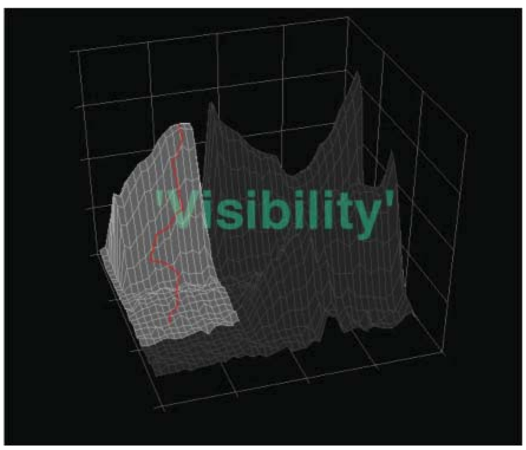

Figure 4. Design Space and Visibility

Without using the term explicitly, Randall Beer takes up the issue of visibility with particular clarity. Beer is a cognitive science researcher employing dynamical systems theory. He writes having noted that researchers from competing disciplinary frameworks have great difficulty in recognizing the legitimacy and value of research in traditions that are not their own. He notes that disciplinary frameworks specify the research questions that will be asked, the kinds of methods that can be used to answer them, the data that will be collected and the techniques that will be undertaken to analyze them. It guides the interpretation of the results, and so ultimately, circumscribes the answers that will be found (Beer 2000). It is exactly the relationship between frameworks and answers that I point to when I use the term visibility in the context of a solution or design space.

The shifting of a conceptual framework may a change a difficult task into simpler one, by suggesting an alternative approach to the problem. A brief example may serve to illustrate this. Since I first saw their wooden frames exhibited in the Sheldon Jackson Museum in Sitka, I have long admired the ingenuity, design and craftsmanship of the *baidarka*, the native kayak of the Aleutian Islands. Eventually I had the opportunity to purchase a modern version rendered in wood and canvas. But the round-bottomed hull, 50cm wide and 5.5M long, was extraordinarily unstable. None of my years of experience handling canoes, even narrow ones, proved to be any help. It was difficult to sit in it and keep it upright especially when encountering broadside waves. Yet, the people who first made these kayaks ranged the open ocean from Japan to Mexico and probably on to New Zealand. How could that be? Eventually I realized that I should not sit in this watercraft, but wear it instead. That is to say, to make it a part of me. Once I understood that, my concern with stability was greatly reduced and I could begin to attend to other things. Rather quickly the kayak became a prosthetic.

This change in my relation to the watercraft allowed a fundamental shift in the dynamics of the system. When I sit in the boat and it is rocked by waves, my center of gravity is moved out of plumb. To compensate, I lean in the opposite direction. Once the initial movement is stopped, reversed and my center of gravity is again above the kayak, I must counter the momentum I now have with precision in order to remain balanced and avoid overturning on the opposite side. If this countering movement coincides with the arrival of the next wave, I add my momentum to its force. I now have the same problem as before, but must exaggerate my previous effort to remain balanced setting up a dangerous oscillation. This way of controlling the boat is reactive. It requires fast reflexes, concentration, and is tiring. The movement is of the head and shoulders. When I integrate with the kayak, I maintain balance by keeping my center of gravity, my head, and shoulders steady and allowing the boat to move beneath me. I accept the lateral force of the waves by movements at the hips and bring the boat back under me when the wave has passed. This approach is much more relaxed and does not require constant adjustments in my relationship to a tipping boat. Quickly it becomes 'second-nature' and it happens automatically.

4.0 TRANSPARENCY

I recall a particular moment when learning to draw. There was a point when I was no longer concerned with manipulating the pencil, how it was held, its relation to the paper, its pressure, sharpness or rotation, but only with moving the space, light, and volume within the picture plane. In effect, the drawing instrument and the mechanics of drawing had become completely transparent and the act of drawing was immediate and direct. 'Finally', I thought, 'I'm *really* able to draw'. Michael Polanyi (1958) noted essentially the same thing when he described a blind man and his cane, noting that the man does not feel the cane in the hand, but instead feels the tip of it touching the sidewalk. His focal awareness has shifted from the hand through the instrument to its interface with the world. The cane has been incorporated.

In all these cases the artifact became perceptually transparent because it is reliably coupled to the body. No longer separate, but through habit and effectiveness, it comes to function as part of the body itself. It becomes prosthetic. In fact, there is growing evidence that this is not only experiential, but neurological (Cacola 2012)

5.0 ANAMNESIS

In electronic design something similar has happened with the convention of the digital. For many, it is an assumption that is no longer questioned. Its familiarity and efficacy have rendered it transparent. Disciplinary frameworks take on the same transparency as tools that have been long and successfully wielded. Indeed, they too are tools. They facilitate effective work just as a physical implement. Phil Agre has noted something similar in the field of artificial intelligence. Writing in the mid-1990s, he addressed the difficulties that field had in making progress by looking at the fundamental philosophical assumptions that guided the work. He traces the split between software and hardware to the mind-body dualism of Descartes. In doing so he notes:

> As a result, formalization becomes a highly organized form of social forgetting -- and not only of the semantics of words but of their historicity as well. This is why the historical provenance and intellectual development of AI's underlying ideas claim so little interest among the field's practitioners. (Agre 1995, p 14)

While Agre uses the term forgetting, he intends much the same thing as I do by transparency; the movement from explicit to tacit knowledge. When Agre spoke about institutionalized forgetting it was in reference to conceptual frameworks, tools, and patterns and was from within the domain where the tool or the framework enables. But, the constraints imposed by these frameworks eventually set limits on what can be achieved. At these limits, the once transparent tool regains its visibility. Agre observes, "…technical impasses are a form of social remembering, moments when a particular discursive form deconstructs itself and makes its internal tensions intelligible to anyone who is critically equipped to hear them (Agre 1995, p15)."

Thompson (1999) and Beer (2000) illuminated the relationship between conceptual frameworks and the kinds of solutions that may be found; visibility into solution or design space. Agre (1995) points to a second related, but distinct, kind of visibility, the recovery of tacit assumptions driven by impasses in the work. This kind of visibility is a corollary of the first. Just as disciplinary frameworks and personal and cultural histories enable the invention of certain kinds of solutions, they also constrain the kinds of things that might be achieved. The problems encountered delineate the domain of applicability of the framework. These problems then are not just impasses that need to be overcome, but are information about the domain of design space that is visible from a particular perspective, specifically about how the domain is bounded.

Agre suggested, in the case of AI, that it was an assumption about the primacy of information over material substrate founded in the dualist traditions of Western thought that constrained what the discipline could achieve. Understanding this, brought alternative approaches to light that opened new possibilities for the field. Enactive approaches to cognition, for example, put an emphasis on embodiment and so hardware and tightly coupled interaction with the environment became more prominent.

This same assumption about the primacy of information remains prominent within our culture in many disciplines. When genetics is looked to for answers concerning disease, personality and behavior, achievement and human nature, it stems from this common belief. In Architecture, some practices and many schools foreground form over material. Computational techniques as a principal determinant of form are consistent with this approach. Projects within this tradition tend to require innovation in building technique to achieve the forms required. Alternatively, often additionally, the formal objectives of the project are compromised for buildability. The use of three-dimensional printers for models is common and their development as building-scale form printers is under active development. In these cases, material is neutralized and plays a passive role to information's active one.

My purpose here is not to criticize an information-based approach, but rather to suggest that encountering difficulties in construction, compromises in form, or failures of building systems points out that in certain cases, the limits to the viability of this approach have been encountered. Following the example of the changes undertaken by AI, one might suggest that greater attention to material substrate and environmental conditions may yield access to other domains of design space. These alternatives, however, are subject to their own assumptions and limitations.

6.0 VARIABLES AND CONSTRAINTS

Susan Oyama, a developmental systems theorist, criticizes of the information-processing model of biological development that recognizes an opposition between that which determines variety, the variables, and what determines continuity, the constraints. This is an active vs. passive characterization. She notes, instead, that one way of understanding a constraint is that it is a variable that isn't varying. She also notes that constraints are as interdependent as variables are and that what constitutes an effective constraint depends as much on the properties of the rest of the system as does an effective stimulus. Conceptual and disciplinary frameworks, cultural histories and personal experience all function to shape ones ability to engage in successful design activity. Which of these functions as a variable and which as a constraint? With Oyama, we should consider variable and constraint to be a current and perhaps temporary function of the frameworks we employ. Ones strength as a designer may come from recognizing self-imposed constraints and, instead, employing them as variables when it serves us.

CONCLUSION

I have attempted to show that the underlying conceptual frameworks function both as illuminators of design space as well as restrictors. They can be seen as either depending upon ones intent, but also upon the degree to which they facilitate the design activity at hand. One could see that the domain of effectiveness for each framework differs. Problems that arise in the course of design activity outline the domain of effectiveness of the underlying assumptions that guide design activity. The nature of the impasses may give clues about the nature of the assumptions that give rise to them. Misfits, anomalies, and surprises can be understood as markers outlining the applicability of the framework. Instead of pointing exclusively to the new, they are also capable of delimiting the existing framework. In addition, as Agre noted, problems, especially those that do not yield to repeated attempts at solution, may point to inherent limitations in the underlying conceptual frameworks. As problems outline, define, or circumscribe the domain of applicability of a framework, they give it a 'shape'. The more interesting questions for me concern the conditions under which a framework yields suitable results and those under which it is inapplicable. Given a relationship between frameworks and a domain of effective design activity, how can one anticipate the selection of or a switching to an appropriate framework based on the nature of the design challenge one is facing? Can one develop an ability to understand either by taxonomy or by intuition, the shape and structure of frameworks, or to develop any general notions about their use?

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SMATS: Sketch-Based Modeling and Analysis of Truss Systems

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ABSTRACT: The present work intends to introduce a domain-specific sketch method for modeling and analysis of forms and structures of trusses concurrently. The main contribution of the research presented here is the development of a computer-assisted structural modeling tool where the structure can be sketched, subjected to loads, a structural analysis is performed, and the results can be observed. The Sketch-based Modeling and Analysis of Truss Systems (SMATS) allows the user to test what if scenarios in real-time by using simple sketches. To interpret the sketch and extract data for a structural analysis, SMATS uses a gesture recognition algorithm. The results are then brought back to the same environment for visualization in terms of color/thickness-code and animation. Moreover, the interactive environment of the user interface (UI) allows the user to manipulate the design and observe the outcome of the changes on the truss structural behavior. SMATS is developed for the particular use of architects, aiming to provide them a natural environment to present and appraise structural configurations of different truss systems by means of sketching. Iterative usage of the method will give architects, engineering perspective about the class of structures used here. The approach is intended to optimize the conceptual design of trusses by bridging architectural vision in creating forms, and engineering analysis. It also helps architects gain better understanding of the effect of variation in form on structural behavior of trusses. In addition to its application as a design tool, SMATS can be used as an effective educational tool. Architecture students have used it to learn about the fundamentals of structural engineering in building structures classes.

KEYWORDS: Sketch-based Modeling, Truss, Computer Aided Design (CAD), Design Integration, User Interface

INTRODUCTION

Sketching is an essential tool in the professional life of architect from the moment they start their education. Despite the advances in computer aided design (CAD), architects initiate a conceptual design through physical sketches on paper or a sketchbook. It then goes under careful CAD modeling process for detailed modeling and engineering analysis. Design in terms of engineering is also an iterative process. To create an optimal design, the engineer must develop a variety of solutions, evaluate each one, and then select the alternative that best satisfies the design requirements. During the conceptual design, the initial idea is usually altered many times. This may affect the architect's intention in terms of the original design. However, if the architects are provided with an understanding of the structural behavior of their conceptual design, they could alter the design accordingly by instantly comparing alternatives during the preliminary design phase.

Although computers have made great contributions to facilitate architectural practice, the essence of design cannot be achieved through generating forms from sets of computer instructions, and parametric assembly of segments available in most CAD software. "Architecture cannot divorce itself from drawing, no matter how impressive the technology gets" (Graves 2012). Architects' sketches express the interaction of their minds, eyes, and hands; apart from that, buildings will no longer be the outcome of visual and spatial thoughts of architects, but they would be 'computed' via interconnected databases (Graves 2012). There have been many attempts in transforming the architects' design environment into digital sketch-pad with considerable possibilities to imply creativity and produce forms. While current state-of-the-art sketch-based UIs can handle the geometry very well, few however address the needs of an engineering analysis and the possibility of manipulation, simultaneously within the same environment. A key factor to create an ideal design is to allow natural tendencies of designer to be integrated into a digital environment which can perform engineering analysis, and presents technical feedback to the user.

Within a narrower two dimensional (2D) scope, SMATS is intended to integrate structural analysis of truss systems with the architect's freehand sketching in order to facilitate the design process and improve the architect/engineer interactions. A truss is a popular structural form commonly used for covering large spaces. It is usually assumed to be made of pin-connected linear elements. Due to this assumption and loads being applied at the connections only, the members of this structural system are only subjected to tension or compression. Through the visualization of the structural analysis outcomes, SMATS can allow the user to check if the forces and deformations are within the acceptable limits, based on the engineering requirements. SMATS has three modes/states of operation: building, simulation, and animation. While in the building mode, users can sketch in an intuitive medium and explore architectural forms by freehand sketching. They can manipulate each attempt, change, adjust, or add structural elements to their desired form. In the simulation mode, SMATS performs the structural analysis of the design. The analysis results can be easily observed both visually and numerically. Other that visual representation of results, in the animation mode, users can actively view the behavior of the truss under the applied load.
Within any of the aforementioned modes, users can instantly switch to the next or previous mode and apply the desired modifications. The easy navigation through the sketching modes and subsequent analysis of the truss system provides the users an integrated medium to optimize their initial design.

1.0. SMATS SKETCH-BASED SYSTEM OVERVIEW

1.1. User interface

The UI for SMATS provides architects an interactive environment as simple as their sketchbook. Architects can create the outline of their design using a stylus in the 'building state'. While a background scaled grid gives an overall estimate of the dimensions, the user can also examine the exact length of the lines which are being drawn (Fig. 1). Once the initial outline is complete, it can be built into a 'beautified' version, in which, modification of the form is enabled. In a beautified version of a truss, the ambiguous freehand sketches are transformed into a more precise and structured representation. The user can also assign load and support conditions to the truss.

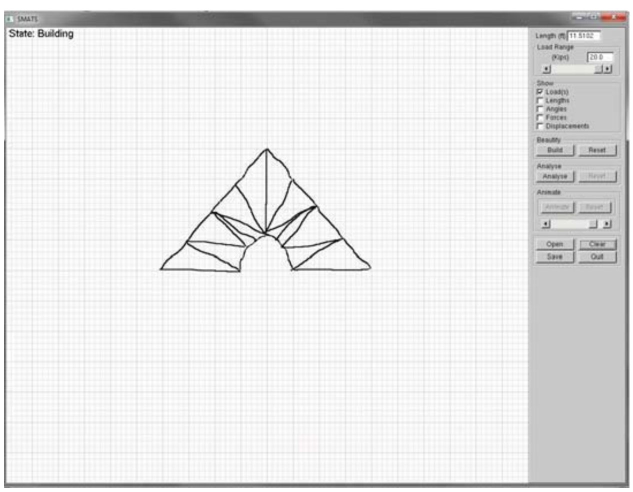


Figure 1: SMATS user interface, 'building' state. Any desired form can be drawn on the sketch pad using a stylus.

Each element of the sketched model has to be recognized by the computer before further manipulations and processing can be conducted. For this purpose the $1 Unistroke Recognizer (Wobbrock et al. 2007) is used as the gesture recognizer in order to manipulate the sketch and also determine required data for further analysis. Supports can be assigned to the nodes by drawing symbolic gestures. Sketching a triangle would be conceived as a simple support (movements not allowed, rotation allowed), and a circle would be recognized as a roller support (movement in one direction and rotation allowed). The user can also assign loads to each node by sketching an arrow in the desired direction (Fig. 2). The magnitude of the load can then be increased or decreased through a sliding bar to observe the effect of load on the structure. All the magnitudes of the loads, member lengths and angles of the loads and supports can be chosen to be viewed or not. Finally, a delete gesture enables the user to remove unwanted elements.

Once the sketched truss is fully recognized by the program, and the initial sketch is replaced by an enhanced version of the model with the standard symbols (beautified), users will have the option to either visualize the behavior of the sketched design under the assigned loads, or manipulate the design to a desired geometry, load, or support condition.

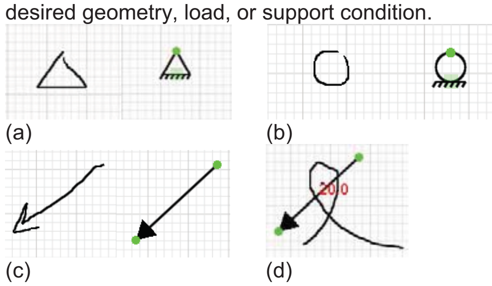


Figure 2: Examples of symbols recognized by SMATS: (a) simple support, (b) roller support, (c) load, (d) delete gesture.

1.2. Interaction

SMATS interface enables the user to create, resize, or remove nodes and members, or supports, as well as move the position of nodes by dragging the node locators. Performing each of the stated alterations updates the data for structural analysis. Unlike many of the available literature such as 'STRAT' (Peschel and Hammond 2008): a pen-based tool for students to learn standard truss analysis, Mechanix (Valentine et al. 2012): A Sketch-Based Tutoring System for Statics Courses, 'FEASY' (Murugappan and Ramani 2009): a tool to transform, simulate and analyze finite element models, or 'APIX' (Murugappan and Yang 2011): Analysis from pixelated inputs in early design using a pen-based interface, and '2DSketchFEA' (Hutchinson et al. 2007), which is a unified framework for finite element analysis, or adaptation of it in education application: 'VisClass' (Grimes et al. 2006); in SMATS, the user is able to manipulate the sketch and apply alterations to modify form or function of the structure. The user can adjust the members, loads and supports to the desired lengths and angles, and even go back to the state of the model prior to beautification and modify the truss within its initial outline. Figures 1 and 3 show a user's attempt to design and modify a truss iteratively towards a desire form. In Fig. 1, the user has tried an initial idea which it's beautified version in shown in Fig. 3(a). Figures 3(b) and 3(c) show the user's attempted alternative configurations of the same truss members by dragging the node locators.

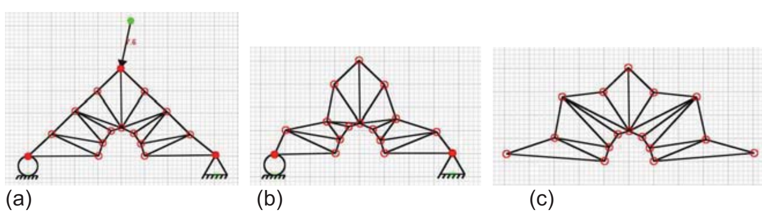
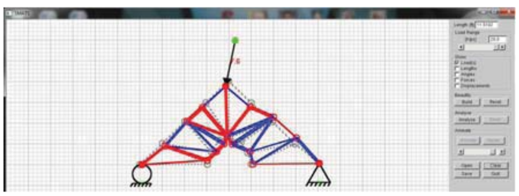


Figure 3: (a) Beautified truss after sketching; (b) & (c) User manipulation of the initial design.

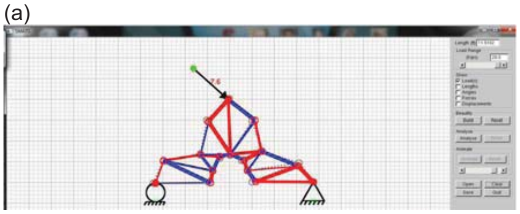
1.3. Integration of engineering analysis and visualization of results

SMATS is designed to allow the user to sketch and manipulate the sketched configuration of a truss while receiving instant feedback on its structural behavior. Once the sketched model is complete in terms of geometry and structural conditions such as load and boundary conditions, the response of the system can be simulated within the simulation mode. The Finite Element Analysis (FEA) method (Bathe and Wilson 2009) is used to calculate the internal forces and deflections of the structure. The users can then view the results directly on their drawings. The visualization of the behavioral feedback is in the form of color/thickness codes for member internal forces, and animation of structural deflections under the applied loads. Since the sketch-based interface is intended for use by non-engineers (architects), the analysis process is not apparent to the user. Only the visual results of the deformed structure will appear on the sketch-pad in real-time. Figure 4(a) and 4(b) shows the generated member internal forces of the trusses shown in Fig. 3 under an applied load. The members under tension are colored in blue and compression members are in red. The thickness of each member represents the relative magnitude of the internal force of that member in comparison to the other members. In the simulation mode, the user is also able to view the exact amount of internal forces in each member, or the amount of displacement for each node. The final mode in SMATS is the animation mode, in which the user can observe the figurative deformation of a sketched truss subjected to the assigned loads. At this stage, by observing the overall deformation of the truss, the architect can better comprehend the inter-relationship between the form and function of the design and adjust it based on the information provided by SMATS.

SMATS is a self-training UI where an architect can gain engineering perspective on the structural behavior of forms through using the program iteratively. Due to its intuitive, sketch-based design, the training period for SMATS is substantially shorter than the traditional menu-driven software tools. Once the data is updated, the users receive instant feedback about the effects of that change on their design in terms of structural behavior. Users can visualize the new results through the color/thickness codes and animation. This gives them the ability to compare different configurations and optimize the design both aesthetically and structurally. For example; one configuration might collapse under a certain load, but by changing the configuration or adding/replacing the supports, the structure would become stable under the same loading condition.



(a)



(b)

Figure 4: Simulation mode: (a) Color/thickness coding of the initial design; (b) Color/thickness coding of the modified design.

2.0. APPLICATION

SMATS is an integrated design system which contributes to both architectural and engineering designs. It provides an intuitive environment for the architects to be creative and not get distracted by the complicated menu based CAD software while using their relatively familiar pen and paper design medium. The digital ink and sketchpad which the system provides, proves to be better than traditional pen and paper in some aspects, such as, it is easier and faster to edit. In addition, every design attempt can be saved for future reference. This helps with improving productivity of the initial sketches to a great extent. Furthermore, SMATS provides a very fast and easy to use engineering analysis medium, in that it performs real-time calculations with minimum required manual input.

2.1. Application in practice

Application of SMATS as a design tool in construction industry is considerable. The system provides integrated medium for multidisciplinary design incorporating aesthetics, and structural characteristics. Therefore, SMATS can provide an environment in which architects and engineers may interact more efficiently towards a holistic outcome during the preliminary phase of design. SMATS maintains a common ground in design process for both architects and engineers to communicate ideas and make design decisions more effectively.

2.2. Application in education

Iterative usage of SMATS as an integrated design tool greatly contributes to the education of young architects. SMATS does not require any prior engineering knowledge from the user, and avoids complicated analysis and design environments. It can also help architects and architecture students gain a better understanding of the relationship between the form and structural behavior, and as a result acquire engineering intuitions from their design trials.

CONCLUSION

The present work is part of an ongoing collaborative research effort in the area of architecture, structural engineering and computer science to develop sketch-based tools which enhance integration in the preliminary design of structures. The ultimate goal of this project is to enhance creativity through optimization of the overall design process. This allows architectural freedom to create forms, and better comprehend their relationship to structural behavior, without the need to learn or concentrate on the software-specific tools. Such integration is valuable as a common language in facilitating the interaction between professional architects and engineers. Also, the iterative nature of the design process in the presented system allows the designers to be creative and provides them feedbacks as related to the structural behavior. This is a great asset in educating architects to integrate engineering requirements into their conceptual design.

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Making Science Seen: Le Corbusier's Photomural at the Pavillon Suisse

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ABSTRACT: Le Corbusier aligned science with Modern movement architecture. At the opening of the Pavillon Suisse in 1933, he was directed by the Pavillon's president to 'cover up' the exposed stone wall in the building's lounge-dining room. Opposed to the decorative arts, Le Corbusier conceived of a photomural comprised of highly scientific, dramatically enlarged 'new vision' views of nature, artistically composed and integrated into the building. The mural imaged science and high technology, metaphorically aligning both with the new architecture. The provincial press understood the mural as propaganda exuding the virtues of high materialism. André Breton praised the mural as an example of 'concrete irrationality' that set the 'object in crisis'. Like beauty, Le Corbusier's picture of science resided, it seemed, in the eye of the beholder. This paper proceeds by interpreting Le Corbusier's early works as 'exhibition', underscoring notions of propaganda and mobility in Modern movement architecture, and then details the demand for the Pavillion Suisse photomural, its make-up, and the assessment of the mural by the press and by artists. It attempts to illuminate one way of making science visible while underscoring the ambiguity of visual imagery in an age when science carried great authority.

INTRODUCTION

1 Fresh Eyes

In 1933, with the opening of the Pavillon Suisse, a dormitory for Swiss students in Paris, the President of the *Cité universitaire*—the community in which the building resided—was appalled by Le Corbusier's brutalist gesture of leaving the curved rubble wall exposed to the inside of the students' dining lounge. He directed Le Corbusier to cover it up with pictures, this despite the architect's adamant opposition to the decorative arts.[1] What to do?

Le Corbusier had intended the exposed wall as manifestation of his belief in a direct, *honest* use of material. He understood the rustication and coloration of the stone as part of a larger palette, a palette that—conspiring with the rough-cast concrete 'legs' of the building—offered contrast to the ultra-slick block of sleeping rooms. A traditional French wall, the rubble design had been employed by Le Corbusier to great effect at the Villa de Mandrot a few years earlier. Its carefully construed mortar projected beyond the face of the wall and appeared a veil in front of the stone itself.

In 1933, in the initial years of Great Depression, Le Corbusier could only do as his client directed. His cover up, though, would not be of the arts-and-craft kind; rather he would conceal the wall with a photomural. Together with his partner, Pierre Jeanneret, he composed a mural comprised of 44 'new means' images of nature. The photographs came from Parisian scientists and naturalists and were generally of three kinds: x-ray, microscopic, and aerial views of nature. There were exceptions, these being centrally located in the photomural and essential to Le Corbusier's polemic. They showed mass-produced building materials and the Pavillon Suisse itself under construction.

The photomural was a visual polemic, promoting Le Corbusier's well-honed new vision. Throughout the 1920's, when objectivity, materialism and machine technology dominated his writings on art and architecture, Le Corbusier was intrigued and delighted with 'seeing things' not visible to the unaided eye. This fascination did not contradict his firm belief in science and rational thinking, though. On the contrary, making visible that which could not be seen was both the task and procedure of science then, and the 1920's and 1930's were decades in which 'seeing through things' and thus unveiling layers of life not visible to the human eye, was a much-celebrated, popular activity.

In 1923, in *Vers une architecture*, Le Corbusier wrote, "*Our epoch is fixing its own style day by day*. […] *It is there under our eyes. Eyes which do not see*." And he urged his readers to adopt a new way of thinking about what and how they saw. "*Forget for a moment that a steamship is a machine for transport and look at it with a fresh eye*," he advised, look at it "*as an architect (i. e. a creator of organisms).*"[2]

"*Fresh eyes*" were found in tools intended to enhance vision: cameras, telescopes, microscopes, binoculars, distorting mirrors, instrument panels, celestial charts, maps, and speedometers.[3] Zeppelins and airplanes offered views of the world never before experienced. Photographs featured in the then-blossoming illustrated press were indicative of the public's appetite for images of the otherwise invisible or momentary. The photograph was, itself, a new way of seeing.

2 Representation *Becomes* Architecture
For Le Corbusier in these years, representation was becoming to architecture. In addition to his novel houses packaged in geometry and elevated on legs, Le Corbusier designed two exhibition pavilions in the 1920's. In both pavilions, representation was integral and essential. Both were promoted as portable.

Portability was an essential and distinguishing quality of the new technology architecture. "*With the plan in our pockets*," Le Corbusier wrote of the house he and Pierre Jeanneret designed for his parents in the mid-1920's, "*we spent a long time looking for a site*."[4] More so than the house, though, the exhibition pavilion provided a program for building in which portability and graphic art were vital, essential functions. The pavilion was both architecture and propaganda art.[5] It was a sign, a billboard, a display intended to call attention to itself. Functional, its function was to provoke.

With his 1925 Pavillon Esprit Nouveau (Figure 1), Le Corbusier quite literally built a full-scale model. The Pavillon represented modern architecture itself. It presented a typical living unit in Le Corbusier's "Immeuble-Villa" housing complex while serving to test new materials and techniques.[6] It possessed a kind of economy. A simple painted rectilinear box, it was promoted as a portable building.[7] Le Corbusier intended it to be sold, dismantled and reassembled in a Paris suburb after the exhibit.[8] He priced it at 209,000 Francs excluding land.

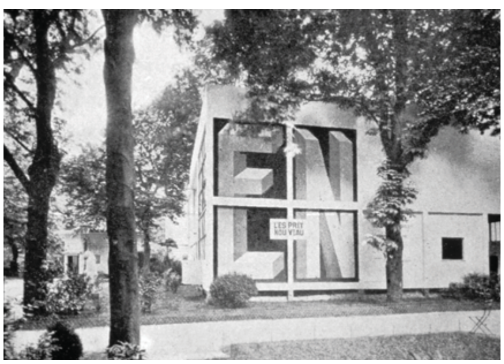

Figure 1: Pavillon Esprit Nouveau. Source: FLC

Figure 2: Nestlé Pavilion. Source: FLC

In 1927, the Nestlé Pavilion was built—not as the representation of a new architecture, but as advertisement (Figure 2). Demountable and portable, it traveled from exhibition to exhibition—brightly colored signs artfully collaged into an on-the-ground, walk-thru billboard.

Le Corbusier wrote *on* both pavilions, but the letters and words that the buildings carried were not decoration. Rather, writing and architecture were conjoined, made one. Delicate, logical, abstract, autonomous, the mural was undoubtedly propaganda, but also art. Le Corbusier would employ it as integral element of the Pavillon's palette. In the hands of Le Corbusier, the photo would be similarly integrated into architecture.

3 Make Bigger, Add Function

Le Corbusier was commissioned to design the Pavillon Suisse in the late 1920's, a *gran project* far larger than the residences and small pavilions he had previously built. (Figure 3) Like the Pavillon Esprit Nouveau, the Pavillon Suisse was itself a kind of set piece, a building 'type' Le Corbusier believed essential to his various visions of a contemporary city. Heavy, rectilinear, on stilts, it permitted the flow of continuous landscape below it, offering an entry and necessary amenities in a slightly whimsical building slipped under the elevated block. Though soil conditions were not conducive to carrying the enormous weight of the 5-story building on only 6 points, Le Corbusier was eager to build the box-on-stilts model and ordered tremendously deep piles to be drilled.

Figure 3: Pavillon Suisse. Source: FLC

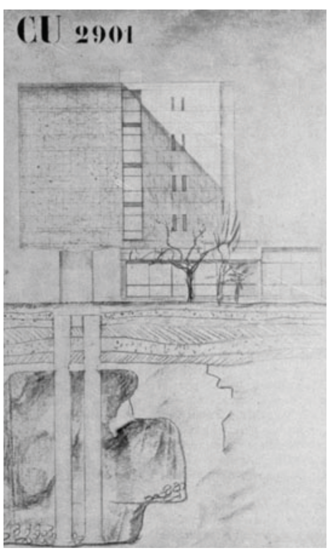

Figure 4: drawing of Pavillon Suisse showing piles. Source: FLC

In the *Œuvre complete-2*, Le Corbusier imaged these piles not as an unnecessarily costly design decision, but as a technological feat (Figure 4)—contemporary building science defeating an inconvenient obstacle imposed by nature. The *Œuvre complete* presented Le Corbusier's activities as '*reportage*'. This *reportage* was not personal promotion, but objective, outside review and assessment. With this forum, Le Corbusier could cast himself as both daring and progressive, frequently achieving this combination by admonishing those who were critical of his enterprise. This was the case regarding the Pavillon Suisse photomural. The one-sided debate shows Le Corbusier at his dialectical best.

As was noted, Le Corbusier had specified that the uninterrupted 36-foot curved wall in the lounge-dining room be of rubble, its surface exposed on the interior. When the building neared completion in the Spring of 1933, according to Le Corbusier, the President of the Cité Internationale asked him to put "*aux murs de ce Pavillon Suisse de grans tableaux représentant les rocs, les neiges et les glaces, etc., etc... rappelant leur patrie aux pauvres étudiants venus se perde dans le Paris dangereux*."[9]

Regarding this request, Le Corbusier noted "*J'eus alors l'idée de réaliser, en deux ou trois jours, le premier 'mural photographique,' considéré non pas comme un document mais comme une oeuvre d'art*."[10] The resulting photomural was composed of forty-four square photographs, each approximately one meter by one meter, butted together covering the curved wall of the Pavillon Suisse library floor to ceiling and end to end. (Figure 5). Eighteen or so additional images covered the lozenge-shaped 'column' in the entry hall, next to the staircase (Figure 6). All the photographs on the column were micro-cellular views, most of them white, ghost-like images on a black background.[11]

Figure 5: left portion of Pavillon Suisse photomural. Source: FLC

Figure 6: photomural on elliptical 'column' in lobby of Pavillon Suisse. Source: FLC

The photographs were first selected by Le Corbusier and Pierre Jeanneret from pre-existing photographs and then re-composed. Thirty years after its creation, Le Corbusier told how he found the 'documents' for this mural in "*chez les naturalistes, dans les laboratoires, chez les araignées, chez les briqueteurs, sur les dunes de sable et les plages d'océan à marée basse, etc, etc.*" He described the murals as "*Magnifique tapisserie opulente et belle en soi, d'un gris profond, - un camaïeu: tout simplement le gris des photographies au bromure.*"[12]

The images—both alone and as an ensemble—tended towards abstraction and otherworldliness. Most of them presented unnatural, 'new vision' views of nature and of man-made materials, views which emphasized patterns or designs. Micro-photography and the aerial photograph were prominently represented. Micro-photography had a long history in France, was popular among certain avant-garde artists at the time,[13] and as early as 1921 was featured in *L'Esprit Nouveau*. Some of the micro-photographs shown in the mural were by the renowned photographer Laure Albin-Guillot, who collaborated with numerous French scientists.[14]

The images of stacked, mass-produced building materials featured in the mural were similar to photographs made at the Bauhaus some five years earlier; while close-up abstractions mirrored those done by Edward Weston and Paul Strand in the mid- and late-1920's. The abstract landscapes on the right were similar to those made in Egypt by Frederic Boissonnas at the time.[15] Other mural images were comparable to those found in Ozenfant's 1927 book, *Foundations of Modern Art*. *Plans*, the journal Le Corbusier co-edited in the early thirties, featured similar, if weaker, images; and in the early 1930's, aerial, micro- and close-up photography were regularly found in the popular press as were the truly remarkable photographs of Karl Blossfeldt, whose extraordinary images of plant life were celebrated by numerous avant-garde artists, from Ozenfant to Bataille.[16] As a *magnifique tapisserie* the photo mural bore remarkable resemblance to the exercises in pictorial composition done years earlier by students in the basic design course of Johannes Itten at the Bauhaus.

4 Imaging Science as Art

The geological and biological themes dominating the mural were indicative of the organic analogies Le Corbusier adopted at the time to describe architecture metaphorically.[17] In *Croisade*, published the same year that he was asked to make the mural, he wrote:

> *Where is architecture?* […] *everywhere nature manifests in its creations: geology; organic life; seeds, roots, trunks, branches, leaves, flowers and fruits* [...][18]

And three years later in his reply to a group of modern architects in Johannesburg who had written him for counsel regarding inspiration for a new architecture, Le Corbusier wrote:

> […] *of combinations of harmonious engenderings in which nature offers a spectacle in each thing. Inside to outside: serene perfection. Plants, animals, trees, sites, seas, plains or mountains. Even the perfect harmony of natural disasters, of geological cataclysms, etc. Open your eyes! [...] Architecture is an extraction of the spirit and not a trade [...]*[19]

And something like this must have been Le Corbusier's message to the students for whom he created this photomural. Such analogies were an essential part of his own early education in Switzerland, so much so that the photomural might be regarded as an 'advanced technology' version of the drawings of the patterns of nature that filled the walls of the School of Art studio that he taught there in 1915 (Figure 7).[20]

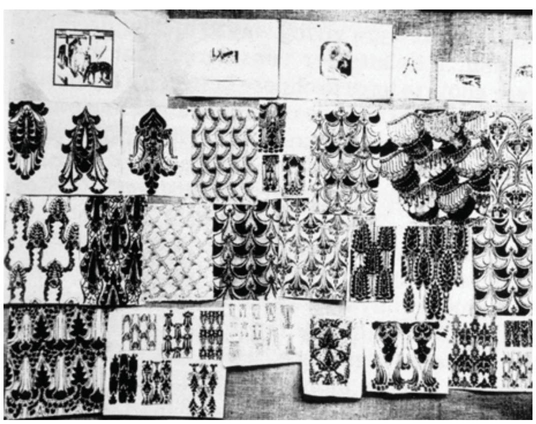

Figure 7: hand drawn exercises in abstracting nature from La Chaux des Fonds School of Art, ca. 1915. Source: FLC

Yet despite the *intended* wholesomeness of the message, in December 1933, six months after the inauguration of the Pavillon Suisse, the *Lausanne Gazette* denounced the photomural as a corruption of minors. Le Corbusier responded by reproducing their article in full in Volume-2 of his *Œuvre complète*.[21] The *Gazette* article dismissed the exterior of the building, labeling its aesthetic as "*the 'Parthenon of the modern Greeks' emptiness*" and noting that this

> *kind of Noah's Ark that is the Hellenic pavillion, goes quite well with the Swiss Pavilion and what is, I believe, a water tank, towards Gentilly.* [22]

The author of the article (it was signed "*CH. - F.L.*") believed the most troubling aspect of the building was its interior, specifically its photomural. "*I will tell you firstly about that which is against the walls, the same as the walls, on the walls*,"[23] he began, intelligently identifying the mural's ambiguous relationship to architecture. He then proceeded to compare the images of the mural with those featured in *L'Esprit Nouveau* and in Ozenfant's *Art*.[24] Insightfully, he concluded that:

> [...] *a theory accompanies these photographs. A theory of materialism: "*everything is only a question of structure; everything is only, more or less, good organization of material.*" (The soul, naturally, the Spirit, are replaced by structuralization).*[25]

What affect, the *Gazette* author asked, would this have on Swiss youth—"*intelligences en formation*"—who, by necessity, must reside in this dormitory and daily come into contact with "*cette théorie de matérialisme* "? The author answered his rhetorical question by directing the reader to:

> *Look at any number of Soviet Russian illustrations. Russia is a country that knows well the role that image plays. Here is its name: Propaganda*. [26]

Presumably Le Corbusier published this reactionary review to satirize the *Gazette*, defusing its criticism, while at the same time, portraying himself and his art as provocative, stirring, radical, important, and quite distant from his very provincial native land. Yet the *Gazette* criticism astutely underscored the most significant quality of the mural: its narrative and symbolic capacity.

5 Object in Crisis

Less than two years later, in 1935, as a guest of the Czech functionalist architect Karel Teige, the Surrealist André Breton gave a lecture titled "Surrealist Situation of the Object."[27] Breton was no fan of Le Corbusier; the opposite was true. But in his lecture, he heartily praised the photomural Le Corbusier had created for the Pavillon Suisse, highly commending it as an example of "*concrete irrationality*." He viewed its inclusion in the Swiss Pavilion—a building he felt answered "*all the conditions of rationality and coldness that anyone could want in recent years since it is the work of Le Corbusier*"—as indication that architecture was again attempting "*to break through all its limits*." He compared it directly to "*the desire for ideal things*" found in Art Nouveau architecture, likening Le Corbusier's "*irrationally wavy*" wall to the mailman Cheval's 'Ideal Palace' and to Gaudi's "*magnificent church, all in vegetables and crustaceans, in Barcelona*." Breton understood the mural as an example what he called '*the object in crisis'*, and applauded it for exactly that reason.

It is doubtful that Breton had personally seen the Pavillon Suisse before making his remarks, for the curved wall and lozenge-shaped column that held the photomural were not irrational waves. Nor did Le Corbusier intend the photomural to provoke the irrational, quite the contrary. But Breton recognized in the photomural what perhaps was not evident to Le Corbusier at the time of its execution. The mural was a representational overlay. As such it placed 'irrational order' beside the 'rational order' of Corbusian architecture, created a dialectic condition that was both spatial and humanizing. It dematerialized architecture. Like camouflage, it placed the object in crisis, shifting emphasis away from a sense of architecture as an objective artifact, reinforcing the subjective and phenomenal perception of building and space.

6 Making Science Seen

At the end of his life, in the 1960 book *Creation is a Patient Search*, Le Corbusier again considered the photomural and again returned to the *Lausanne Gazette* article. He noted that some had regarded the mural with enthusiasm, but

> *From others, for example the* Lausanne Gazette--*a newspaper which benefited from an international situation during the First World War--came front page headlines which read "THE TRUTH ABOUT THE PAVILLON SUISSE OF THE CITE UNIVERSITAIRE: Who requested this photographic mural? Who has dared to accept it? It is necessary to denounce those responsible! A single goal might describe this mural: "IT IS THE CORRUPTION OF MINORS!"*

To his account of the article, he added: "*Ten years later, Hitler's people, during the Occupation, sharing the anxiety of the* Lausanne Gazette*, scraped this photo mural from the Pavilion*."[28]

Nevertheless, the claims made by the *Lausanne Gazette* did have merit. The images of the photomural, like those found in Le Corbusier's many books, were unavoidable. Anyone who resided in the Pavillon had to see them. And they *were* propaganda. In the late-1930's, the photomural became commonplace, almost banal. The renowned photographer Gisele Freund, in her review of the 1937 Paris Exposition, described it as perfect for propaganda because, she said, its "*power to exactly reproduce reality*" conferred on it "*documentary value of the first order*."[29]

When world war and atomic power brought the human race to the brink of destruction in 1945, Le Corbusier could no longer align a redemptive Modern movement architecture with science and technology. For the Pavillon Suisse, in place of the photomural that had been 'scraped' from its wall, Le Corbusier painted a mural of myth and color. And if the photomural had de-materialized architecture throwing the object into crises, the new mural—painting that might have been considered decorative appliqué before Picasso's *Guernica*—re-materialized it. Ambiguity was dissolved even as science itself turned from hard to soft.

ENDNOTES

Parts of this article appeared in both my 1996 University of Pennsylvania dissertation, "Le Corbusier's Seeing Things," and in my "Le Corbusier & the Space of Photography: Photo-murals, Pavilions, and Multi-media Spectacles," History of Photography*, vol. 22, no. 2 (Summer, 1998) pp127-138.*
References below to 'FLC Box' are to archival material at the Fondation Le Corbusier in Paris as organized in the 1990's. This material has since been digitized and ordered according to a new numerical system. Unfortunately, no cross-referencing between the old system and the new was established.

[1] In his 1925 *L'Esprit Nouveau* essay "Milestones," Le Corbusier insisted "*The decorative arts were anti-technology*[…] *Their efforts were directed to opposite ends from the common effort of the age. They aimed to restore manufacture by hand."* Because of this, he concluded, "*The physical products of decorative arts have no place within the context of the age*." "Milestones" became a chapter in Le Corbusier's *L'Art decoratif d'hourd'hui*.

[2]Le Corbusier, *Towards a New Architecture* (Trans. Frederick Etchells. New York: Dover Publications Inc., 1986), p103.

[3]These extra-somatic devices are depicted in Amédée Ozenfant, *Foundations of Modern Art*, trans. John Rodker (New York: Dover, 1952), originally published in French as *L'Art* (Paris: J. Budry & Cie., 1928). Ozenfant juxtaposed these images with others: modern paintings, the 'ladies club' Sunday painters, primitive sculpture, miniaturization in toys, the bicyclist, Negro 'eggshell' architecture, etc.

[4] Le Corbusier, *Une Petite Maison* (Zurich: Artemis, 1954).

[5]For a history of the pavilion see Edward N. Kaufman, "The Architectural Museum from World's Fair to Restoration Village," *Assemblage* 9 (June 1989): 20-39.

[6]See "Procédés et matériaux nouveaux" in Le Corbusier, *Almanach d'architecture moderne* (Paris: Éditions G. Crès, 1926) pp190-197 as well as in the many advertisements which appear in the back of this book. The book was written as a response to Le Corbusier's *détracteurs* following '*le scandale du Pavillon de l'Esprit Nouveau*.'

[7]"*La Pavillon est sur pilotis, isolé du sol*." Le Corbusier, *Almanach d'architecture moderne*, p152.

[8]Given the pavilion's materials and detailing, such an intention seems absurd.

[9] FLC Box C2-5, #127, a four-page draft dated 8 October 1962 for the preface of a catalogue for the "Exposition de Peinture Le Corbusier" in Barcelona.

[10]FLC Box C2-5, #127. Following this claim, Le Corbusier noted that "*This document of 55 square meters (11m x 55m) was made of 55 documents*[...]" However, published photographs of the photomural show it as four documents high, eleven wide.

[11]These photographs were rectilinear, not square. Three photographs of the lobby of the Pavillon Suisse show the column clearly. Today this column is wrapped in rectilinear images, mostly of Le Corbusier's urban and architectural projects.

[12]FLC Box C2-5, #128.

[13]In the 19th C several journals were dedicated to this new vision. See, for example, *Zeitschrift für wissenschaftliche Mikroskopie und mikroskopische Technik*, first published in 1884.

[14]On Albin-Guillot and micro-photography, see *Images d'un autre monde; la photographie scientifique*, intro. by Monique Sicard (Paris: Centre National de la Photographie, 1991).

[15]See, for instance, his "*Dune au Sinai*" in Nicolas Bouvier, *Boissonnas: une dynastie de photographes 1864-1983* (Lausanne: Editions Payot, 1983) p155.

[16]*The Illustrated London News*, for example, featured the following articles in early 1932: "Revelations by Air," (Jan. 2, 1932): pp29-31; "Architecture only the Insect Can See," (Jan. 23, 1932): p141+; "Photography without Lens or Negative," (Feb. 20, 1932): p285+; and the photography of Karl Blossfeldt, (May 14, 1932): pp798-799.

Georges Bataille featured five Blossfeldt photographs in "Le Langage des fleurs," *Documents* 3 (1929): pp160-168. His selection was remarkably similar to A. Ozenfant's who featured four in *Foundations of Modern Art*, pp270-272 and p288.

Blossfeldt achieved international recognition with the publication of his stunning portfolio of magnified images of plants, *Urformen der Kunst* (Berlin: Ernst Wasmuth, 1929).

[17]Walter Gropius exhibited '*tableaux* suggestive of functions of the human body in relation with architecture' at the International Building Exposition in Berlin in 1931 [See *L'Architecture Vivante* (Winter, 1931), pl. 26]. In a lecture in Delft that same year, Marcel Breuer dismissed accusations of formalism in modern architecture, arguing: "We see our mission in creating a home that is simpler, lighter, more comfortable in a biological sense, and independent of exterior factors [...] See Christopher Wilk, *Marcel Breuer: Furniture and Interiors*, (London: The Architectural Press, 1981), p37. In the same year, Le Corbusier published *Precisions*, titling one of its chapters "A Man=A Dwelling, Dwellings=A City". He developed this analogy in a

series of articles—"L'élément biologique: la cellule de 14m. par habitant," "Vivre (Habiter)," and "Vivre (Respirer)"—which first appeared in *Plans* 9 (Nov. 1931), pp49-65; *Plans* 4 (April, 1931), pp49-66; and *Plans* 3 (March 1931), pp33-48 and later in his *Ville Radieuse*. The Pavillon Suisse photo mural visually manifested of what Le Corbusier stated most succinctly in *Aircraft* in 1935: "*In nature microcosm and macrocosm are one."*

[18]Le Corbusier, *Croisade ou le crépuscule des Académies* (Paris: Éditions G. Crès, 1931), p21.

[19] Letter dated 23 September 1936 and addressed to the "Groupe des Architectes Modernes de Johannesbourg (Transvaal)." As quoted in Jean Petit, *Le Corbusier lui-même* (Geneva: Editions Rousseau, 1970), p82.

[20]Of those years, Le Corbusier wrote: "*Here in rational France the appeal to nature; analysis. The entomologist Fabre excited us. We realized that natural phenomena have an organization, and we opened our eyes. 1900. An outpouring. Truly, a fine moment*!" See his *The Decorative Art of Today,* p137.

[21]Le Corbusier and Pierre Jeanneret, *Œuvre complète*-2, ed. Willi Boesiger, 9th ed. (Zurich : Les Éditions d'Architecture Artemis, 1991), p76.

[22]"*Le vague Parthénon des Grecs modernes, cette espèce d'arche de Noé qu'est le pavillon hellénique, va très bien avec le Pavillon suisse et ce qui est, je crois, un réservoir d'eau, vers Gentilly*."

[23] "*Je vous dirai premièrement ce qui est contre les murs, à même les murs, dans les murs* [...]"

[24]Ozenfant's *Foundation of Modern Art.*

[25][...]*une théorie accompagne ces photographies. Une théorie de matérialisme: "*tout n'est que question de structure; tout n'est que de plus ou moins bonne organisation de la matière.*" (L'âme, naturellement, l'Esprit, se remplacent par structuration).*

[26]*Voir le nombre des illustrés russes U. R. S. S. Or il est des pays où l'on connaît très bien le rôle que peut jouer l'image. Cela se nomme:* Propagande.

[27]André Breton, "Surrealist Situation of the Object," *Manifestoes of Surrealism*, trans. Richard Seaver and Helen R. Lane (Ann Arbor: The University of Michigan Press, 1969), p261.

Breton had represented the Ideal Palace in his "*Le Message Automatique*," *Minotaure* 3-4 (1933): pp55-65. Gaudi's architecture was featured in Salvador Dali, "*De la beauté terrifiante et comestible, de l'architecture modern style*," *Minotaure* 3-4 (1933): pp69-73 with photographs of Gaudi's Casa Mila by Man Ray.

[28]There is no evidence that 'Hitler's people' were responsible for removing the photomural.

[29]Gisele Freund, "La Photographie à l'exposition," *Arts et Métiers Graphiques,* 62 (March 1938): pp38-41.

Agency and Personification: Core Analogical Operators in the Architectural Design Process

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ABSTRACT: This paper examines the intrinsic use of the analogical operators of agency and personification in architectural design. Agency, the capacity of an entity to exert power or force, and personification, the projection of human qualities on non-human entities, exist as examples of a larger set of conceptual tools humans used to interact with their environment. It is common in architectural design to discuss a form or a composition, which is a relationship between forms, as *acting on that (agency)* or *feeling like this (personification)*. The feeling or activity are part of the transfer of meaning between the designer's intentions and how another human interprets the design *intuitively*. The feeling or activity is only projected by the designer onto static forms and does not actually exist in the form or composition – the form is not capable of having human feelings nor does it physically engage in action. What they do is engage cognitive metaphors that are at the heart of human mental processing (Lakoff & Johnson, 1980).

By examining agency and personification, the paper will explore major cognitive metaphors and their existence as an inherent part of understanding architecture. The discussion will involve both the theoretical and the practical as well as an introduction to image schema – recurring cognitive structures used to connect patterns with understanding and reasoning. In architectural design, cognitive metaphors will be discussed as part of a toolkit of analogical operators which connect architectural design to architectural experience. These operators, it will be seen, use low-level knowledge categories, such as innate and sensorimotor content, to give meaning to architectural objects in context.

KEYWORDS: *latent knowledge, image schema, conceptual metaphor, analogical operators, innate meaning*

INTRODUCTION

The result of an architectural design process is the creation of a set of formal relationships which engage a territory and situation. Those formal relationships – a composition – and their context are then interpreted by individuals who occupy, use and engage the constructed spaces. One goal of an architectural designer is to transfer a proposal's intentions from the understanding of the designer to a successful interpretation by a user. However, while source material for the designer might come from many different 'inspirations', the *interpretation* of an architectural space is due to the way humans process our environment. This use of interpretation does not refer to the "true meaning" of the work (Sontag 1961), the use of interpretation as a critic (Bonta 1979), interpretation as a secondary event parallel to design (Colomina 1988), nor even architecture *as* interpretation (Snodgrass and Coyne 2006). It is addressing the sensorimotor translation of environment into human dimensions as a central operation of the design process. When an architectural designer speaks of a form *feeling like this* or *acting on that* as part of the design process, they are selecting objects, their properties and relationships in order to predetermine how a composition is interpreted. Compositional elements, in this way, are selected based on their latent content in order to transfer that content to another human *intuitively*. The form and its compositional elements do not need to be intellectually analyzed by the occupier in order to produce meaning. As such, the manipulation and interpretation of form belongs to a greater set of tools that humans use to interact with the world. These are called image schema – recurring cognitive structures used to connect patterns with understanding and reasoning. Many of the image schema that humans use are based in spatial and visual qualities. Image schema are also at the heart of another major tool of compressive mental processing – the analogy or cognitive metaphor (Johnson, 1987). There is a clear case for image schema and their analogical extension being involved in non-linguistic reasoning (Hurtienne and Blessing 2007), and by association, understanding architectural space.

While spaces are activated by an architectural designer through concepts of action and feeling, those concepts are not something that is *real*. In this sense, *not real* means that the feeling or action ascribed to the architecture isn't possible beyond being a projection of the human mind. The form, or situation the form is in, does not actually act in the way described – the form is not capable of having human feelings nor does it physically engage in action. However, architectural designers give forms *agency*, the ability to conceptually act on their surrounding, and *personification*, the ability to take on human characteristics including emotions, as a standard way of designing. Both these are conceptual design tools that engage conceptual metaphors at the heart of human mental processing (Lakoff & Johnson, 1980). The processes use analogical operators that transfer meaning at a very basic level of human mental processing ensuring a successful dialogue between designer and user. However, the processing level seems to be so intuitive that is has been unconsidered and ill examined. Architectural designers, as well as most other individuals, use the mechanism without recognizing the theory or greater structure, thus losing access of inquiry to a significant tool.

This paper examines recent advances within cognitive science, focusing on factors relevant to the interpretation of architectural spaces as a process of design. The relationship between image schema, conceptual metaphor, analogical content, formal-to-human meaning transfer and designer-to-occupier content transfer is addressed, stressing *latent* rather than *explicit* interactions.

1.0 EMBODIED INTERPRETATION

1.1 The Experience Of Architecture in the Visual Field

In 1963, Le Corbusier completed the Carpenter Center for the Visual Arts at Harvard University. The building was designed to house studios for the visual arts with an intention to synthesize the arts and be an expression of freedom (Giedion 1971). As such, Corbusier designed the building with a dynamic relationship between public and private space, focusing on the use of a central ramp to activate the design. The ramp, in what could be considered the major design move, travels seamlessly from the site perimeter and moves through the main mass of the building in both plan and section. The ramp was meant to encourage public circulation and make interior private activity adjacent to more casual exterior movement. It is possible to move up and through the Carpenter Center, brushing against the interior activities, without ever actually entering the building (Fig. 1a).

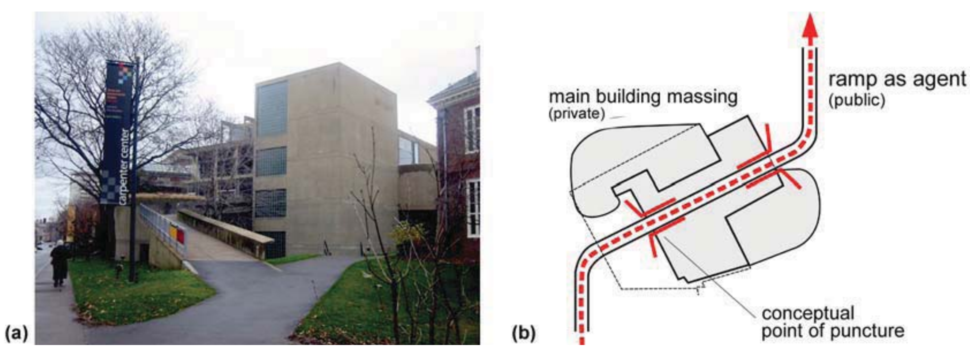

Figure 1: [a] Carpenter Center, Harvard University by Le Corbusier. Source: (Dsmack/Wikimedia Commons 2006), [b] Ramp as agent, building massing as context. Source: (Author 2012)

When viewing the Carpenter Center as an situation to be interpreted in the visual field, there are clear elements that can be recognized. The ramp is seen as both part of the ground lifted up to engage the building as well as part of the building. It is a discrete object when compared to the dominate massing and maintains a indeterminable relationship with the surrounding context. There is a clear sense of movement and speed to the ramp. There is also a point of puncture when the ramp moves through the building and slips out the other side to reengage the ground. Users of the space understand how the ramp operates as circulation and its relationship to the major massing (Fig. 1b). However, where do these ideas come from? The ramp isn't capable of movement or speed, it isn't separate to the main massing, it can't apply pressure and it doesn't physically puncture the mass as a foreign object. These are human interpretations of static objects, actions that are applied to objects incapable of those actions. In other words, the ramp has been given agency by human interpretation – the power to *appear* to act on its surroundings even though that action is impossible.

Agency can also be found in the Cesar Chavez Library (2008) in Phoenix, Arizona by Line and Space. The building was designed as a climatically responsible structure for the harsh Arizona sun with large overhangs and earth berms. Even though driven primarily to environmental factors, the designers choose to make the roof communicate to the users through its formal composition. Conditioned spaces are pulled back from the perimeter and nestled under the soaring plane of the roof structure. The relationship to the ground is reinforced by angled, intermittent structural connections roof and the physical disconnection of the roof from vertical elements like retaining walls. The overall effect is one of pressure between the exaggerated roof plan and the landscape. The program seems to be caught between the two as threshold space (Fig. 2). What do we mean when we say “creates pressure” or program is caught in a threshold? The roof doesn't change the density of the air, there isn't an increase in kPa (PSI) nor is there a change in gravitational forces or any real change in the physical environment. Again, what we are speaking about is the *interpretation* of force which is based in the way humans interpret our surroundings. A person adjacent to the library interprets the angle and volume of the roof as having *agency* on the surrounding space. The roof is consider as an active player which physically acts on its surrounding but without actually being able to do so.

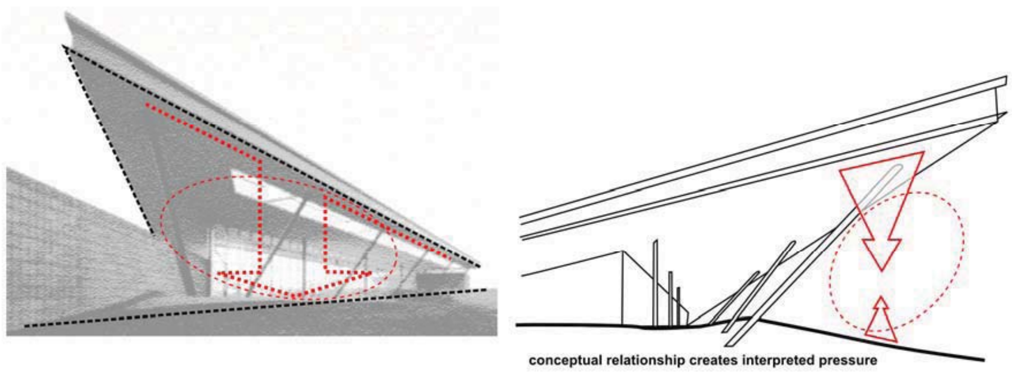

Figure 2: Cesar Chavez Library. Source: (Author, 2012)

Le Corbusier's only American project and the Chevez Library are not an isolated incidences. Examining a single aspect of a much more complex project, the steeple/belfry tower at Sainte Marie de La Tourette is another clear example of agency (Fig. 3). The monastery involved many of Corbusier's philosophical positions towards architecture driven by sequential understanding of space and playfulness between rationality and sculptural effect that marked his later work (Potié 1997). However, in the steeple there is an isolated event which is clearly engaging visual interpretation. While there isn't the same sense of a circulation path pushing into an architectural mass or pressure created by a elevated plane, the steeple still appears to act on its surroundings with agency. It can be considered an agent as it creates a sense of pressure under its extended side while implying rotation away from the main massing of the steeple. There is dynamism in the event of the belfry due to the visual interpretation of asymmetry given by an *interpreted sense* of the unbalanced loading of gravity. This composition can be considered to *be* an event due to the application of agency onto the static forms.

Figure 3: Sainte Marie de La Tourette by Le Corbusier. Source: (James Stevens, 2010)

Agency can take many forms working with solids, voids, circulation and other primary architectural content to make a connection between designer intention and user's interpretation. Since the source for agency comes from human cognition, it is often combined with the projection of human characteristics onto non-human elements, or *personification*. Objects with agency can be given the conceptual overlays of sight, emotion or personality. When we speak of an architectural object projecting or presencing on its surrounding, we give that object characteristics that it is not capable of having and base those characteristics on what is known to the observer – the human experience. An example of this analogical operator of personification is seen in urban space and monuments. If two monuments, or prominent objects, are within "sight" of each other (visual field), they are considered to be "looking" at each other. The conceptual understanding of that sight creates a implied physical connection which is driven by the objects having agency and personification. The objects conceptually extend beyond themselves. Agency and personification analogies can be found in Peter Zumthor's Val Thermal Baths (1996). The architectural presence of the Baths is one of a close relationship with the situation in which it resides – the mountains. The building appears to be either sinking into the slope of the mountain or emerging out of it. Either way, there is a very close association being made between the architectural forms and the context it resides. The building is given personality by the viewer that relates it to the mountain (the mountain likewise is given a personality). Zumthor engages agency and personification when he stated that the project was "a hotsprings and bath born of the mountains" (Copans 2001). The building can not physically push out of the mountains, this is an implied movement. The project is personified when considered to be born. Buildings are not born (in the human sense) and are not the offspring of mountains – at least, not without being heavily processed first – which makes the building interpreted as if it were personified as a human.

2.0 THEORETICAL STRUCTURE

How does personification and agency work? If we look at the previous examples, there is a transfer of knowledge from a non-architectural domain of knowledge to overlay architectural content. When Zumthor speaks of birthing a building, he is mapping both human characteristics and the action of animal procreation onto a building. When a belfry is given agency to exert pressure through rotation and void, this is a mapping of domains of locomotion and force schemata onto a domain of formal composition. Any mapping from one domain to another in order to enrich and clarify the later is considered a conceptual metaphor. Conceptual metaphors use analogical mappings in order to transfer meaning from a known domain to a less known domain. The process has been shown to be fundamental to human cognition (Lakoff & Johnson, 1980; Lakoff & Turner, 1989; Lakoff & Johnson, 1999; Gibbs, 2008). It is an act of compression of data and an aid to comprehension of the less known domain of knowledge. Agency and personification are, in essence, both analogical mappings. They engage the conceptual metaphors that are at the core of human mental processing of our environment. Conceptual metaphors, in turn, operate using image schema.

2.1 Image Schema

Image schema are elements in a set of foundational conceptual tools humans use to interact with the world. Technically, they are mental patterns that are embodied in our cognition. When we innately understand space – be it walking around a table, catching a ball or knowing something is overbalanced and will fall – we are using image schema to process our environment. Image schemata are used to understand paths, containment, center-periphery relationships, cycles (starting and endings), forces, balance and spatial orientation (Johnson 1987, Croft and Cruse 2004; St. Amant et al. 2006; Hurtienne and Blessing 2007). Image schema are also at the heart of how humans use conceptual metaphors to map one domain onto another. When justice is considered as a balance and represented as a set of scales, this is a metaphorical transfer using force and balance schema. Force schema involves physical or metaphorical causal interaction and includes direction, intensity, path and target of the force along with a sequence of causation (Loos et al 2003). Justice isn't actually a scale and isn't balanced – this is a human conceptualization. It is image schema that allows the analogy of a balanced scale to be mapped onto the idea of justice.

In the same way, when an architectural designer proposes a spatial composition in order to have it interpreted in a certain way, that designer actively uses image schema. The same mental patterns that allow for justice to be understood as a scale operate in architecture to allow formal relationships to be interpreted in a consistent way. It might be considered that architecture has an exclusive formal language unique to its discipline. However, architecture's formal language is not its own. Nor is it intellectually disconnected from our world but an embodied process that relies on a set of conceptual operations housed in the relationship between our mind, body and environment. Foundational exercises in architectural thinking manipulate form and sets up dialogue (a personification) between various elements in the compositional system. Primary formal elements such as cube, sphere, pyramid are reinterpreted as architectural objects such as wall, column, vault, dome, arch, and so on (Ching, 2007; Prina, 2008). The objects are then associated with each other using basic operations to be considered when pursuing formal composition. Standard reference books used to teach formal architectural design reference the operations as ones of paths, containment, center-periphery relationships, cycles (starting and endings), forces, balance and spatial orientation (Hanlon 2009, Lavine 2008, Ching, 2007, Conway and Roenisch 2005, Eisenman 1999, Tschumi 1994). They are not architectural operations but applied image schemata.

As image schema has been shown to play a strong role in metaphor generation (Johnson, 1987), architectural operations of composing form can also be understood as analogical transfers or conceptual metaphors. When a static object, such as a roof, is given agency to conceptually act on its surrounding, this is a mapping of force and orientation schemata onto a target domain to produce conceptual action. The roof becomes more than a surface to keep out the elements. It is enriched and produces stable meaning by engaging low-level conceptual understanding in the human comprehension system.

2.2 Analogy Operators Supporting Agency and Personification

Although not the only way that meaning is transferred, conceptual metaphor as an analogical operator is persistent in all aspects of our experience as the “most fundamental values in a culture will be coherent with the metaphorical structure of the most fundamental concepts in the culture” (Lakoff & Johnson, 1980). As formal architectural space is primarily “read” in the visual field, humans use the same conceptual rules found in processing the rest of the physical world.

According to Lakoff and Johnson, there are three major generic-level metaphors operating as the engine behind agency and personification in architecture. These are EVENTS ARE ACTIONS, ACTIVITIES ARE CONTAINERS and STATES ARE LOCATIONS. Generic-level metaphors are important because they provide a skeletal structure with little specific detail allowing for basic cognitive understanding. Generic level metaphors have no fixed source or target domains and no fixed lists of entities specified in the mapping. They can be applied to a conceptual formal domain by taking the skeletal structure and relating it to relevant schemata for the situation and adding parameters.

The operation of these analogical operators can be seen by looking at the Diamond Ranch High School (1999) by Morphosis (Fig. 4). The building was to merge with the site topography to create a hybrid landscape/structure while aggressively addressing programmatic organization on a limited budget. As Thom Mayne stated, ”Diamond Ranch High School engages architecture in the act of education; it speaks to students experientially through a physically kinetic architectural language that makes no references to traditional typology, but rather looks elsewhere to encourage student inquiry and provoke curiosity.”(Mayne 2006). There are already analogies found in the intention of the work by the use of terms such as 'speaks', 'kinetic' and 'look' – acts that architecture is not capable of performing except through analogy.

Figure 4: Diamond Ranch High School by Morphosis. Source: (Highsmith Archive, Library of Congress 2005)

Agency uses generic-level conceptual metaphors in order to give authority and imply behavior to architectural forms. EVENTS ARE ACTIONS is at the core of any activation of a static object. The basis of the analogical operation is the conceptual translation of something that is inert and static into something that acts upon the surrounding environment (Lakoff and Johnson 1980). This conceptual metaphor primarily uses the image schema domains of locomotion (momentum, path, visual inertia), balance, containment, and force (compulsion, blockage, diversion, counterforce, restraint, resistance, attraction, and enablement). As a generic-level shell, there is neither an expected scale nor a fixed source. The agency generated by EVENTS ARE ACTIONS might be at the scale of building to environment, at the smaller scale of elements to another element or an aspect of the architectural massing. The event is the engagement of formal elements in the composition created by the architectural designer.

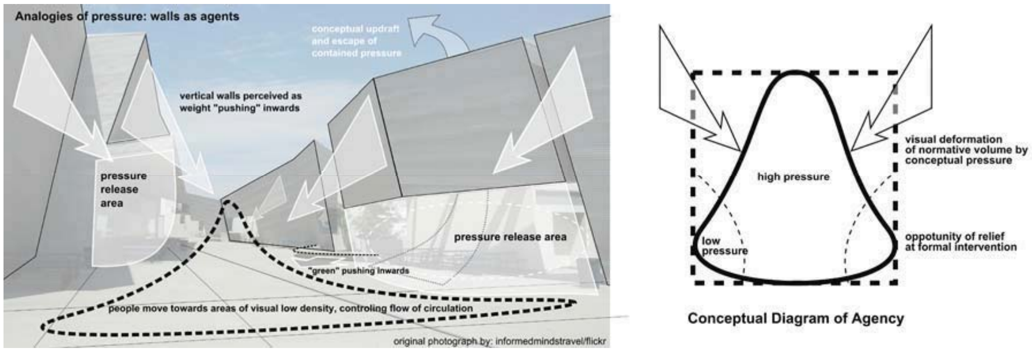

Figure 5: Analogy of pressure created by the conceptual metaphor EVENTS ARE ACTIONS. Source: (Author)

At Diamond Ranch, one example of EVENTS ARE ACTIONS is in the creation of pressure through the formal composition of the walls in the central street (Fig. 5). The idea of the street is an analogy itself, as Morphosis sought to transfer urban ideas of density and activity to a suburban context where that situation does not exist (Mayne 2006). To take the idea further, the buildings fronting the central circulation lean inwards to produce a contained space akin to a canyon (another analogy used by Morphosis in this context). The sloping buildings are described as “compressing” space. But that compression isn't literal – again, there is no change of air pressure or physical density. The compression is achieved through giving the walls agency, the ability to be perceived as pushing even through the walls do not move and cannot push. This is an analogical transfer using the conceptual metaphor EVENTS ARE ACTIONS. The event is the relationship between the walls and central circulation while the action is the act of creating visual pressure by walls that lean inward toward the visitor..

Agency does not only need to use physical objects and defined formal elements as its target domain. Architectural design leverages containment schemata heavily in order to address two of its most fundamental criteria in architectural composition – occupation (how a space is used) and circulation (how a space is moved through). A critical requirement for architectural design is the ability to communicate both spatial qualities of occupation – traditionally called the *distribution* of program – and movement as a relationship of formal composition to human interaction. The attempt is to make both of these intuitive to the user. Considering that conceptual metaphors are used as communication devices acting below conscious awareness to connect design intentions to natural understanding (Blackwell 2006), this makes their involvement critical in interpreting circulation and program by a user. Good analogical transfers are not apparent, they simply work.

The major conceptual metaphor that engages programmatic elements and occupation is ACTIVITIES ARE CONTAINERS. This mapping uses containment schemata and operates by creating a conceptual boundary around activities that do not have a physical boundary. Once the activity has been conceptually bounded, it may be either given agency or be acted upon by force or identity schemata such as compression, intersection, interlacing, expansion, or superimposition. Activities, through this conceptual metaphor, take on characteristics of formal objects and can be manipulated in the same way. At Diamond Ranch, the central exterior circulation, conceived as a pedestrian street, operates using ACTIVITIES ARE CONTAINERS (Fig. 6).

Morphosis considered the street as providing “the primary opportunity for students to interact haphazardly or by plan with one another, with teachers and with administrators as they move about the campus.” (Mayne 2006). In order to operate in this way, several different types of activities where considered to co-exist within a space which did not formally define territories with physical demarcation – there where no walls, barriers or “lines in the sand” to show the location of these activities. Instead, the activities were conceptually bounded and then engaged through overlap, interlacing and superimposition. There is nothing *making* the central street operate as supporting any activity other than circulation except through human perception of differentiated space. The creation of perceptual pressure using EVENTS ARE ACTIONS supports

ACTIVITIES ARE CONTAINERS through overhangs and angled walls which create interpreted pockets of spaces. These spaces become meeting areas, seated discussion locations, informal discussion spots and gathering points. The large monumental stairway moving from the street to the upper level playing fields doubles as an outdoor amphitheater. In this way, the stair acts as both circulation and seating – metaphorically an act of superimposition with two containers – the stair of movement and the stair of spectator occupying the small space but having different purposes. It must be noted, however, that the spaces don't need used in the way suggested as there is nothing physically present to make it so (except some movable tables for the seated discussion). The interpretation of a space within the major circulation as supporting interaction is due to perceiving that space as fundamental different to its immediate surroundings as a conceptual act.

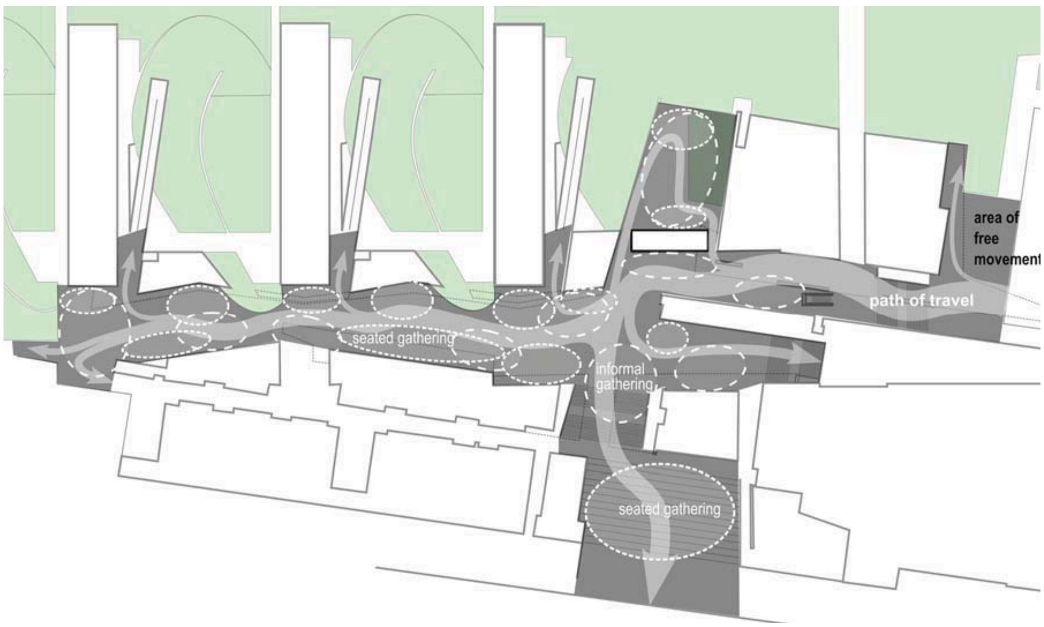

Figure 6: Conceptual bounding of activities in demarcated circulation space using the conceptual metaphor ACTIVITIES ARE CONTAINERS. Source: (Author 2012)

There is often personification involved in agency when EVENTS ARE ACTIONS or ACTIVITIES ARE CONTAINERS are engaged as analogical operators. When a building is discussed as 'feeling' in a particular way, looking in a certain direction, or having a relationship with its context, these are statements of personification. As an example, some students complained that Diamond Ranch High School “looks like a prison, though, all concrete and cold.” (Borow 2003). The intention in this statement was not that the building was physically cold but it was interpreted as being *emotionally* cold. Yet, as noted, it is impossible for a building to have emotions as this is a human projection. The primary ability for an architectural space to be personified comes from the conceptual metaphor LOCATIONS ARE STATES. This conceptual metaphor operates by mapping a state of mind or personality onto a location, programmatic boundary or bounded space. It isn't necessarily as straightforward as a space “feeling” inviting, noble, serious, somber or nurturing as in the traditional use of the term *character*. When Thom Mayne of Morphosis described the lower courtyards of Diamond Ranch as “buffers” which act to engage the classroom with the landscape (Mayne 2006), he was stating that the courtyard space had a particular personality and state of being that was different to its context (Fig. 7). A buffer is a recognizable *space of difference* from the immediate adjacency and the only way that difference can exist is through interpretation of human dimensions. In addition, the courtyard contains two different 'personalities'. The east side is 'tame' or 'polite' and acts as an extension of the classroom. The west side reinforces the idea of buffer by being conceptually separated from human space by appearing 'wild' or 'natural'. The act of buffering could also be considered an event but it operates through the difference of emotional state between the two spaces (identity schema), and not through force schema. In the end, however, these are all human conceptualization of space.

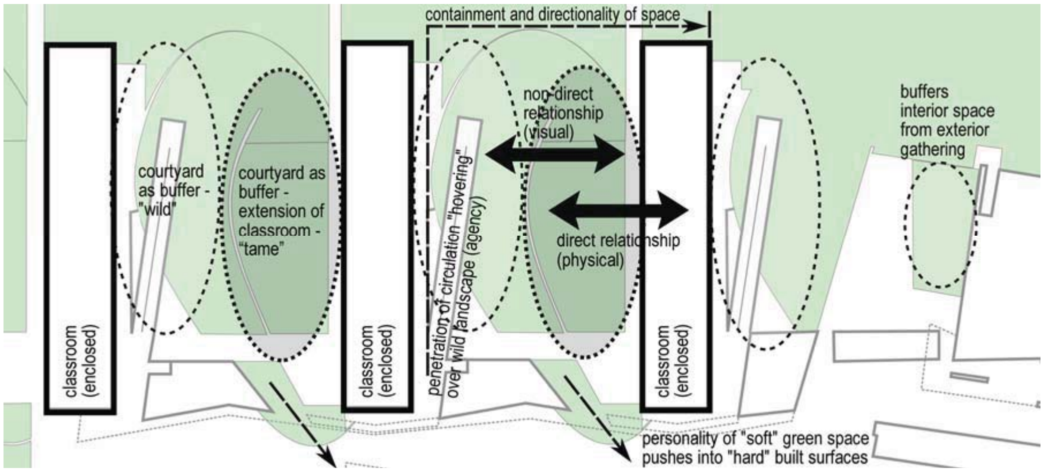

Figure 7: Personification of architectural space by the conceptual metaphor LOCATIONS ARE STATES. Source: (Author 2012)

CONCLUSION

To adapt a statement from Lakoff and Johnson – since the processing of our physical surroundings is based on "the same conceptual system that we use in thinking and acting" (Lakoff and Johnson, 1980), those same conceptual structures are used in architecture whether we admit it or not. Interpretation, both generative by the designer and experiential by the occupant, will be easiest transferred through basic conceptual functions – the role that analogy and metaphor fills in our cognition. The most active understanding of analogies in architecture comes from the use of agency and personification. While these are not the only conceptual tools behind the shaping of architectural space, they seem to provide an essential link in the transfer of intentions and how space is moved through and occupied. This is because through analogy, the concepts transfer at a low level and without the need for active interpretation. They engage innate and sensorimotor levels of comprehension. If these analogical operators are not present in architectural spaces, the question is: could there be any meaning generated by that architectural space, considering architectural meaning is a relationship formed between the space, elements and human cognition?

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An Anarchist Guide to Historic Rooms and House Museums

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ABSTRACT: Historic house museums (HHM) and period rooms contribute to the national identity and a cultural memory. Traditionally they have stood as shrines to a person or concept - reminders for social continuity. Today, most HHMs are struggling for relevancy, and their place within the complex new structure of fast-paced, Internet based media. As a result of these cultural shifts, HHM and period rooms are having difficulty in finding new audiences, increasing fundraising, maintaining volunteers, producing relevant programming and planning for long-term stewardship.

These houses and rooms hold a unique position in modernity. They have been actual private domestic worlds encapsulated and re-presented as public narrative. These architectural fragments exist in the volatile world between the REAL and the IDEAL. This paradoxical existence contains the most potential for an authentic "reading" of these domestic realms.

Our research presents a methodology that makes visible a more holistic narrative of habitation. It begins with a critique and mapping of three HHMs and nine period rooms at the Metropolitan Museum of Art in NYC. These recordings reveal a less than authentic experience characterized by a proliferation of *denied spaces*; the lack of the detritus of human habitation and the choreography it suggests; and, the absence of *preservation variation*. This cleansing of history denies the potential use of *Conjecture/Rumor and Gossip in narratives*; or the presence of *Simultaneity* and *Fingerprinting*. To address these shortcomings, we suggest through illustrative recordings and design proposals how the visitor experience can expand to include *Ownership, Overlapping,* and *Trans-position*.

The sustainability of HHMs will depend on a new methodology that makes visible a more holistic narrative of habitation, one that embraces a chorus of diverse voices from both inside and outside the museum. *The Anarchist Guide to Historic House Museums* is a manifesto offered toward that cause.

KEYWORDS: Civic Engagement, Historic House Museum, Anarchist, Period Room

INTRODUCTION

In 2007, national leaders of historic sites gathered at the Rockefeller Estate of Kykuit to discuss the challenges being experienced by historic sites. They found that:

> America's historic sites offer unique opportunities for learning, for reflection, for inspiration. At their best, they can be powerful places that provide great value to their communities. They can offer programs, services, and experiences that are relevant to many of the most pressing issues of our day. America's historic places should be places to nurture the human spirit.
>
> Despite this potential, however, many of America's historic sites are experiencing declining attendance, financial instability, and poor stewardship, and they are increasingly viewed by their communities as irrelevant and unresponsive to the societal changes around them. (Vaughn 2008)

1.0 CONTEXT

Museums must become more central to community life by inviting people to actively engage as cultural participants, not passive consumers. (Simon 2010) In the past 40 years, museum theory has focused on doing just that, creating a symbiotic relationship between museums and their surrounding community. If there was an unnecessary separation heretofore, it was because museums were originally established as temples of high culture, intended to reform and civilize the masses. (Moore 2000) This disconnect is due to the objectification of building design and artifact conservation, following modernist theories of architecture and art history, that have resulted in an artificial disjunction between historic buildings and their evolving context. (Hewitt 1984)

Museums must demonstrate their social relevance if they are to survive. Institutions need to become more knowledgeable about the needs of their visitors and be more adept at providing enjoyable and worthwhile experiences. (Hooper-Greenhill 1994) Gretchen Sorin, Director of the Cooperstown Graduate Program advocates for, “engaging the community--whatever it happens to be in the process. Otherwise, it's *just us* guessing what is of interest or use to the community.” (Sorin 2013)

Museums are places that empower their community by acting as informers and educators. (Watson 2007) Their outreach to their larger community is imperative, as they can change the world around them. (MacLeod and Watson 2007, Genoways 2006)

Museums should be portals for reflection for the outside world rather than a fortress of knowledge that people enter. They should be more than a collection of beautiful and rare objects, but rather be a place of dialogue and social gatherings. (Chew 2009, Pitman 1999)

The Kykuit attendees further stated that innovation, experimentation, and collaboration were essential to Historic House Museum (HHM) sustainability, acknowledging that success would be dependent on the leadership’s willingness to change its structure, programs, and services. These national leaders specifically recommended that HHMs no longer think of the docent-led tour as the primary method for structuring the visitor experience, and that they should generate more varied ways to utilize their resources to enrich people's lives. Michelle Moon, Assistant Director for Adult Programs at Peabody Essex Museum agrees:

> One thing it means for the quality of tours is that people less inclined to be tolerant than you avoid them like the plague! Having the reigning model of historic house experience be the guided tour comes at a very high cost: we lose the potential support and interest of the majority of visitors who don't enjoy guided tours. That worries me most of all. (Moon 2013)

When Americans visit historic sites and museums, they want more than just information. They seek to make a personal connection with the people and spirit of earlier times. (Cameron and Gatewood 2003) Many want to pretend to be part of the past, through doing crafts or chores, or to be included in curatorial decisions that help determine the experience of their visit. (Magelssen 2006)

Figure 1: Embracing *Conjecture, Rumor and Gossip* per the AGHHM, Danielle Scesney proposed tying ribbons with hand-printed secrets to the fence of the Van Cortlandt House family vault, reinforcing it as a place where history was (and potentially remains) hidden.

Yet even with the extensive support for re-imagining and especially community engagement, HHMs have been slow to adapt. Some suggest that is a consequence of many HHMs being run by well-meaning and hard-working volunteers. Many are elderly, educated, wealthy white women with conservative views of what history encompasses. They follow in the footsteps, or are members themselves of patriotic societies like the Daughters of the American Revolution (DAR), or the Colonial Dames. Both organizations were founded in the 1890s with a mission *to teach patriotism by erecting monuments and protecting historical spots, by observing historical anniversaries, by promoting the cause of education, especially the study of history, the enlightenment of the foreign population, and all that makes for good citizenship*. (Butcher-Younghans 1993) For many involved with HHMs, it is a mission that needs to be revisited, but a significant challenge to undertake. As Carol Ward, Deputy Director at the Morris-Jumel Mansion asks, how can, “I get tour guides who have been at a site longer than I've been alive to buy into these new ideas?” (Ward 2013)

2.0 THE ANARCHIST GUIDE TO HISTORIC HOUSE MUSEUMS

HHMs must demonstrate their value and relevance in contemporary life. They must look at familiar issues from new perspectives and using new methods. (Donnelly 2002) *The Anarchist Guide to Historic House Museums* (AGHHM) calls for the holistic de-construction of the HHM and the re-establishment of a paradigm from the perspective of **human habitation**. Offered as an evolving graphic manifesto, the AGHHM contains 21 measures within four thematic categories:

- Community engagement and information exchange
- Physicality and inter-activity
- Visual expression of habitation
- Condition and preservation

Students in the School of Architecture at the University of North Carolina at Charlotte (UNCC) and Cooperstown Graduate Program in New York have been testing the AGHHM for the last several years. Their work began with comparative mapping of human habitation in their own homes, and of the Historic Rosedale Plantation House (built 1815) in Charlotte. Later, they deconstructed the visitor experience at the Van Cortlandt House in the Bronx, Wyckoff Cottage in Brooklyn, and nine period rooms at the Metropolitan Museum of Art in NYC and offered proposals to improve community engagement and historical interpretation through an Anarchist lens.

2.1 Community engagement and information exchange

HHMs should be re-conceptualized as places that bridge the past and the present, and bring together diverse communities by taking on the role of depositories of social history, shared memories and shared identity. (Matejková 2009). The AGHHM suggests *embracing the neighborhood politically, contextually, and programmatically.* To meet those goals and reach out to the three very distinct but diverse neighborhoods that surround the Van Cordlandt House, UNCC architecture student Danielle Scesney proposed parking food trucks at the estate once a week. (Fig. 2) Through food and drink, her intent was to introduce a shared history of immigration, and increase awareness about the estate's once thriving wheat fields, and the bread and beer the Van Cortlandts produced from it.

Figure 2: *To embrace the neighborhood politically, contextually, and program-maticly* per the AGHHM, Danielle Scesney proposed parking food trucks at the Van Cortlandt House once a week.

The AGHHM suggests *ending the romanticizing of history and embracing conjecture, rumor and gossip* Similarly, Kathryn Boardman, Adjunct Instructor at Coopers-town Graduate Program states that HHMs should…

> Push the envelope - but just be aware that some stories are not ready to be told because the board, family and supporters of a site are not ready to have them told. History as we would like it to be gets in the way. (Boardman 2013)

A short walk from the Van Cortlandt House, but hidden from view on a heavily treed hill is the fenced, family vault. As would be expected, members of the Van Cortlandt family were buried there, although their remains have long since been moved. More importantly, is the belief that the vault was where NYC's founding papers were hidden and kept safe during the Revolutionary War. It was a place where history was hidden, and remains largely so today. Embracing the vault's history as a place where secrets could still be kept, Scesney expanded her food truck proposal, suggesting that each vendor wrap their food or drink with a ribbon on which a secret, a bit of conjecture, or rumor about the Van Cortlandt Family was printed. (Fig. 2) On the back of the ribbon, customers would be encouraged to write their *own* secrets and tie them to the fence of the vault for safekeeping. While there, they could read the other secrets left behind, and come to better understand the human frailty of their neighbors, whether past or present. (Fig. 2)

The AGHHM encourages the development of opportunities for *Ownership*, an emotional or physical take-away from a visit, and *Fingerprinting,* a physical or digital mark left by a visitor. UNCC architecture student Steve Craton proposed attaching Ipads to Scesney's food trucks, inviting patrons waiting in line to take headshots of themselves, which would be inserted into digital replicas of the portraits hanging in the house of the Van Cortlandt family. After entering the house, they would then search for the portraits and learn more about the family members they were *replacing* through written material posted nearby. The technology to undertake Craton's proposal already exists and is incorporated at www.bbcamerica.com/copper/mugshot-yourself, the website for the BBC America crime drama series *Copper*, set in NYC in 1864. At http://www.takethislollipop.com an equally engaging online *Ownership* process scrapes visitors' Facebook pages and inserts their personal photos into a video.

Trans-position is the transfer and replication of historic exhibitions in non-museum spaces like retail and service settings with an acknowledgement that there is a role for *both* authentic and re-created rooms in conveying history. (Gordon 2008, Matejkova 2009) *House Stop* was a proposal by UNCC architecture exchange student Paula Benitez-Ruiz to create a replica of a room from the Van Cortland House in a

Figure 3: Employing *trans-position*, Paula Benitez-Ruiz proposed replicating a room from the Van Cortlandt House in a shipping container and using it as a bus shelter and coffee shop.

shipping container, and to move it throughout the city for use as a temporary bus shelter. Once off-loaded from a truck, the container would fold open and the public would be invited in to use the room as it was originally intended, while enjoying coffee from a small, embedded café. (Fig. 3)

2.2 Condition and preservation

Ignoring the growing diversity of the American public, and relying solely on outdated, traditional practices can result in HHMs being pretty boring to all but the most ardent history fans. To broaden interest in the museum to a wider demographic, the AGHHM suggests *embracing the concept of simultaneity*, or the overlapping of a series of narratives, rather than just that of the head of the family. The museums' usual emphasis on white, male political leaders is partially because many of the HHMs were created at the end of World War I, when there was a rise of nationalism and a enthusiastic allegiance to the U.S. Unfortunately, this myopic focus led to the omission of most other members of family, and of the servants that also called the house a home.

When visiting Rosedale, UNCC architecture and dance student Steve Craton became uncomfortable with the lack of attention given to the slaves that contributed to the running of the plantation. Taking offense after learning that the room

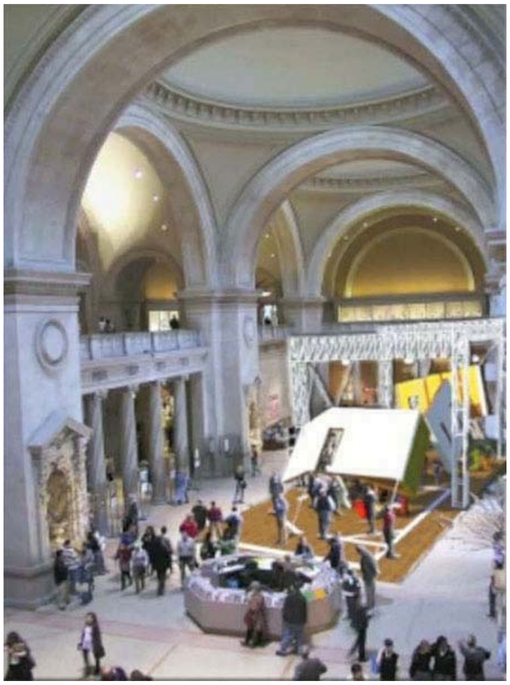

Figure 4: Robert Miller II proposed deconstructing the Fitzhugh Room and relocating its walls to the Met Entry Hall where they would be hung askew and presented as the art.

Where the kitchen slaves slept was now being used for storage, and that their presence was almost entirely omitted from the house's narrative, Craton performed and recorded an interpretive dance of restraint and bondage in their closet-sized bedroom.

The AGHHM encourages *preservation variation*, and argues for *complexity* as expressed through the detritus of human habitation. Others have also critiqued the sterile preservation of objects in museums, and the restoration of HHMs to their *original* condition, often stripping them of the essence that conveyed their historic use as a home. While preservation must contain an element of renewal, nostalgic sentimentality should be avoided. Restoration should be concerned as much with the future as it is with the past, while also preserving and communicating a spirit as well as a form. (Mansfield 2001)

The Fitzhugh Room (ca. 1758) is a beautifully paneled, painted empty period room at the Met, completely devoid of both detritus and furniture. In *Wall as Art,* UNCC architecture student Robert Miller II proposed deconstructing the room, and relocating its walls to the Metropolitan Museum of Art Entry Hall where they would be hung askew and presented as the art curators purported them to be. Doing so would allow both the front and the back of the walls to be visible, exposing their structure and illustrating a broader range of *preservation variation*. (Fig. 4)

2.3 Physicality and inter-activity

Tactility is the physical connection to artifacts. HHMs privilege visual experience even though touch is crucially important to many visitors' experiences, and offers an accessible and inclusive way of engaging with museum collections. (Candlin 2010) The Director of the Cage Center reports that her institution allows unrestricted access to *everything* including Gage's original desk.

> You're invited to sit down at it, help us figure out words we can't decipher in one of her letters, and write her a note, which you leave in a cubby hole in the desk. People treat it as a sacred space, one woman sat there for over an hour. We can do it because, guess what? I own the desk. And I'm not giving it to the Gage Center until I prove my point - that when you trust people, they will respond in kind. We're new, underfunded, understaffed, and in the nearly three years we've been open, we've not had a single thing walk out the door. But people leave us fascinating comments on our walls, where they are invited to write on an entire whiteboard wall in each of the rooms. (Wagner 2013)

Figure 5: Courtney Hathaway pro- posed relocating 15 Period Rooms along the open corridors in the Charles Engelhard Court of the Met's American Wing. *silence, and engaging all the senses.* Baird employed sound as his mapping medium, and intermixed the sounds of his own life, and those he presumed once filled plantation. It is a haunting recording that emotionally links the past and present through the shared experience of sound.

In *The Dollhouse*, UNCC architecture student Courtney Hathaway proposed to relocate and stack fifteen Period Rooms along the open corridors in the grand, light filled Charles Engelhard Court of the Met's American Wing. (Fig. 5) The rooms are currently located in a difficult to navigate, maze like arrangement behind a beautiful but imposing, classical stone façade that overlooks the Court. Moving them in front of but perpendicular to the facade would significantly increase their visibility and accessibility within an already active space. Further, she proposed moving some of the original furniture in the relocated rooms to the Met's Visible Storage area, and replace it with reproductions. Doing so would allow visitors to actually experience the rooms as they were originally intended: as parlors, living and dining rooms. In the spirit of full participation, Hathaway further specified that the floor level Period Room replicas should replace the generic seating in the existing café.

When music enthusiast and UNCC architecture student Seth Baird visited Rosedale, he found the absence of music and conversation to be what most differ- entiated his life at home and his experience at the HHM. The AGHHM recommends *killing the*

2.4 Visual expression of habitation

Overlapping is the design of a visitor experience that layers different life cycles and eras, and it was the basis of UNCC architecture student Aracelli Bollo's proposal for the Met's Haverhill Period Room (ca. 1805).

Figure 6: Aracelli Bollo proposed the use of black screen technology to project images of visitors into a Period Room.

Entitled *Projections on the Past*, she proposed using black screen technology to insert visitors' own images into the Period Room. Her plan would place a black bed on a black screen, and a black wingback chair in front of a black screen in the arrival hall of the Met, and visitors would be photographed sitting or lying on them as they would in their own home. After a delay long enough to allow the visitors to find their way to the Period Room, she would project their images into the Haverhill Room. She also proposed filling the rooms' windows with real time images from the streets of NYC, layering inside and outside, and the present with the past. (Fig. 6)

Unveiling reveals hidden operations that can be either architectural or social. In *Living is Not Still*, UNCC architecture student Angie Scharrer proposed replacing a wall in the Met's Baltimore Room (ca. 1810) with a large video screen that appeared to reveal an adjacent room where the owner's guests could be seen dancing to a mix of period and contemporary music. To further set the scene, Scharrer also proposed broadening the sensory experience by piping in simulated cooking smells from the adjacent but unseen kitchen, and by playing a tape of the house's maids preparing to serve dinner while gossiping about the guests.

3.0 THE MANIFESTO

HHMs hold a unique position in modernity. They have been actual private domestic worlds encapsulated and re-presented as public narrative. These architectural fragments exist in the volatile world between the REAL and the IDEAL. This paradoxical existence contains the most potential for an authentic *reading* of these domestic realms.

The sustainability of HHMs will depend on a new methodology that makes visible a more holistic narrative of habitation, one that embraces a chorus of diverse voices from both inside and outside the museum. *The Anarchist Guide to Historic House Museums* is a manifesto offered toward that cause. It was written in response to four general statements:

- HHMs can be boring.
- HHMs are too narrowly curated.
- HHMs promote selective propaganda and can be socially out of touch.
- HHMs are expensive to preserve and maintain.

The AGHHM encourages the celebration of physicality and inter-activity by choreographing the visitor experience to convey real use, allowing them to roam freely through the building and collections, and by engaging all of their senses. HHMs should focus on the expression of habitation through the creation of environments that are complex, messy, full of human detritus, and reflect daily cycles. Community engagement and the exchange of information are essential to long-term sustainability. These actions should embrace conjecture, gossip and rumor through complex narratives, and include all forms of personal fingerprinting made available through social media. HHMs should embrace multiple theories of preservation, be honest about the illusion of authenticity, and celebrate simultaneity.

HHMs are already doing many of these things, but they are often done as one-offs, rather than as part of a coordinated strategy. The intent of the AGHHM is to provide a relational framework to promote on-going, though sometimes seemingly disparate efforts within each HHM.

Critiques are easier than solutions to produce. The chart in Figure 7 presents a graphic metric attempting to bridge the two processes. Intended as a self-assessment tool, the goal would be to color in increasingly larger circles and increasingly more pie pieces as the quality and quantity of the Anarchist efforts grow at each HHM. With each new project the graph evolves just as historic sites do. It is intentionally left incomplete, waiting for more public input.

Figure 7: The Anarchist Guide to Historic House Museums Graphic Manifesto.

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Reconsidering the Voice of Architectural Discourse: A Case for Qualitative Research

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ABSTRACT: The voice of architectural discourse is primarily derived from institutional power. Research focused on disrupting this power has become more prominent in the field. Beyond the quantifiable roles architecture and urbanism play in poverty and access to services, more insidious social imbalances of gender and race in architectural history and practice have been unveiled through feminist and multicultural lenses. Though invaluable, the presentation of these issues continues to adopt the conventional institutional voice of scholarly removal. This essay explores a variety of more inclusive research methods established in the social sciences under the banner of qualitative research.

KEYWORDS: Architectural discourse, institutional power, qualitative research, social justice, social science

INTRODUCTION

Who has the right to speak for a building? Is it the scholar who has spent their life understanding its cultural and material context, perhaps only visiting once? Or is it the untrained individual who spent their life living or working in the building, witness to ten thousand sunsets, ten thousand different sounds, ten thousand chances to touch and smell the place intimately? This paper recognizes that both answers should be correct, though the balance is currently tipped toward the institutionally knighted scholar.

Scholarly architectural research has a common voice rooted in institutional cultures and products. Writings in this voice are a self-fulfilling prophecy of what we will call transactional scholarship. Rather than empowering citizens of the built environment, their function is to control by transmitting knowledge. The institutional approach comprises an inescapable voice in the intellectual and material lives of the field.

Architectural research in the topic of disenfranchised populations has sounded an implicit call for methods of inquiry that will give voice to silenced populations in a meaningful way. Yet, the grip of convention in architectural scholarship is tenacious. This research is still primarily structured on the same critically detached, monocular model that has reinforced predominant narratives of design by excluding non-authoritative perspectives. However, we do not want to disparage these efforts. We are no less guilty of such hesitation. We see this as necessary simply to gain the legitimacy to dip our toes in the pool of discourse. However, we agree with Audre Lorde's adage that "the master's tools will never dismantle the master's house."

This essay first explores the dominant voice of architectural discourse characterized in historical and theoretical scholarship. It is our assertion that this voice contributes not only to the exclusion of socially and economically disenfranchised voices, but to the exclusion of the voice of the public at large. Secondly, a sampling of scholarly literature currently striving to expand access of other voices into architectural discourse is reviewed. Finally, these are contrasted with the methods of qualitative analysis used in the social sciences to give voice to populations that have historically been silenced.

1.0 THE VOICE OF ARCHITECTURAL DISCOURSE

1.1 Institutional Legitimacy

C. Greig Crysler's book *Writing Spaces: Discourses of Architecture, Urbanism, and the Built Environment* proved an invaluable resource in distilling the qualities of scholarly writing about architecture. To understand the role of scholarly texts in the discipline of architecture Crysler analyzes five exemplary journals in the field of built environments: *The Journal of the Society of Architectural Historians* (*JSAH*), *Assemblage*, *The*

Traditional Dwellings and Settlements Review, *The International Journal of Urban and Regional Research*, and *Society and Space*.

It is Crysler's position that scholarly journals play the preeminent role in establishing the discourse of architectural. They play a key role in the promotion of departments and programs for things like admissions and recruiting, fundraising, and general cachet (Crysler 2003, 10). He asserts that because of its institutional legitimacy journal research is able to influence policy decisions related to the field (Crysler 2003, 9). As a central component of the educational climate, journal research affects and shapes the positions and perspectives of students who will go into practice constructing the built environment.

In Lesley Lokko's introduction to *White Papers, Black Marks* she notes that identities in power "pursue their own pleasures – from the writing of history to the media of representation" and that "the world is usually organized according to principles that flatter the dominant imagination (Lokko 2000, 33)." Indeed, journals have a major role as a gatekeeper of the information, positions, and voices that establish the dominant narrative for contemporary practices. Art critic and curator Lawrence Alloway calls these "spectacular acts of exclusion (Alloway 2006, 243)."

Two journals that Crysler profiles clearly represent the homogenous voice of contemporary discourse, both historical and theoretical, and its influence on the tones and trends of education and practice in architecture: the *JSAH* and *Assemblage*.

1.2 *The Journal of the Society of Architectural Historians*

Crysler's analysis of the *JSAH* finds its perspective to be univocal. Works are predominantly omniscient third person narrations that favor a scientific voice, where the "narrative is… treated as a neutral container of historical fact (Crysler 2003, 36)." Works in the *JSAH* are of two genres: the architect and the work. The first genre fixates on the heroism of the architect by embedding economic, social, political, and building forces into their consciousness. Conversely, the second treats their buildings as acontextual apart from purely typological or formal ancestry (Crysler 2003, 37). In both approaches the third person voice focuses on a mimetic presentation of history that attempts to embed the content outside of the author's consciousness, into the unassailable matter of the object. By appearing to lack speculation this voice fosters the belief in a positivistic natural order to architectural history that it has itself applied.

1.3 *Assemblage*

Regarding architectural theory, historian Hanno-Walter Kruft rejects the validity of this positivism. He argues for a more polyvalent and unlimited scope of inquiry (Kruft 1994, 14). Crysler's assessment of the journal *Assemblage* establishes its origins in an assault on the "cycle of affirmations" inherent in abstract and idealized scholarly journals such as *JSAH*. *Assemblage* reacted against a voice that "maintains disciplinary boundaries, dominant institutions, and disengaged modes of practice (Crysler 2003, 58)." One of *Assemblage*'s foundational principles was to reject that meaning is inherent in the architectural object. *Assemblage* approaches objects obliquely hoping to dislodge the static narrative of their cultural context. The expanded constellation of referents comes into play through what editor K. Michael Hays calls "transcoding." By transcoding architectural knowledge to locations of outside of architecture proper its effects are moved outward into the general socio-cultural field (Crysler 2003, 58). Calling their work "text as architecture (Crysler 2003, 65)", these writers consider the text itself to be a parallel construction parallel not an attachment.

1.4 Institutional voice

Assemblage has profoundly influenced the character of contemporary architectural scholarship. But did the voice of *Assemblage* really differ in a material way from that found in journals like *JSAH*? Crysler himself asserts that:

> *Assemblage* reproduced many of the characteristics of the modernist writing it criticized. Both the critic and the designer become heroic figures who endow form with the capacity to capture and transform the social world (Crysler 2003, 75).

While the reliance on and necessity of the social world to actualize and make meaning of form are paid lip-service through the assertion that the texts are architectural conditions whose meaning is constructed outside their form, this postmodern sleight of hand continues to serve the goal of ossifying institutional authority. At their foundations, both journals construct representations on a lineage of scholarly precedent. We don't argue against the legitimacy of scholarship originating in institutions. However, we argue that they have greater responsibility to the citizens of the built world to be more inclusive in their inquiries.

2.0 ADDITIONAL VOICES

2.1 The social component of architecture

Christian Norberg-Schulz emphasizes the social component of architecture in the introduction to his sweeping book *Architecture: Meaning & Place*.

> Human life cannot take place anywhere, it presupposes… *a system of meaningful places*. It is the task of the architect to give such places such a form [offering rich possibilities], that they may receive the necessary content (Norberg-Schulz 1988, 24-26).

Even the great proponent of inherent architectural meaning, John Ruskin, asserted that:

> It is not until a building has assumed this character… hallowed by the deeds of man, till its walls have been witness of suffering [that it] can be gifted with so much as these possess, of language and of life (Ruskin 1903, 234).

Let us accept that architecture is a social construct as well as vehicle. In this context architectural discourse languishes embarrassingly behind other inquiries into social phenomena.

2.2 Calls for additional voices in architectural discourse

> Architecture continues to be that art with the most irrefutable and unavoidable grounding in social life. In addition to merely evaluating the aesthetic relevance of individual projects, architectural theory, criticism, and education should survey the now-neglected cultural ground – the preconditions of the art of architecture (Pallasmaa 2007, 97-98).

The voice of the public, the citizens of the built environment, is marginalized by the exclusionary conventions of transactional scholarship in architectural discourse. A call from the profession, both practitioners and educators, to explore methods for introducing new, more diverse voices into architectural research is found in a survey of the literature from the diminutive realm of progressive thinking in architecture. These calls for inclusion generally take the form of research projects whose subjects lie on the outside of realms of traditional scholarship (minority groups, women, LGBTQIQ individuals). In Joan Rothschild's introduction to *Design and Feminism*, prominent British architect Etain Fitzpatrick is quoted as saying of the texts in the volume (and indeed all that we surveyed) that:

> A common thread throughout these essays is the promotion of inclusionary practices which challenge predominant ideologies that separate, divide, and erase identity (Rothschild 1999, 2).

Roberta Feldman's essay "Participatory Design at the Grass Roots" (Feldman 1999, 135-148) covers a group disenfranchised by the power structures that architecture can be complicit in shoring up. In this case the subjects are residents of a Chicago public housing development. The essay includes numerous photographs of the residents in spaces they have reclaimed from the housing authority. Though mostly written in the conventional scholarly voice, the article opens with three unattributed quotes. For example:

> We don't give up… We're willing to fight for what we need here and what we want here, and I think that's the strength we have (Feldman 1999, 135).

One other quote attributed to an activist resident detailing her neighborhood's needs is used, though without strong methodological integration in the text. The rest of Feldman's text is heavy with citations, including many of her own publications. In the same volume, Lynne Walker and Sue Cavanagh's essay "Women's Design Service" (Walker and Cavanagh 1999, 149-157) is filled with photographs of forlorn-looking women pushing strollers and emerging crestfallen from subterranean public toilets. The voices of these women are not quoted, or referenced, or included.

White Papers, Black Marks deals in a diverse and complex manner with issues interrelating racial identity and architecture. The photographs in many of the book's essays capture disenfranchised figures in the architectural conditions that subjugate them. Malindi Neluheni's essay, "Apartheid Urban Development" (Neluheni 2000, 67-90) is one example. Contrasting these moving photographs is a text that maintains its scholarly distance. By using no quotes or voices of the pictured it continues to yoke these figures as others whose voices cannot be heard. Their stories are filtered through the institutional voice. They are not given license to speak on their own.

Although certainly more such work exists, the greatest break with convention and the most inclusive work in this survey is artist Imogen Ward-Konao's "Anything Red Doesn't Come to the House" (Ward-Kanao 2000, 305-347). This text is described as a "visual diary" of the author's apprenticeship to a Ghanaian artist in a section of the book described as including "a more elastic interpretation of architecture (Lokko 2000, 279)." Including a wide range of photographic materials documenting her experience, Ward-Konao also includes a very lengthy and detailed transcription of a conversation with her mentor.

Social ecologist and educator Sherry Ahrentzen approaches the call for a more inclusive voice most definitively in terms of feminism's most basic societal goals and how they might enter into the architectural discourse (emphasis mine):

> "Looking at the social context shifts analysis from abstract and binary differences to the social relations and contexts in which *multiple differences are constructed and given meaning*. Transformative contextual feminism… seek[s] the production of a better set of social constructs than the ones presently available, and thus the creation of new and better sorts of people and places (Ahrentzen 1996, 93-94)."

2.3 Why are additional voices valuable?

The attitude implicit in architectural discourse is that untrained individuals cannot understand the complex interrelations between architecture and its cultural, economic, and material contexts. A countering perspective has been described in detail by Black feminist thinker Patricia Hill Collins. She presents two prevailing positions: that subordinate groups identify with their oppressors and therefore have no personal perspective on their identities, and that subordinate groups are less human and not capable of constructing articulating their own identities. However, in their everyday acts of resistance:

> Black women's political and economic status provides them with a distinctive set of experiences that offers a different view of material reality than that available to other groups... these experiences stimulate a distinctive Black feminist consciousness concerning that material reality. In brief, a subordinate group not only experiences a different reality than a group that rules, but a subordinate group may interpret that reality differently than a dominant group. (Collins 1989, 747)

Consider by extrapolation all of the unique standpoints on architecture from all groups and individuals to which we as architects are deaf. Again, by refusing to acknowledge the validity of these perspectives, of this consciousness, architectural discourse is embarrassingly conservative.

2.4 Qualitative research in the social sciences

Over the last twenty years in the social sciences a distinct research methodology, qualitative research, has gained a significant foothold in the discourse of the field. Educational psychologist and expert in research methodologies John W. Creswell defines qualitative research as beginning:

> with assumptions, a worldview, the possible use of a theoretical lens, and the study of research problems inquiring into the meaning individuals of groups ascribe to a social or human problem (Creswell 2007, 37).

To give form to this methodology Creswell stipulates several common characteristics of qualitative research: natural setting, researcher as key instrument, multiple sources of data, inductive data analysis, participants' meanings, emergent design, theoretical lens, interpretive inquiry, and holistic account (Creswell 2007, 37-39). For our purposes we will describe a few relevant characteristics in slightly more detail. By natural setting, Creswell asserts that data collection is done "in the field at the site where participants' experience the issue or problem under study (Creswell 2007, 37)." By multiple sources of data, Creswell indicates that qualitative research uses heterogeneous forms "such as interviews, observations, and documents (Creswell 2007, 38)." Great value is placed on participants' meanings. Creswell emphasizes that:

> In the entire qualitative research process, the researchers keep a focus on learning the meaning the participants hold about the problem or issue, not the meaning that the researchers bring to the research or writers from the literature (Creswell 2007, 39).

These characteristics are particularly pertinent to architecture, being a site or setting itself and reaching across multiple spheres of influence.

Creswell goes on to characterize subjects that would benefit from qualitative research as meeting eight loose criteria. We have reorganized them in order of their pertinence to the project of change described in this paper. First is the desire to empower individuals, "to share their stories, hear their voices, and minimize… power relationships." Second is "to study a group or population… or hear silenced voices." Third is the belief that "we cannot separate what people say from the context in which they say it." Fourth is the need for "a *complex*, detailed understanding of the issue." Fifth is the usefulness of following up more formal studies to "help explain the mechanisms or linkages in causal theories or models." Sixth is to expand on theories that "do not adequately capture the complexity of the problem we are examining." Seventh is the desire to write in a more inclusive, literary style "without the restrictions of formal academic structures of writing." Finally, the eighth criterion is that formal and quantitative analyses "simply do not *fit* the problem." (Creswell 2007, 40)

2.5 The fitness of qualitative research to architecture

Architecture is a field that has worked very hard to both tether itself to and distinguish itself from the subjectivity of the arts. Similar to the obstacles qualitative analysis faced from positivists in the social sciences, its acceptance in the conventions of architectural research would not be without detractors. Conventional scholarly architectural research is praised for its reasonableness, its logic, its grounding, and its inventive use of canonical positions. And, although it is valuable to the gross progress of architectural discourse, it overwrites, or writes around the contradictory and downright messy social constructions of architecture's existence.

The formal characteristics and topical criteria of qualitative research inherently fit architectural research. The theoretical perspectives that establish much of contemporary architectural discourse, such as phenomenology, critical inquiry, and postmodernism, are methodologically congruent with qualitative research.

2.6 Potential application of qualitative research to architecture

Because of inherent plurality of its data, the goal of qualitative research in architecture could never be the objective judgment of a building. It would likely address ways in which its inhabitants construct and perceive aspects of its interconnection with its own fabric, with the oeuvre of the designer, other works of architecture, further afield manifestations of culture, historical conditions, social conditions, functions of perception, and so on.

Creswell describes five qualitative approaches, of which we will look at two, narrative research and phenomenological research, and propose potential areas of application. The other three, grounded theory research, ethnographic research, and case study research, would certainly also be applicable.

Narrative research focuses on being a singular and deep forum for personal experience. The sample size of narrative research is limited to one or two individuals. Data gathered takes the form of life-stories and related individual biographical experiences with an interpretive interest in causality (Creswell 2007, 54). In relation to architectural research this limited scale of inquiry and broad scope of temporality might be suited for gross scale analyses such as urban or cultural fabrics and typologies. Conversely, more intimate and smaller scale, limited access settings like dwellings might profit from narrative research.

Phenomenological research "describes the meaning for several individuals of their *lived experiences* of a concept or phenomenon (Creswell 2007, 57)." Phenomenology is a theoretical perspective already applied in scholarly architectural research as a philosophical lens as opposed to a methodology for collecting data. This approach's broader participant sample is balanced against the goal of looking for shared meaning and experience. Phenomenological research is grounded in the belief that the reality of an object is inextricably linked to one's consciousness of it (Creswell 2007, 59). This seems suited to the physicality of architecture and particularly to singular works that are able to be experienced in a number of different ways. It may also be applicable to a particular aspect of architecture across a variety of types, or of multiple instances of a particular type. Because of its focus on common experiences, phenomenological qualitative research provides a deep foundation to developing practices or policies related in a field (Creswell 2007, 60).

Within the variety of approaches to qualitative research are a wide range of data collection methods. In addition to those described above, methods such as unstructured interviews, life histories, and participant-guided tours or shadowing, are applicable to architectural research.

Many articles in *Society and Space*, although not definitively an architectural journal, rely heavily on qualitative data. For example, an article exploring constructions of femininity in the Russian penal system includes fieldwork and qualitative data gathered from interviews with prison staff and from media sources to give deeper understanding into the intensely personal constructs of gender in relation to the strictures of the architectural type (Moran, et al 2009, 700-720). Another article analyzing the conditions of gentrification in Edinburgh, Scotland uses interviews with new residents in gentrifying neighborhoods to provide representative texture to the language and direct insight into motivations, which often deviated from quantitative data also gathered (Bondi 1999, 261-282).

As is evident in the characteristics and criteria for qualitative research, the subjects open to inquiry are wide-ranging and of all extremes in scale. Social researcher Michael Crotty jokes:

> not too many of us embark on a piece of social research with epistemology as our starting point… We typically start with a real-life issue that needs to be addressed… a question that needs to be answered (Crotty, 13).

Based on the wide range of topics surveyed in this paper, from compartmentalized histories to urban facilities for underprivileged women, there is no shortage of fodder for qualitative research in architecture. We do not presume to limit the possible scopes. Indeed, we hope to have illustrated a necessity for the richness of information that can come from these types of inquiries in all arenas.

CONCLUSION

Sherry Ahrentzen places the responsibility for change squarely in the discourse of academic institutions, calling for a deeper look and reconfiguration of “education as well as indoctrination of the professional and non-professional involved in placemaking (Ahrentzen 1996, 95).” She emphasizes the importance of social communities and consciousness-raising groups as a means to influence institutional meaning in society. The question is: how is the design profession currently fostering these communities? How is the design profession giving these communities a voice? We can start by recognizing their role in our profession, and by allowing them to constructively participate in the dialogue that materially shapes their world.

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The Projective Credibility of Fictions: Robin Evans' Methodological Excursions

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ABSTRACT: Although central to Robin Evans' studies of history, his use of "fictions" is as novel as it is unexplored. Expanding from intensive studies of traditional architectural forms of representation (plan, elevation, perspective, photography) Evans includes paintings of human figures, novels, and plays. Rather than marginalizing these depictions for their fictional basis, he places them alongside, on equal footing, with their architectural counterparts.

As Evans examined the past, he used these fictional devices to project vitality into space. In so doing, Evans imbues these fictions with a type of credibility not similar, but complementary, to types of credibility at work in traditional architectural representations. He leverages the architect's ability to read circulation, depth, and enclosure into the plan to anchor the reader while allowing fictions (narratives, paintings, conversations) to speculate about the character of social life. The overt and explicit artifice of fictions, in effect, facilitates and legitimates their use.

This paper examines Evan's use of fables, novels, courtesy books, plays, paintings, and advertisements through a selection of his most canonical articles. Although varied from article to article, Evans explicitly defines each fiction's use in relation to other more conventional source materials. Each of these uses expands upon their deployment as a *projective*, rather than simply documentary, device. The product of this study is a grounded, yet provisional, methodology of research as a form of architectural speculation.

KEYWORDS: Robin Evans, methodology, fiction, projection

INTRODUCTION

Given the depth and extensiveness of knowledge displayed in Robin Evan's writings, his use of fiction might appear to be a simple eccentricity. It would seem to be either an idle affectation or a demonstration of his worldliness and literariness. However, given the centrality and continuity of these deployments, they might suggest something else, a provisional methodology: one that enlists fictional scenarios, bound explicitly to concrete situations, to attenuate the effects of architectural decisions.

In order to retroactively construct this methodology, this paper documents the active use of fiction within a selection of Evans' writings. This analysis is ordered chronologically for two reasons. One, it describes an expanded development of fiction as source material. Early writings make explicit reference to works of fiction as fictional scenarios while later writings build upon tacit correlations between historical and fictional documents. Two, it counters the assumption that Evans' writings moved from concerns of social and political efficacy (the impact architecture has on social and cultural norms) to more professionally introverted questions of architectural representation and form. Specifically, this paper argues that the qualification of the *projective* within Evans' studies of representations is meant to reframe questions of architectural representation and their relation to human affairs. Fictions, in this way, play a critical role.

Projection, as an operation, is readily tied to forms of architectural thought and production by way of representation. Orthographic and perspectival projections establish potential relationships between what is drawn on a page (as a representation) and what happens in the world (as a consequence). Evans uses the projective to describe this as an operation, as a form of speculation rather than a form of documentation.

In a chapter of The Projective Cast titled "Seeing through Paper," Evans describes Palladio's San Petronio as "a layering of thin parallel planes… The effects were obtained by drawing lines on a flat sheet that looked as if they represented something with considerable depth, then building it with limited depth." As long as the piece of paper could resemble the façade, the architect could speculate about the effect of depth through the representation. Furthermore, "Under these conditions, projectors need not extend very far from the picture to reach the thing pictured, and the imagination of the designer need travel no further than the projectors to envisage what has been designed"(Evans 1995, 117).

In this way, Evans organizes the projective as an image, augmented by the imagination of the designer, to speculate about architectural effects. While such a relationship is not exclusive to Evans, his inclusion of fictions enlarges the types of effects within this realm of speculation. The uses of fiction and their correlation to the visual practice of projection are implicit. Just as Palladio's elevation illustrated a hypothetical perception of depth, Evans use of fictions illustrates a hypothetical occupation of space. Both facilitate the projection of architectural effects, although in categorically different registers, through the ability to visualize potential relationships.

1.0 Initiation: *The Rights of Retreat and Rites of Exclusion*

The Rights of Retreat and the Rites of Exclusion provides a useful starting point for this analysis. It is one of Evans' earlier writings, born contemporaneously and sympathetically to his first book, *The Fabrication of Virtue*. His agenda is explicit, affording a frame with which to register the deployment of fiction. He begins, "This article will attempt to chronicle, in a rather anecdotal way, some incidents in the environmental history of the war against information." (Evans 1971, 335) Given this purview, the article provides two parameters. By remaining anecdotal and incidental, the evidence he supplies is assumed to be partial, non-encyclopedic, making the use of fictional examples more manageable. Also, he frames his interests around a conflict between two constituents: the spatial (the environment) and the perceived (information). The confrontation of the real and the perceived produces a useful setting for this analysis.

To wit, he begins the investigations with the fictional character, Des Esseintes in J.K. Huysmans's *Against Nature*, ("a fictional character certainly, but one based on the antics and attitudes of the author's contemporary, the Comte de Montesquiou" (Evans 1971, 335)). In an effort to secure himself from the banalities of the Parisian world, Des Esseintes begins by barricading himself from the outside world and turning the everyday into the ceremonial. Although the practice of seclusion or the embellishment of pedestrian actions are hardly exclusive to fictional characters, their combination and exaggeration in the case of Des Esseintes collapses and heightens the two through his environmental maneuvering. As Evans explains:

> But he found that even in his secluded apartments the more quotidian realities of Paris impinged too much on his consciousness, so he decided to move himself to the remote and deserted suburb of Fontenay.
>
> > Together with the desire to escape from a hateful period of sordid degradation, the longing to see no more pictures of the human form toiling in Paris between four walls or roaming the streets in search of money had taken an increasing hold on him. Once he had cut himself off from contemporary life, he had resolved to allow nothing to enter his hermitage which might breed repugnance or regret.
>
> Having in this way distanced himself from all that he despised and all that disturbed him Des Esseintes populated his new habitation with jewel-encrusted tortoises, obscure early Christian tracts, and the symbolical drawings of Odilon Redon and Gustave Moreua, making a secret enclosure for his own delectation – heavily bedecked with significance for him alone. (Evans 1971, 335-6)

Using a fictional character, rather than describing the real person upon which he is based, benefits Evans in two ways. One, he is not obliged to describe the historical reckoning of Comte de Montesquiou-Fézensac by way of the French Court's gossiping. Two, Evans is able to construct the character to his own necessities, much as J.K Huysman constructed Des Esseintes. The description of the process, however, is no less real because of its fictional source.

The second deployment of fiction within *The Rights of Retreat the Rites of Exclusion* uses both fictional source material and fictional devices. In describing the reciprocal tendency of the thing excluded to shape the nature of the boundary between included and excluded, Evans references Jorge Luis Borges's *Tlon, Uqbar, Orbis Tertuis.* In this short story, access to an imagined world is constructed through a fictional encyclopedia entry. As the entry is read, portions of the world to which that fiction belongs begin to slip into reality, as if the epistemological qualification of the encyclopedia were enough to qualify its certainty (Evans 1971).

Evans' use of Borges is foreshadowing. In the next paragraph Evans introduces a conversation written by William Morris, a real person frequently cited in architectural histories, in relation to the fragmentation of experience:

This, for instance, is how William Morris disposes of the possibility of such civic atomization

> Said I… 'there is a third possibility – to wit that every man should be quite independent of every other, and that thus the tyranny of society should be abolished'. He looked hard at me for a second or two, and then burst out laughing very heartily; and I confess that I joined him. (Evans 1971, 337)

The quote, given by a real person, a real architect and credible historian, is taken from the novel *News from Nowhere: or an Epoch of Rest*. And just as quickly as Evans introduced the possibility of fictions informing the real has Evans made a fictional conversation real. The endnoting certainly qualifies the source as a fiction, but just as the authority of the encyclopedia gives Uqbar inroads to reality, so does Evans' conscription of Morris.

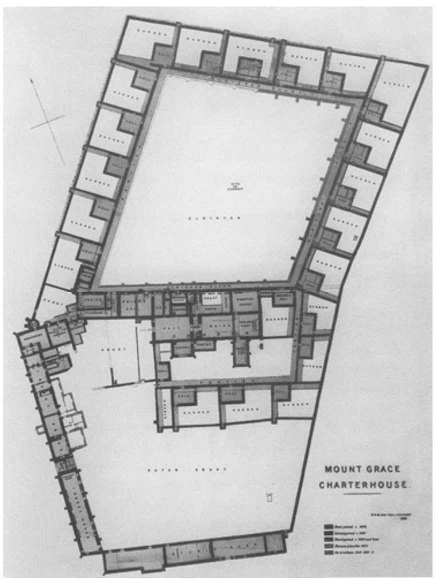

Figure 1: Plan of Mount Grace Charterhouse. Source: (Evans 1971)

Were fictions deployed without a material or spatial referent, Evans would certainly lose credibility. However, connecting these fictional components are plans of monasteries, the Bicêtre (an orphanage, prison, lunatic asylum, and hospital), and a set of experimental wall sections developed by Michael Faraday for Millbank Penitentiary. In *The Rights of Retreat and Rites of Exclusion*, these links between the fictional and architectural remain suggestive and implicit. Their explicit development as complementary domains emerges in later work.

2.0 Evidence: *Figures, Doors and Passages*

Evans' most noted work, *Figures, Doors and Passages,* is also the work that most heavily relies on fiction and is most explicit in its methodological intentions.

> If anything is described by an architectural plan, it is the nature of human relationships, since the elements whose trace it records – walls, doors, windows and stairs – are employed first to divide and then selectively to re-unite space. But what is generally absent in even the most elaborately illustrated building is the way human figures will occupy it... Take the portrayal of human figures and take house plans for a given time and place: look at them together as evidence of a way of life, and the coupling between everyday conduct and architectural organization may become more lucid. (Evans 1978, 267)

By pairing architectural plans with fictional portrayals of figures, Evans hopes to examine how architecture provides "a format for social life"(Evans 1978, 278). What is telling about this introduction is the declaration that he considers their pairing to constitute evidence. In an anachronistic twist, the combination of existing architectural spaces (represented by plan) and fictional social events (represented by paintings, courtesy books and novels) allows the reader to project into them so as make more clear relationships that never, actually, occurred.

The first such pairing illustrates the organizational relationship of circulation to privacy and convenience. Quoting Alberti's *The Ten Books on Architecture* and including a plan of Paladio's Palazzo Antonini, Evans argues that a matrix of interconnected rooms normalizes types of seclusion and intrusion. This, in turn, affords particular ways of constructing privacy in relation to the movements and activities of others. In order to demonstrate how the matrix of interconnected rooms forms a particular social milieu, Evans cites the courtesy book, *The Courtier* by Baldassare Castiglione. (Evans 1978)

The first such reference describes the romantic liaison between a fictional courtier and his maidservant:

> …as was only fitting at the age of twenty-nine, I had taken a charming and very beautiful young girl as my maidservant… Because of this I had my room at quite a distance from where the workmen slept, and also some way from the shop. I kept the young girl in a tiny ramshackle bedroom adjoining mine. (Evans 1978, 270)

In this instance privacy is established syntactically, a calculus of distances and adjacencies correlating to the interconnected matrices of rooms.

The second reference to The Courtier describes an attempt to engineer a chance encounter with a patron:

> I had myself carried to the Medici Palace, up to where the little terrace is: they left me resting there, waiting for the Duke to come past. A good few friends of mine from the court came up and chatted with me. (Evans 1978, 270)

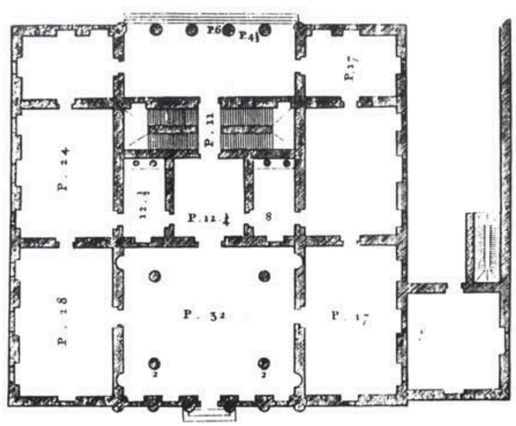

Figure 2: Plan of Palazzo Antonini, Paladio. Source: (Evans 1978)[2]

In this scenario, one of the courtiers opportunistically locates himself within a space of high connectivity, improving his chance of the Duke happening upon him, and allowing him to be visited incidentally by a group of friends. Both of these types of encounter are informal, afforded by the configuration of rooms and circulation.

Before finishing the section of doors, dedicated mostly to this constellation of Italian renaissance buildings and fictions, Evans brackets the types of conclusions one might draw from this evidence:

> The examples given above, though hardly furnishing a proof, serve to indicate that the fondness for company, proximity and incident in sixteenth-century Italy corresponded nicely enough with the formation of architectural plans. (Evans 1978, 271)

Evans specifically identifies the two sorts of information, the architectural plan and the social scenarios of their contemporary fictions to indicate their affinity. That is, given the audience's ability to understand hierarchy, sequence, and circulation in plan they can project the potential for informal and incidental situations through them. Though not providing proof, these suggestive affiliations allow us to speculate about the collusions of space and social life.

To elaborate this connection, Evans juxtaposes the informal and interconnected Renaissance literature and villas with Victorian-era English literature and houses. Evans argues that the organizational shift of circulation, from interconnected rooms to discrete spaces reconnected by the passageway, heightened the spatial priority of privacy, particularly in concerns to the body. To emphasize this transition, particularly the aversion to physical proximity and contact, Evans quotes Samuel Butler's *The Way of All Flesh*:

> 'My dearest boy', began his mother, taking hold of his hand and placing it within her own, 'promise me never to be afraid either of your dear papa or me; promise me this, my dear, as you love me, promise it to me', and she kissed him again and again and stroked his hair. But with her other hand she still kept hold of his; she had got him and she meant to keep him… The boy winced at this. It made him feel hot and uncomfortable all over… His mother saw that he winced and enjoyed the scratch she had given him.

> The thing to notice is that when flesh touched flesh a subtle style of torture was taking place. (Evans 1978, 275-6)

Figure 3: "Family Prayers," Samuel Butler (1864). Source: (Evans 1978, 275)

This excerpt (written in1903) is bounded by two sets of plans: Bearwood by Robert Kerr (1864) and the Functional House for Frictionless Living by Alexander Klein. Again, the plans evidence an intentional disentanglement of bodies and movements. Evans also notes this is the same passage that Edward Hall uses in studying proxemics in *The Hidden Dimension*.

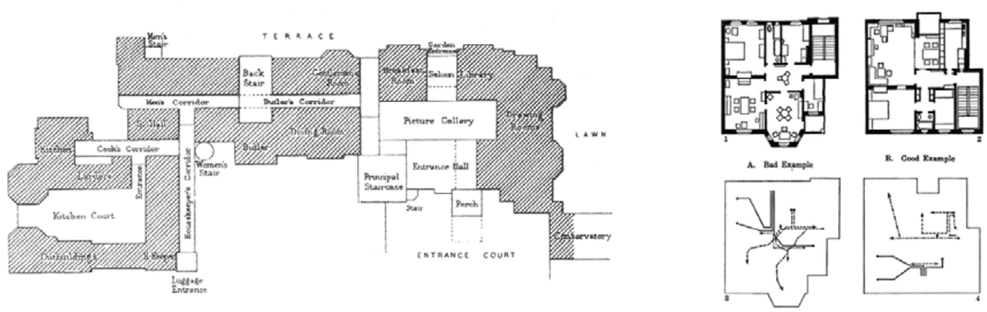

Figure 4: Bearwood (1864) and The Functional House for Frictionless Living (1935). Source: (Evans 1978, 273, 276)

Again, Evans uses fiction to illustrate the efficacy of spatial conditions by binding it to two credible sources: the architectural plans of Kerr and Klein and the anthropological research of Edward Hall. Although Butler references neither, his fictional family becomes symptomatic of these spaces. That is, the fiction evidences a potential manifestation of the architectural configuration.

However, Evans cautions against certain uses of literature and architecture:

> In reaching these conclusions architectural plans have been compared with paintings and various sorts of literature. There is a lot to be said for making architecture once more into art… This is sometimes done in a rather guileless way, by equating architecture with literature or painting so that it becomes an echo of words and shapes; sometimes in a more sophisticated way, by adopting the vocabulary and procedures of the literary critic or art historian and applying them to architecture… A different kind of link has been sought: plans have been scrutinized for characteristics that could provide the preconditions for the way people occupy space, on the assumption that buildings accommodate what pictures illustrate and what words describe in the field of human relationships. (Evans 1978, 277-8)

By bracketing his motives as such, Evans makes clear that his use of fiction is not metaphorical or analogical, but projective. These studies are meant to analyze the "preconditions" of space so that we might speculate about their respective social tendencies. This agenda is borne out in his concluding paragraph:

> The cumulative effect of architecture during the last two centuries has been like that of a general lobotomy performed on society at large, obliterating vast areas of social experience. (Evans 1978, 278)

3.0 Projective: *Translations for Drawing to Building* and *The Developed Surface*

Although central to his studies on the social consequences of architecture, the projective use of fictions also emerges in Evans' studies of architectural representation and geometry. In fact, his use of fiction in *Translations from Drawing to Building* is the most overt argument for the projective. In this article, Evans uses two versions of a painting titled "The Origin of Painting," based upon a story by Pliny the Elder on the origin of drawing. He examines the difference between Karl Schinkel's version (an architect) and David Allan's version (a painter).

> Both paintings, true to the original story, show drawing as a function of projection, and both show quite clearly the combination of elements required: a source of light, a surface behind the subject, and something to trace with. (Evans 1978, 278)


Figure 5: "The Origin of Painting," Left: Schinkel, Right: Allan. Source: (Evans 1986, 6)

In Schinkel's version, the light source is the sun, distant and parallel. In Allan's the light source a lamp, approximate and intimate. In the former, the drawing surface of the rock precedes building, in the latter, the wall of the apartment precedes drawing. From this difference, Evans draws a conclusion about the projective drawing of architecture.

> Drawing in architecture is not done after nature, but prior to construction; it is not so much produced by reflection on the reality outside the drawing, as productive of a reality that will end up outside the drawing. (Evans 1986, 7)

This ability to envision, to speculate, to project "a reality that will end up outside the drawing" is the crux of Evans development of the projective. Focusing on forms of representation gives Evans the opportunity to leverage architectural techniques. However, this focus on drawing and representation does not abandon his previous questions of social efficacy. In fact, he argues specifically it gives him the opportunity to credibility to do so without moving outside the discipline.

In *The Developed Surface: An Enquiry into the Brief Life of an Eighteenth-Century Drawing Technique* Evans writes:

> English interiors of the later eighteenth and early nineteenth century, although not within the compass of what is usually regarded as properly serious or significant in architecture, are, I believe, capable of providing what a good deal of material within that orbit has not been able to provide: evidence of strong interactions between things visual and things social…
> I have attempted, then, to displace the customary foci of interest, considering the interiors of the late eighteenth and early nineteenth centuries neither as object of connoisseurship, nor as adumbrations of architectural theory, nor as moral counters for or against an ingratiating profession, but as visible entities within a particular area of human affairs. And within this area of human affairs they are meant to retain their visibility, not lose it. This evasive tactic of mine, trying to write a piece that was neither this, nor that, nor the other, in an effort to conserve a property so easily lost in passage from buildings to words, would have floundered completely were it not for the substitution of an alternative focus: the drawing technique. (Evans 1989, 120-21)

The drawing technique in question is what Evans refers to as the developed surface interior, a set of interior elevations folded from a plan. The drawing technique, Evans argues, produces a heightened sense of interiority and prioritization of the wall as surface. In an effort by designers to elaborate these surfaces, furniture became integrated, if not materially then graphically, into the surface of the wall. This annular distribution of furniture, he suggests, abets the parlor's custom of matrimonial scrutiny. As evidence, Evans cites landscape designer Humphrey Repton's painting "The Old Cedar Parlour and the Modern Living Room."

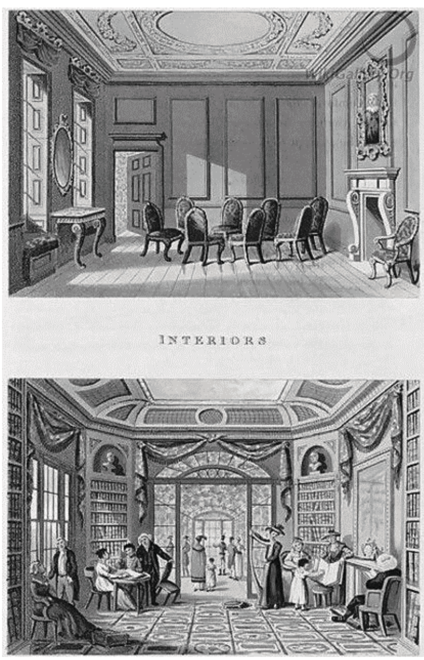

Figure 6: Left: "The Old Cedar Parlour and the Modern Living Room." Source: (Fragments on the Theory and Practice of Landscape Gardening 1816),

The image shows an abandoned ring of chairs juxtaposed by a vibrant set of minor constellations of furniture. Again, Evans uses a fictional representation, the imagined rendering of the modern living room, paired with self-consciously architectural drawings, to constitute a type of evidence reminiscent of *Figures, Doors and Passages*. The methodological evolution, however, binds fictions more intricately to the architectural representations.

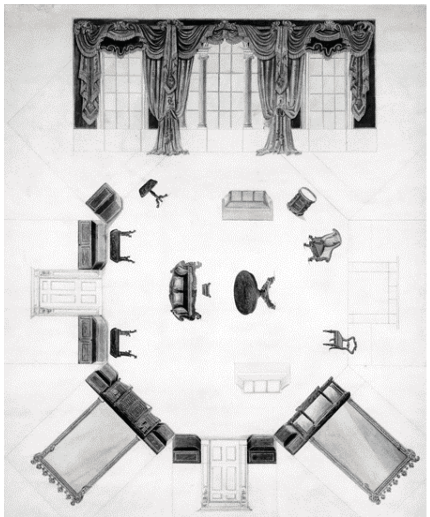

Figure 7: Developed surface drawing by Gillows and Co., Design for the furniture and interior decoration of an octagonal room (1806-1831). Source: (© Victoria and Albert Museum, London)

In the following pages, rather than exclusively pairing fictions with their contemporary architectural plans, Evans uses advertisements and furniture catalogs from the Victoria and Albert Museum. Having implicated the matriarchal hierarchy to the ring of chairs, Evans returns to the drawing technique. This collapse, of fiction/architectural representation and social/geometrical is intentional. By focusing on the drawing technique, as described at the outset of the article, Evans holds all the elements as part of the representation and projects their reality outside the page, regardless of their fictional or factual foundations.

CONCLUSION

Just as Evans intentionally substitutes the drawing technique as the focus to avoid questions of relevancy and significance, the use of the projective avoids the false dichotomy of fact and fiction. Alongside this analysis of the intentionally fictional could easily be paired actually false in Evans writings (the false reconstruction plan of Raphael's Villa Madama by Percier and Fontaine, or de l'Orme's own false account of his design of the Anet chapel). This, however, obscures the point. Fiction's use as a speculative device should not be marginalized because it is not actual. No projective illustration is (yet) actual. As Evans demonstrates, fiction should be opportuned for its capacity to project architecture's potentials.

Given Evans' conclusion to *Figures, Doors and Passages* and introduction to *The Developed Surface*, it is clear that these potentials should address architecture's social consequence. Although these studies are limited to domestic spaces, and are addressed as historical research, the overt suggestion is to develop forms of representation that project the social life of space. By binding situations and scenarios portrayed in fictions to architectural drawings, Evans argues that although space does not have a causal relationship to human affairs, it is unmistakably contingent.

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Maintenance Art, Architecture, and the Visibility of Time

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ABSTRACT: No matter how well built, architecture is consumed in time. The only remedy against a building's degeneration is maintenance—fixing deterioration once it becomes visible. There are three human acts with physical consequences: to create, to destroy, and to maintain. Of these three, maintenance requires the greater vigilance, observational skill, and intimacy. Real buildings are unavoidably captive to time's transformations. Despite how hard architects try to reduce its effects, time refigures a building—which over its lifetime alternates between periods of shabbiness to moments of shine. Between a building's opening day and its demolition is the period of maintenance.

Maintenance is seldom discussed by architectural theoreticians; perhaps because maintenance has long been associated with drudgery, menial tedium, and the non-heroic efforts of janitors, maids, and grounds keepers. In 1973, conceptual feminist artist Mierle Laderman Ukeles famously recast maintenance into art by washing down the Wadsworth Atheneum in Hartford, Connecticut with her performance pieces, "Maintenance Art—Washing, Tracks, Maintenance: Inside/Outside." Subsequently, many artists have imitated her event in various settings and situations.

Maintenance is the slow and careful adoration of the built. Architects can recognize instantly the shades of neglect in a place not properly maintained. Architectural educators would do well to include the implications of maintenance and maintenance art in their classes. This essay seeks to spark critical discourse on the role of maintenance and maintenance art in architecture. Caretaking and upkeep are recast as thought-provoking acts of cultural intervention. Using examples from design theory, art, and literature, this essay describes the art of maintenance envisioned in intimate acts of cleaning, repairing, and renewing.

KEYWORDS: Maintenance, Maintenance Art, Time, Mierle Laderman Ukeles, Phenomenology

INTRODUCTION

> "Maintenance is a drag; it takes all the fucking time . . . MY WORKING WILL BE THE WORK"—**Mierle Laderman Ukeles**, "Manifesto for Maintenance Art (1969)"[1]

No matter how well built, architecture is consumed in time. The only remedy against a building's degeneration is maintenance—fixing deterioration once it becomes visible. There are three human acts with physical consequences: to create, to destroy, and to maintain. Of these three, maintenance requires the greater vigilance, observational skill, and intimacy. Maintenance means affecting what we build by endeavoring against the entropic forces that prey on architecture.

Unless confined to a rendering, architecture never keeps its original conception. Real buildings are unavoidably captive to time's transformations. In 2010, David Leatherbarrow suggested that buildings are clocks that visualize the imprint of time.[2] Despite how hard architects try to reduce its effects, time refigures a building—which over its lifetime alternates between periods of shabbiness to moments of shine. Between a building's opening day and its demolition is the period of maintenance. Maintenance sustains, forestalls ruin, and rejuvenates after dereliction—imprinting, and sometimes erasing, the effects of time on whatever we build. No specific example of maintained architecture is dissected in this essay; but essential aspects of maintenance, as collected through lived experience and everyday encounters, can be gleaned from these descriptive passages.

Maintenance is seldom discussed by architectural theoreticians; perhaps because maintenance has long been associated with drudgery, menial tedium, and the non-heroic efforts of janitors, maids, and grounds keepers. Maintenance, or the lack of it, will determine a building's longevity or whisper its demise. Maintenance cooperates carefully with building. The architecture we revere, we maintain. What we devalue, we neglect. A building's vitality is coupled precariously to its corruption. After we finish building, we are obliged to either act and maintain or stand by and witness the progress of ruins.

1.0 MAINTENANCE

> "If a better type of civilization is ever to be developed, one of the very corners of the scheme must be understanding of and reverence for labor. Reverence for labor is the basis of art, for art is the labor that is fully worthy of reverence."—**W. R. Lethaby**[3]

The world happens around us whether we reckon it or not. Bugs burrow beneath our feet, wind scatters with effect, pockets of air-suction pull, water flows over surfaces, and droplets cling to undersides—soaking absorbent materials deeply. The daily sweep of sunlight bakes a building, causing every part to expand irregularly and every joint to creak, crack, and widen a little more each time.

Maintenance doesn't oppose construction; it is counterpart and progeny to construction. Maintenance is better considered the opposite of vandalism. Maintenance and vandalism occur in similar, dilapidated contexts, at the cusp of decay, or in moments of decline. Maintenance is both venerate and preventative. Vandalism is deliberate and destructive. Both maintenance and vandalism are expressive of feelings aimed oppositely; one is geared to sustain, the other, to defame.

We have many names for grime and dilapidation; the accumulation of dirt, the wear from weather and use—if explored fully, the list would be long, graduated, and varied. Mold, lichen, moss, pestilence, weathering, wear, waste, pollutants, residue from bodily contact, dust accumulation, soiling, silting, and myriad forms of water damage are just a few. Altogether, they comprise the agonists of maintenance.

A building is a matter of intelligence, will, and work. During design, a building is mostly an abstraction of the world. After construction and once a building encounters the world, other aptitudes must be engaged in order to maintain a building. A building is a presence in time; without continued care and attention, it will wither to ruin. Over the course of its useful life, a building requires many people of various intelligences cooperating in its creation and retention. Buildings are peopled participations in time.

Maintenance is the caretaker of architectural excesses. 'Maintaining' as a word, means to practice an action habitually. It found its way into English lexicon via the Old French, *maintainir*, which combines two terms from Latin: *manu*, or 'hand,' and *tenere*, which means 'to hold.' Its fundamental meaning suggests a holding in which the hand plays a part. Synonyms include *tenure*, or 'to possess for a time,' and *tenant*, which means 'to occupy a property for a time.' So basic to maintenance are language-laden notions that include: *hand, holding, possession, and time*. At the core of maintenance is a simple wish and expectation applied generously to body, events, and place: continuance.

If not engaged, the world rusts. If engaged vigorously, the surface of the world wears to a polish. Maintenance applies additional layers onto a building. We speak of sanitizing or the stripping of grime as though the places we inhabit are bodies to be cleaned, like evidence of good hygiene. Simple solvents such as water are essential to the proper upkeep of buildings—yet abrasive and penetrating solvents slowly disintegrate materials. Contradictions appear in the cultural art of maintenance; maintaining can also mean challenging longevity. Maintenance is the slow and erosive adoration of the built.

Society points its members away from maintenance work. We are conditioned to its general avoidance. However, a maintenance worker is no drudge or spectator to ruin. A spectator never engages, only watches. The poet Charles Olson stated that the spectator asserts an ownership which is absentee.[4] One cannot maintain a thing and remain a spectator absent of an active or creative role. Maintenance means observing closely, scrutinizing, and acting in a methodical way—planning, protecting, and organizing so as to retain and resist. A maintenance worker participates directly and empathically in the life of a building or a landscape. Maintenance means participation. We enact our environment always—and we participate with things when we care for them. Certainly, there is an ethical dimension to maintenance work that should transfer over to architecture but seldom does. The intentions of architecture are typically distant from the ethics of maintenance. The building, as a material presence, is the hinge upon which the practices of design and maintenance sway.

Maintenance forms an enduring bond between a person and a place. The bond between people and their place must be complex, reciprocal, and active—otherwise it will fall into ruin. If architecture is to be of any lasting importance, then architects must broaden the scope of design to include the totality of human inhabitation. Architects cannot be spectators; we must understand the dual importance of inhabitation and maintenance. Charles Olson, when considering the topics of geography and poetry wrote, ". . . any humanism *is* as well place as it is the person . . ."[5] If we acknowledge ourselves as beings embedded in time's broader context—as capitulations of a past that cannot exist unless tethered responsibly to the future—then we'll maintain our place. Maintaining in place implies also sustaining in time.

Ethos, before it ever meant the pattern of a person's behavior, meant an accustomed place—suggestive of comfort and protection against inclemency and the ravage of time.[6] An architect may have ethics, but a building emancipated from its maker and enduring against both weather and use acquires its own ethos. The ethos of a building determines how well it withstands. For a building, weather is fate. So how a building withstands its climate reveals the character of the building.[7] Maintenance corrects against decline, allowing the building to endure and remain purposeful a little longer. If a building's purpose endures, then so will its ethical meaning.

2.0 MAINTENANCE AS ART AND MAINTENANCE ART

> "Maintenance has to do with survival, with continuity over time. You can create something in a second. But whether it's a person, a system, or a city, in order to keep it, you have to keep it going. I think that one thing we must do is value and learn from those who provide this service."—**Mierle Laderman Ukeles**[8]

Throughout Juhani Pallasmaa's book, *The Thinking Hand*, he emphasizes the hand's role in creation, in making new things.[9] However, he forgets to mention the hand's role in maintenance. After the initial flurry of creativity, the hand continues to be needed in the continuity of inhabitation. A building, in its fixedness, seeks to be maintained. The artwork, in its mobility, can be exchanged or reproduced. Art, when it becomes a lasting possession of the community, requires conservation and maintenance.

In a single furious sitting in 1969, following her child's birth and while fulfilling the needs of her family, artist Mierle Laderman Ukeles wrote "Manifesto for Maintenance Art" which was a proposal for an exhibition to be titled, "Care." Ukeles expanded on the themes outlined in "Care" as part of Lucy Lippard's traveling exhibition, *c.7,500*. This exhibition, which travelled the country from May 1973 to February 1974, brought together many women concept artists. During the exhibition, Ukeles approached the Wadsworth Atheneum and suggested a series of four performance artworks: *Transfer, The Keeping of the Keys, Washing/Tracks/Maintenance (Outside), and Washing/Tracks/Maintenance (Inside)* on July 20 and 22, 1973. As Ukeles' wrote many years later,

> "It was very hard work. Did that make it real work? I think so. And in the saga aspect of the long duration, something else happened, a piercing through the wall of work into a new place."[10]

That "new place" where her work entered—a situation that deconstructed the context where art is typically manifest and replaced menial labor with concept art—was a place where her working became the artwork. Her works elevated hidden and dismissed acts of maintenance and equivocated them with art. This watershed work, as well as all her subsequent works, required a place to maintain, a person to do the maintaining, and a reason for something to be recovered and cared for. Ukeles' work at the Wadsworth Atheneum has become iconic, and is often repeated through similar performances in different contexts by other artists.[11]

However, Ukeles' work is not without artistic precedent or derivation. Two performance sidewalk cleaning pieces by Fluxus artists were performed a decade earlier. In both instances the group, comprised of different members, called themselves *Hi Red Center*. The first event was held on October 16, 1964, and encompassed the cleaning of a section of street in Ginza, Tokyo. The second similar cleaning event was held in July 1966 around Grand Army Plaza in New York City. George Maciunas, a key member of Fluxus, photographed the event. These performance pieces were conducted with the appearance and rigor of art conservation. White coats, white gloves, surgical masks, officiating armbands, and folding signs cordoning off the area marked for cleaning were used in the performance. A gradually more precise set of cleaning implements were employed—beginning with brooms and moving on to scrub brushes, tooth brushes, and cotton swabs. The work was absurdist in its pseudo-scientific precision. However, it revealed the rather complicated division between the effort that goes into conserving something cherished and the effort expended to maintain something ordinary. Like most happenings, the art was cleverly embedded in the act.

Ukeles' themes were also foreshadowed in the iconic photography of Gordon Parks. The exploitation and suppression of maintenance workers, which includes matters of race and gender, was revealed in *American Gothic, Washington, D.C.*. In 1942, Gordon Parks posed Ella Watson, a Farm Security Administration maintenance worker, who held her mop and broom under an American flag in an image recalling Grant Wood's iconic painting *American Gothic* from twelve years earlier. Looking sternly, if not accusingly, at the camera, Park's portrait of Watson indicts a society which continues to divide its liberties along lines of race, gender, and association with maintenance work.

The work, "I Make Maintenance Art One Hour Every Day," was part of a show held September 16-October 20, 1976, in the Whitney Museum's Downtown branch facility in 55 Water Street in New York City (the branch existed from 1973 to 1983). 55 Water Street, a dull and anonymous high-rise development designed by Emery Roth & Sons, is distinguished by being the largest single office building in New York City by floor area. Ukeles enlisted the building's 300 maintenance workers to assist her in this performance piece. The distinctions between maintenance and sanitation art get blurred, but Ukeles' fundamental sentiments remain the same: the demonstration of care, of support, of life, of working being the art work. Her work undermines our society's normative expectation for art: that art must be heroic and outstanding, not supportive and invisible.[12]

Over the last four decades, the situations for Ukeles' works have increased in scale, scope, and participation. Her works began in domestic settings and then shifted, intentionally and gratefully by her account, to public domains. Over the years, places have included discrete museums (Wadsworth Atheneum, 1973), landscapes (Vassar College, 1974), or public sidewalks (Wooster Street in SoHo, NYC, 1974). Her work then expanded in scale from one of the largest high-rise office buildings in NYC (55 Water Street, 1976) to the entire system associated with the New York City Department of Sanitation (1978-1980, beginning with "Touch Sanitation Performance"), which included Fresh Kills Landfill, the largest landfill on earth (as part of "Flow City," 1989-2002). The number of participants in her work increased from Ukeles herself at first, to several volunteers, to 300, to 8,500, and on to the entire waste flow of millions of New Yorkers (as in her work related to the 59th Street Marine Transfer Station in Manhattan, 1983-1996).

Themes of empathy, healing, recovering divisions, and caring instead of neglecting suffuse Mierle Laderman Ukeles works. Ukeles' works switched from her doing the work alone to establishing situations where the work of others could be documented, presented, celebrated, redeemed, and transformed into art. Her work reveals the flipside to what society considers profane or undesirable; she seeks to redeem implied divisions. Her work is a redefinition of the role of both art and the artist. She makes art mean more than being an expressive impulse of the individual artist. She revises art into something that selflessly expresses other people and recovers places in society where art never deigns to enter.

3.0 ARCHITECTURE AND THE ART OF SLOW-MOVING ARRANGEMENTS

> "One can read the time of day in the depth of the shadow, time of the year in its angle, and of history, in its shine or its stain. We inherit differences among things, one another, and most importantly, we tend to care for the differences between the essential elements of architecture."—**David Leatherbarrow**[13]

Architecture knows no passive voice. A building, though appearing still, is forever in motion. A building is an event, always on the move. A building is not so much a stable place as it is a particular flow—a confluence of movements, wearings, cleanings, removals, and replacements that imprint time on buildings. Place and building, weather and wear—all four are joined indissolubly. We cannot remember tangibly without architecture.[14]

A work of architecture implies its continued involvement in culture as a material entity. As Hannah Arendt wrote in *The Human Condition*,

> "The durability of the human artifice is not absolute; the use we make of it, even though we do not consume it, uses it up. The life process which permeates our whole being invades it, too, and if we do not use the things of the world, they also eventually decay, return to the over-all natural process from which they were drawn and against which they were erected . . . What usage wears out is durability."[15]

Maintenance is typically more than menial labor. When done carefully, maintenance is never drudgery; it is necessary and beneficent to the higher orders of human culture. Architecture, if inhabited, is never ideal nor permanent. Architecture is not, as Pallasmaa suggests, a dam built against time.[16] A building persists as a transforming vision of itself as a material presence. Architecture is a timepiece, marked by the ravages of life and careful maintenance.

We endeavor to build so that living may endure; architecture is the domestication of time. Buildings are a not a "permanence in transience" as indicated by Pallasmaa.[17] Instead, a building is a marker of time's passage—impermanent and coruscating. A building is a slow-moving arrangement that marks change and is marked by change. Architecture decomposes in time and needs maintenance; a building is a transience in a habituated present. Maintenance both retains and alters, and by altering, maintenance makes subtle changes. We return to witness the change—sometimes with sentimentality and nostalgia, sometimes with surprise. The impermanence of architecture marks time's passage for which maintenance is the metronome.

A building is both a thing and an activity. More precisely, a building is a thing enacted by the people who inhabit it. A building is held together in slow, nearly geological, flux. Buildings sustain us so long as we sustain our buildings. Architecture is less the art of space as it is an expedition in time. Rafael Moneo suggests that eventually, after the efforts of architects and builders subside, a building takes on a life of its own. Moneo believes that the completed building, immersed in its culture and climate, is the real aim of architecture. He states that,

> "Architecture implies the distance between our work and ourselves, so that in the end the work remains alone, self-supported, once it has acquired its physical consistency. Our pleasure lies in the experience of this distance, when we see our thought supported by a reality that no longer belongs to us."[18]

A building is a converter of time—and maintenance repairs time's ravages while introducing its own subtle changes. A building is enacted; it is not an object made for our abstract admiration. A building emplaces human action. Architecture is a constant work; after design and construction provide presence, that presence demands maintenance. You cannot escape what never goes away; time's presence and its effects are inescapable. Building is bitter and fatal. All that is built will eventually fall to ruin. Yet we continue to build knowing that every building will find a similar fate.

4.0 TIME

> "Eternity is in love with the productions of time."—**William Blake**[19]
> "Each work of architecture is a time machine."—**Adolfo Natalini**[20]

Buildings are as fugitive to our lives as time, always departing but enriching memory. Time is a material to be used in architecture just as brick, stone, or steel. Through what medium does time flow? It is present in the interaction of all material things: living bodies, buildings, geologies, and the surrounding firmament. Things are gods—and time is the interplay of things.[21] Things are gods and time is their dance.

Time is never cut with the razor sharpness of the synchronized clock. The clock parses out time like a commodity. Time is spread open so that every moment has temporal thickness. Time lived holds together memory and anticipation, procrastination and vigilance, failure and fidelity. A painted still life simultaneously stops time and opens time up to a depth of experience where moments contain other moments in a matrix of possibilities and past reflections. The stilling of life's temporal movement allows us to see with an integrated depth of experience. The still life is the thoughtful compliment to the motion picture.

Each now is a made anew, compounded and distinct—due to its joining to a specific setting—and each building is shot through with attended pasts, multiple nows, and anticipated futures. Time is a ribbon unrolled, stretched, overturned, knotted, and bowed. A building is a complex of contemplations, a composite of life, and a matrix of associations, occasions, and varied attentions each vital to an unfolding whole. There is a strong phenomenological link between the painted still life and a building in peak maintenance.

Time is a gathering body of experience understood both backwards and forwards.[22] Time is not passing but accumulating (curiously withering as it gathers). Time and space are ceaseless presences lodged everywhere. Imagine simply an hourglass with its pinched, conjoined chambers—losing and gaining in a single flow; accumulating and diminishing simultaneously. The future is consumed while the past accumulates: time is a relation. Matter accumulates time while filling the margins of space. Time has a fineness and an indivisibility like human consciousness. Is time the mind of matter? Is matter the body of time?

Time in human terms, like place, is a continuity of feeling, and only as a continuity is it exactingly human. Made inwardly human, time is an elastic entity that immerses us in the infinite. Time cannot be divided if it is to be truly lived. Maintenance preserves that continuity while simultaneously infusing that continuity with subtle and sometimes unexpectedly abrupt differences. As Heraclitus has been interpreted as saying, "Time is a child building a sand castle by the sea."[23] Time is enacted just like a building is enacted, and maintenance is one of those key and infusing actions that merge time, life, and building into a totalizing experience. Maintenance workers are the conservators of tomorrow.

Property is made and remade, maintained, and renewed so as to be continuously occupied. Our material culture is humanity's real time keeper. So architects should commence with a definition of architecture as the intermingling of time and materials as rendered through a place. A building, through continued habituation and maintenance, will be many spaces temporally arranged.

CONCLUSION

> "I think architecture has always been a way of measuring time, I like to think of buildings as clocks, calendars, and chronicles. Vitruvius saw the design of timepieces as one of the architect's chief skills.

> Surely, the registration of time is one way that architecture confers orientation on the activities of our lives."—**David Leatherbarrow**[24]

In his essay, "Melancholy and Time," Pallasmaa links architecture to death when he writes, "Architectural constructions are a defense against the anxiety of death, disappearance, insignificance, and non-existence."[25] He supposes that architecture is about assuaging death. He interprets a building as a permanence that aims to halt time. But a building is never final, indifferent, impervious to change, ideal, or autonomous.

The goal of architecture should be maintenance because it signals that a building is fulfilling enough to be worth retaining, remembering, and revisiting. If appreciated by those that live there, even the most mundane building is an enlargement of life. Architecture is not built to suppress or express our anxiety over death. Instead, we build in order to affirm, enrich, and accommodate life's activities—and we build for the perpetuation of a life in which maintenance is clearly integral.

Pallasmaa is right to suppose that buildings should protect us from outside threats and inner fears. But architects should emphasize *protection*, including its myriad synonyms, and not fixate anxiously on some predicted loss. Fear is a ubiquitous and uncontrollable feeling; but protection is essential to architectural expression. Protection comes from caring; and caring continues through the task of maintenance. For architectural expression to be whole, we must include the sensibilities of maintenance into the fold of architectural practice.

Grime and debris used to be local considerations that demanded local solutions. However today, waste and sanitation are forces, machine-driven flows, that bridge between localities that together form a global waste stream. Waste is a foul pallor that spreads. It is sometimes exchanged and traded willingly; but many times it is imposed unwillingly on someone else, somewhere else.[26] Even the products with which we clean and sanitize become a danger to broader ecological systems. Maintenance and sanitation, once the discrete activities of a caretaker, have become a massive worldwide system. And like all forms of systematization, it demands vigilant management and careful regulation.

Architects can recognize instantly the shades of neglect in a place not properly maintained. Architectural educators would do well to include the implications of maintenance and maintenance art in their classes. At one time, the students of Auburn University's Rural Studio were expected to repair the enduring works of their predecessors. This exercise seems to have had multiple pedagogical aims. First, to experience working with one's hands and to learn how materials fit together. Repairing is the first step to building. Second, to observe closely what details and conditions do not work in the Hale County climate and learn how to imagine something better. Third, to get comfortable working outside, in the sun, heat, and humidity—to acclimate the body to the rhythms of weather, the heft of materials, and the contortions that a body that builds must endure. And fourth, to retain the continued trust of the community, to demonstrate that the commitment by the Rural Studio to the inhabitants of Hale County is lasting, and to show that what we build we mean to endure. Maintenance accords with the fundamental neighborly sense that keeps community together. Through maintenance, we retain our humanity.

There develops a four-sided conversation between designing, the physical building, its eventual wearing, and its maintaining. Maintenance binds, cares for, and puts things in relation. Maintenance means that we cannot leave a building alone: it must either be engaged with or deteriorate. Material changes reveal time's interconnectedness. 'Maintenance-free' materials discourage our interaction with buildings and steal away time's concomitance with place—making us dismissive, forgetful, and lost. Maintenance has the capacity to form a bond between us and building—making us empathic and gentle listeners who pay attention to place.

Touching confirms a things presence. Maintenance, as a form of touching, confirms a lasting presence. Touch, and the doubt of presence is confirmed through touching. Clean or repair something and the doubt of persistence is confirmed through maintenance. Dilapidation, weathering, and wear exist everywhere and always in varying measures and degrees. Even demolition doesn't delete a building's being. A work of architecture, like its counterpart maintenance, is never finished, never ending, and nearly everlasting—for even after archeologists sift through debris and touch again the traces of materials which have lasted through the ages, it will still be possible to perceive the former patterns of human life crystallized in those fragments.

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[2] A personal note I took while attending a lecture by David Leatherbarrow, "Making, Invention, and Involvement (in the World)," which was part of the 26th National Conference on the Beginning Design Student, *Made: Design Education & The Art of Making*. The lecture was held Saturday, March 20, 2010 at the University of North Carolina at Charlotte. Graciously uploaded to Vimeo on June 30, 2010; http://vimeo.com/12991396 (last accessed 1/16/13).

[3] W. R. Lethaby, "The Foundation in Labor," from *Form in Civilization: Collected papers Art and Labor* (London, UK: Oxford University Press, 1957) 179.

[4] Charles Olson, *Letters for Origin: 1950-1956* (New York, NY: Paragon House, 1989) 103. The actual quote is: "For to be a spectator is to assert an ownership in it which is absentee . . ."

[5] Charles Olson, *Letters for Origin: 1950-1956* (New York, NY: Paragon House, 1989) 127.

[6] Guy Davenport, "The Dawn in Erewhon" from *Tatlin!* (New York, NY: Charles Scribner's Sons, 1974), 204.

[7] I am applying the Heraclitian fragment, "Character is fate," to building. 'Ethos' is translated by both Guy Davenport and Charles Kahn as 'character.' See Guy Davenport*, Herakleitos and Diogenes* (San Francisco: Grey Fox Press, 1979) 9 and 22. Also, see Charles H. Kahn, *The Art and Thought of Heraclitus* (Cambridge, UK: Cambridge University Press, 1987) 81, 260-261.

[8] Mierle Laderman Ukeles, "Flow City," in an interview with Anne Doran; *Grand Street, No. 57: Dirt* (Summer, 1996) 210.

[9] Clearly, Pallasmaa decided not to be extensive in his discourse on the hand and focused exclusively on its capacity to create. However, the thinking hand is just as important in maintenance as it is in creation. Mierle Laderman Ukeles makes that argument clear through her art. See Juhani Pallasmaa, *The Thinking Hand: Existential and Embodied Wisdom in Architecture* (West Sussex, UK: John Wiley & Sons, 2009).

[10] Mierle Laderman Ukeles, "25 Years Later," in *Matrix 137* (Hartford, CT: Wadsworth Atheneum, 1998) 11.

[11] In his editorial "Conservation Cleaning/Cleaning Conservation," Jorge Orteo-Pailos connects Ukeles' performances at the Wadsworth Atheneum with subsequent works by other artists. In particular, he points out the work of Carmen Perrin, a Bolivian-born Swiss-French artist. Her art confronts action with contexts. Known for her collaborations with architects (including Herman Hertzberger) and her interventions into landscapes, Orteo-Pailos looks at a specific piece by Perrin titled, "Swiss Path, Geneva itinerary," completed in collaboration with works by artists Richard Long and Max Neuhaus. In her work, Perrin and others removed layers of earth and animal life from enormous glacier-driven white granite stones. This act of cleaning was understood as a temporary intervention, removing 1500 years of geologic sedimentation. The work uncovered a very personal relation between habitual action and place. As she put it,

> "We clean the stones with simple repetitive motions. We listen to the sounds of the forest. . . Our postures, right up against the earth and the stones, remind you of a scene from an archeological dig. The hidden treasure is essentially in the action, in the focused consciousness. Many of the stones are huge. However, their folds, their bumps, their wrinkles, and their roughness invariably bring to mind our flexibility, our weight, our texture, our joints, our measurements."

Perrin's art embodies experience in its making. The work intimates the conscious attention demanded when carefully cleaning or maintaining things. Her removal of time's marks upon stone becomes the sculpture itself. Only afterward does the unexpectedly pristine granite arrest the spectator with questions about this intervention in time. See Carmen Perrin, *Contexts: Public Situations* (Basel, Switzerland: Birkhäuser, 2004) 63-64.

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[14] John Ruskin, *The Seven Lamps of Architecture* (New York, NY: Dover Publications, 1989) 178.

[15] Hannah Arendt, *The Human Condition* (Chicago, IL: The University of Chicago Press, 1958) 136-137.

[16] Pallasmaa's actual quote: "Architecture builds dams to hold back the flow of time." From Juhani Pallasmaa, "Melancholy and Time," from *Encounters*, edited by Peter MacKeith (Helsinki, Finland: Rakennusstieto Oy, 2005) 311.

[17] This is a section title from the essay "Melancholy and Time." See Juhani Pallasmaa, *Encounters*, edited by Peter MacKeith (Helsinki, Finland: Rakennusstieto Oy, 2005) 314.

[18] Rafael Moneo, "The Solitude of Buildings," *Kenzo Tange Lecture, March 9, 1985* (Cambridge, MA: GSD, Harvard University, 1985) 18.

[19] William Blake, *The Poems of William Blake* (London, UK: Oxford University Press, 1961) 250.

[20] Adolfo Natalini, *Figures of Stone* (Milan, Italy: Electa Editrice, 1984) 93.

[21] A thought derived from the Ancient Greek philosopher Thales and attributed to him when Aristotle wrote, "Some declare that the soul is mixed in the whole, and perhaps that is why Thales thought all things are full of gods." Aristotle on Thales, from *Readings in Ancient Greek Philosophy from Thales to Aristotle*, edited by S. Marc Cohen, Patricia Curd, C. D. C. Reeve (Indianapolis, IN: Hackett Publishing, 1995) 9.

[22] See Aldo van Eyck, "The Interior of Time," from *Meaning in Architecture*; edited by Charles Jencks and George Baird (New York, NY: George Braziller Inc., 1969) 171.

[23] For this particular variant of Heraclitus' fragment see Guy Davenport's short story, "Herakleitos" from *Tatlin!* (New York, NY: Charles Scribner's Sons, 1974) 113. Another version of this fragment has been translated by Davenport in a fuller version, "History is a child building a sand-castle by the sea, and that child is the whole majesty of man's power in the world." See Guy Davenport, *Herakleitos and Diogenes* (San Francisco: Grey Fox Press, 1979) 15. 'Time' is translated variously as *history*, *eternity*, and *lifetime.* See Brooks Haxton, *Fragments* (New York: Viking, 2001) 51. Also, see Charles H. Kahn, *The Art and Thought of Heraclitus* (Cambridge, UK: Cambridge University Press, 1987) 71, 227-229. Davenport's translations come closest to this essay's main points.

[24] David Leatherbarrow, transcribed from his lecture, "Making, Invention, and Involvement (in the World)," from the 26th National Conference on the Beginning Design Student.

[25] Juhani Pallasmaa, "Melancholy and Time," from *Encounters*, edited by Peter MacKeith (Helsinki, Finland: Rakennusstieto Oy, 2005) 310. I am also reminded of an essay by Karsten Harries, "Building and the Terror of Time," where he points to the nature of time in architecture in the final passage of the essay. In describing the painting, *The Tower of Babel*, by Pieter Bruegel the Elder from 1563, Harries compares the colossal construction of the Tower, which he analogizes to architecture's heroic struggle against entropy, to the ramshackle dwellings in the town that clings to the Tower. Each dwelling appearing inhabited, constant, and purposeful—representing the ordinary life we endeavor to maintain. As Harries concludes,

> "Here we have, not monuments, but buildings that speak of a very different, less antagonistic relationship to time. They hint at possibilities of dwelling born of a trust deeper than pride. Such trust demands determinations of beauty and building that do not place them in essential opposition to time."

See Karsten Harries, "Building and the Terror of Time," from *Perspecta: The Yale Architectural Journal*, Volume 19 (1982) 69.

[26] For a broader discourse on this important subject, please see Michel Serres, *Malfeasance: Appropriation Through Pollution?*, translated by Anne-Marie Feenberg-Dibon (Stanford, CA: Stanford University Press, 2011).

HISTORY

Maps, Media, and Models in Architectural History

Delineating the Detail: The Communication of Architectural Particulars, 1750-1872

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ABSTRACT: In contemporary architectural practice, the notion of the architectural detail is complex and contentious. For many, 'details' are synonymous with the smallest scale of construction's resolution. Others believe them to be a building's 'minimal units of signification' and essential to the production of architectural meaning. And still others see the term as interchangeable with ornamentation. While there have been recent and notable contributions to the architectural detail's theorization, the longer history of its etymological evolution and changing meanings in practice has yet to be written. As a means of clarifying our contemporary understanding of the meaning of the practice of detailing, this study intends an overview of one piece of this proposed history, exploring the dynamic relation between architectural details and their delineation in 18th and 19th century France and the United Kingdom.

The word "detail" stems from the French *de taille*r, meaning "to cut up into pieces", which would evolve into the cognate *détail* by the 18th century. The term referred to the 'cutting' of architecture into a collection of significant fragments, a process accomplished primarily via drawing as a means of both development and communication. This practice, however, would be brought to bear on an increasingly complex collection of things as designers responded to the emergence of new social, disciplinary, and technological conditions by the mid-19th Century. From issues of fire-protection to prefabrication and the growing rift between architects and engineers, the stage would be set for the haze of our contemporary understanding of detail.

By analyzing a collection of delineated details from a series of critical moments from the late 18th to mid 19th centuries, this paper seeks to give a conceptual account of the practice of detailing as derived from an understanding of its shifting meanings in the history architectural discourse and practice.

KEYWORDS: detail, drawing, ornament, construction, communication

INTRODUCTION

In contemporary architectural practice, the notion of detailing is often thought synonymous with the smallest scale of a building's design—an activity involving the configuration of relationships between the work's most basic constructive components. In this context, the detail becomes the construction detail, and it is not uncommon for an architect to select such a detail from a stock of standard configurations, or at least to use one such configuration as basis for developing one's own solution to a constructive problem. Others, such as Marco Frascari, have claimed that details are architecture's "minimal units of signification" and, as such, essential to both "the construction and the construing" of architecture.[1] On this view, the activity of detailing pushes beyond mere practicality and aims to communicate or express. Still others have decried the detail as a fetish, and called for an architecture with no details at all.[2] In such a case, the detail would disappear completely, or so they would claim, in order to privilege the reading of a building's form as a seamless whole. And in popular sources, picture books and mass-market periodicals, the terms detail and ornament are used more-or-less interchangeably, a notion that may in fact have the longest history.

To be sure, the concept of the architectural detail is complex and contentious, without clear consensus on either its precise definition or even the necessity of its inclusion within the architectural project. While there have been recent and notable contributions to the architectural detail's theorization, the longer history of its etymological evolution and changing meanings in practice has yet to be written.[3] This study intends an overview of one small piece of this proposed history, exploring the dynamic relation between architectural details and their delineation in 18th and 19th century France and the United Kingdom.

1.0 ORIGINS

In his 1819 *Architectural Dictionary*, Scottish architect Peter Nicholson offered a relatively early definition of detail in architecture: "the delineation of all the parts of an edifice, so as to be sufficiently intelligible for the execution of the work."[4] In other words, for Nicholson "details" were drawings of various building elements from which craftsmen could work. This claim is problematic, for in pre-modern times many building elements that would properly be considered details were not always drawn (or even properly designed) but rather simply produced by craftsmen. And yet, the connection between detailing and drawing is indeed critical, and it can be illuminated by looking to earlier uses of the term.

The word "detail" stems from the French *de tailler*, meaning "to cut up into pieces". One of the earliest appearances of this term in architectural discourse can be found in Philibert de L'orme's *Nouvelles inventions pour bien bastir et a petits fraiz* (1561), where he repeatedly uses the term "*pierre de taille*", meaning "cut stone".[5] Here, in a usage close to its etymological origin, one finds two important implications of the meaning of the practice of detailing. On one hand, detailing involves some act of cutting, and on the other, the production of cut stone is somehow bound to this practice. The precise character of these relationships becomes more clear over the next two centuries.

By the 18th century *de tailler* would become the cognate, *détail*, appearing most frequently in reference to the particulars of a topic described "item by item", as in one's "addressing a subject in greater detail." Though by mid-century, the term began to take on more familiar and architecturally explicit meanings. In his *Cours d'Architecture* (1750), Jaques-Francois Blondel uses the term *détail* extensively, and primarily in relation to particulars of an edifice's ornamentation. He discusses the articulation of columns on which "channels which are recessed in contrast to the projection of fluting… adorned with jewels, bouquets of laurel, [and] seed", suggesting "that these details belong more to bronze than marble."[6] He also dwells extensively on "details of the orders", concerned largely, and in step with the dominant themes of 18th century architectural theory, with the overall *character* expressed by the orders' ornamentation.[7] The primacy of this conception of detail in Blondel is underscored by the two volumes of illustrated plates accompanying his text—overwhelmingly, a collection of ornamental details (fig. 1).

As understood from Blondel's conception of detail and the meaning of its etymological root, the practice of detailing can be said to entail the 'cutting' of an edifice into a collection of significant fragments. What these fragments are, as we will see, will depend on designer's conception of their role in design, those aspects of a work that are deemed properly within the realm of their control, and those features of a building that are thought to necessitate further and more intricate description in drawing to those who will do the constructing.[8] In the mid-eighteenth century France of Blondel, building methods (primarily in masonry or wood) were well known and understood by those who would have constructed buildings, so it was primarily the organization of the plan and character of the ornamental ensemble towards which architects would direct their attention. Said otherwise, prior to industrialization, the practice of detailing was brought to focus primarily on an edifice's significant ornamental fragments, drawn as a means of envisioning and communicating the particular character of a projected work of architecture. This focus, however, would begin to shift by the late 18th century, a process catalyzed by the industrialization of iron production and the growing place of metals in the construction of buildings.

Indeed, metals like iron and lead had long been used in construction, present in significant quantities even in many ancient Roman works of architecture, but until the late 18th century such metal components typically served auxiliary rather than primary structural functions. Metal cramps were used to tie blocks of masonry together, rods were used to reinforce arches in stone, and fasteners were produced to secure connections in timber.[9] In such cases, these techniques were coordinated and implemented in the process of construction, as a matter of practice, not projected in advance via drawing. In the rare cases that such details of connection were delineated, it was typically a matter of documentation following construction rather than its projection beforehand. Such was not the case, however, in the work of Jacques-Germain Soufflot and Jean Rondelet at the church of Sainte-Genevieve (1758-90) in Paris.

To alleviate structural issues arising from the ambitious scale of the dome that was to top the church, Rondelet developed a complex system of iron reinforcement to be concealed within the building's relieving arches. In this case, the configuration of materials was drawn in advance of construction. The building was 'cut' into significant fragments, particular components drawn in detail, illustrating not only the precise location at which reinforcing elements were to be placed, but even the particular shapes in which iron bars were to be forged and the modes of their interlocks in assembly (fig. 2). While this mode of construction was not wholly without precedent, its implementation in practice was by no means a matter of common knowledge by those doing the constructing, and thus these aspects of the building's assembly necessitated further description by its designers in drawing.[10] Without the proper resolution and communication of this information, what was at risk was the building's structural failure. This, an 18th century equivalent of a page of modern 'construction details' arose within a time dominated by the 'ornamental' conception of architectural detail. These two notions would continue to coexist indefinitely, albeit a coexistence of shifting balance.

With the accelerating progress of industrialization at the dawn of the 19th century, new societal needs emerged and building components in iron became more readily available, together, facilitating iron's use at larger scales and in more extensive assemblies. Greater complexity of constructions and more critical structural demands would contribute to the rising prominence of engineers, no longer one in the same with architects. Further, the scientific developments of the Enlightenment and wider adoption of standardized measurement would give rise to an ethos of precision, calculation, and a growing trust in technology. These developments would have a quick and profound impact on the character of the practice of detailing, offering a multitude of new conditions to define and control via drawing and a tension between schools of thought on how to go about doing it.

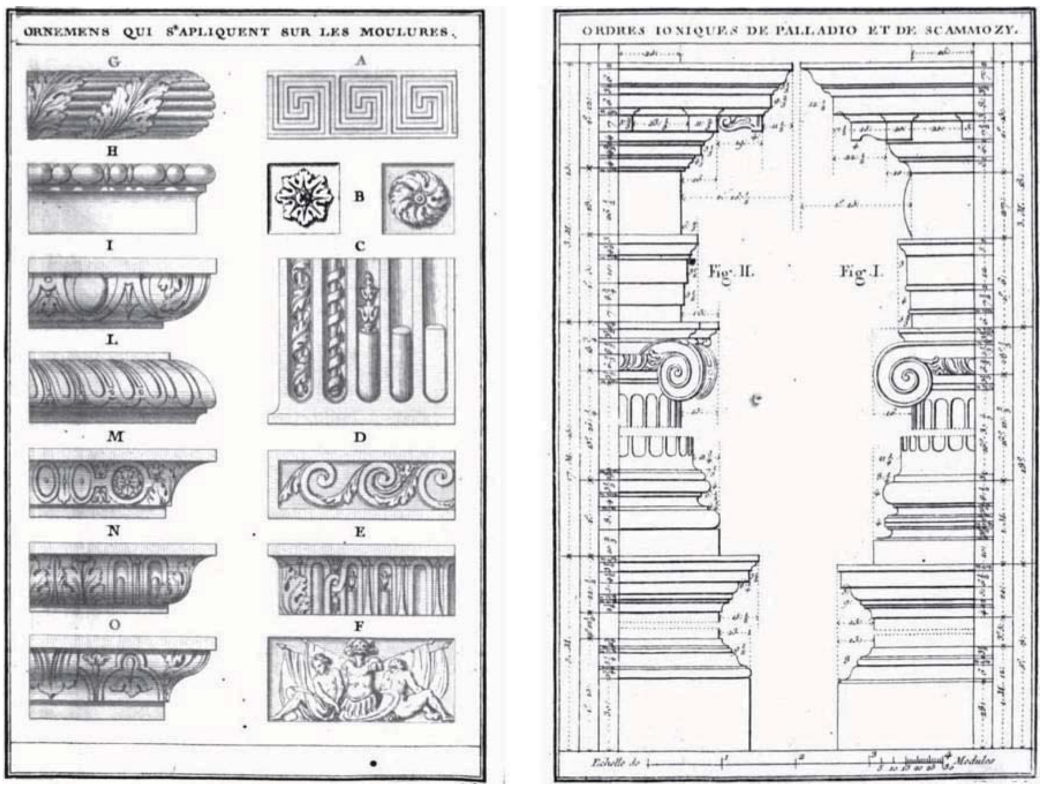


Figure 1: Two pages of the illustrated plates accompanying Blondel's *Cours*. (Source: Blondel, 1750)

2.0 ASSEMBLIES

The last decades of the 18th century bore witness to a rash of deadly fires within specific sorts buildings—theatres in France and mills in England. Before the advent of electricity, the interiors of theatres were lit by flame and productions often included pyrotechnic effects, an environment rife with possibilities for structural combustion. The situation was worse yet in cotton mills as, with the industry's mechanization, the timber structures of buildings housed machinery powered by coal and steam which were enveloped in a highly flammable atmosphere, "full of fine fibers of cotton and… the vapor given off from the oils used to lubricate the machinery," an explosive combination.[11] In these situations, iron was a material with certain appeal, as it offered a greater degree of fire resistance, especially in the proper configurations with other materials.

In 1782, the Parisian architect Ango developed a 'fireproof' flooring system known as *poteries et fer*, a layered system of iron beams, clay pots, and plaster. A different fire-proofing system using sheet metal, brick, and plaster to protect timber structural members was developed in 1792 by the English engineer, William Strutt, and the system was implemented in industrial buildings in the towns of Derby and Millford. Systems such as these benefited from delineation in detail, as the correct assembly and configuration of their components was absolutely critical to their proper function (fig. 3 and 4). Not unlike 18th century techniques for ornamental detailing, these drawings were a means of both projection and control of the constructed outcome, however, they illustrate a shift in motives behind the building's being 'cut' into fragments. While the former mode of detailing aimed to control of a work's character via *visible decoration*, a primarily aesthetic pursuit, the latter techniques aimed chiefly at controlling aspects of *building performance*, a more strictly technical objective, and one of relative *invisibility* in the finished product. Once again, new constructive methods have always posed a challenge in assembly, and in these particular cases of fireproofing construction, the proper configuration of *layers* within assemblies was of the utmost importance. This is not to say that layered construction was a new phenomenon, but rather to suggest that it would be of increasing import in construction from the 19th century onward and, thus, more and more the object upon which the practice of detailing would be brought into focus.

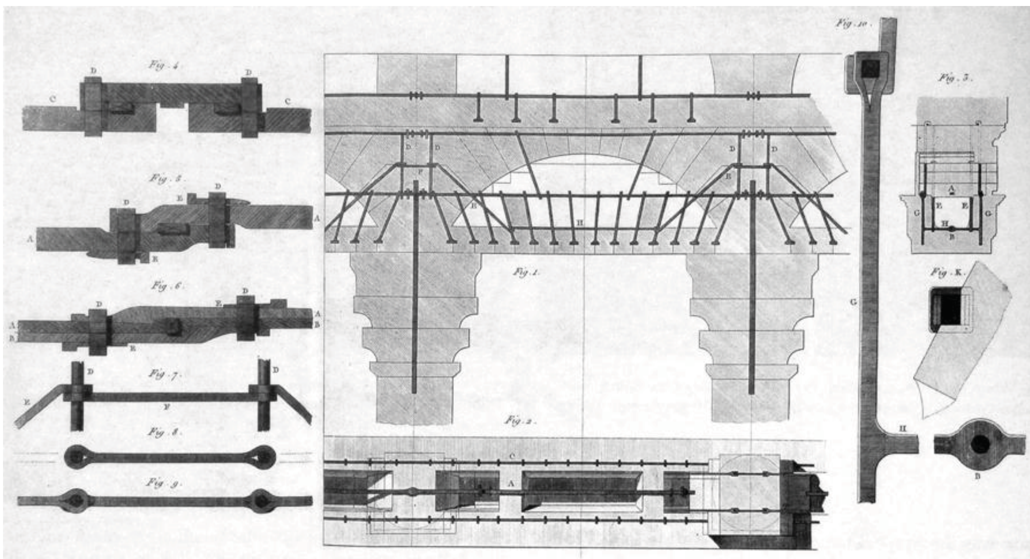
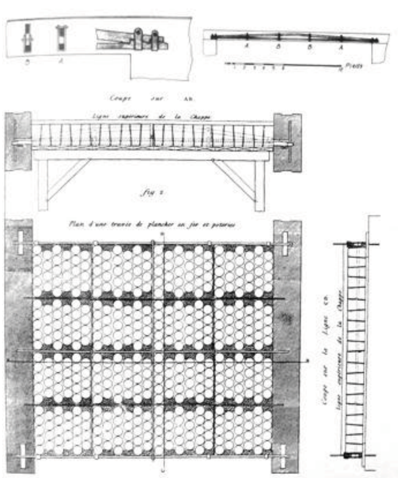


Figure 2: Jean Rondelet's details for the reinforcement of the *Sainte-Genevieve* portico (Source: Rondelet)



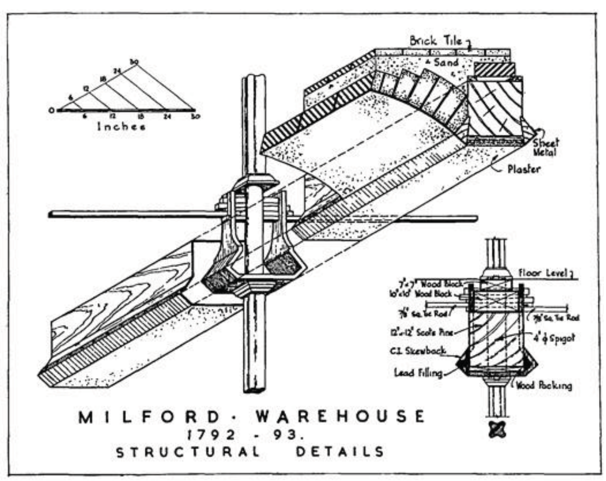
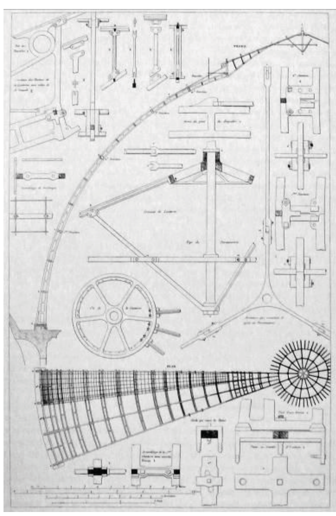
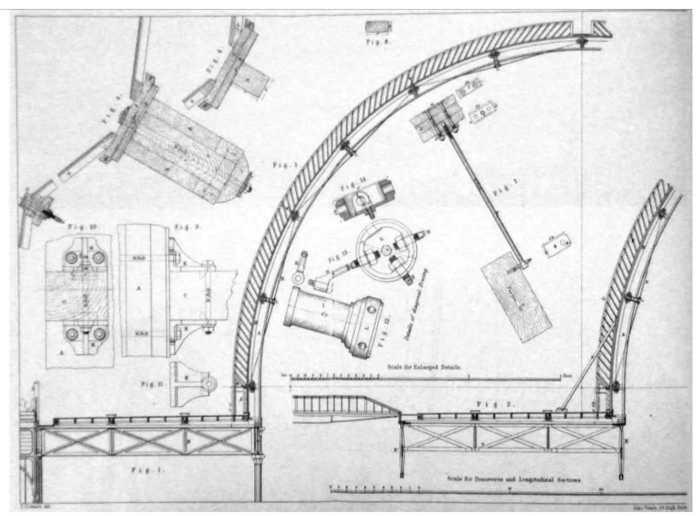


Figure 3 and 4: Ango's *poteries et fer* (left) and Strutt's system of fireproofing (right). (Sources: Ango and Strutt)

Another path forged for the practice of detailing during this time concerned the construction of roof structures in Iron. In 1811, the French architect François-Joseph Bélanger and engineer François Brunet designed a dome of cast iron, wrought iron, and copper for the Halle au Blé, the wheat market in Paris. The structure was of unprecedented complexity and, in fact, was the first example of a wide-spanning iron roof.[12] Naturally such a project would necessitate precise description, both as a means of producing the many components and for instruction as to how they should be assembled (fig. 5). Here detailing again gravitates towards the technical, and this is particularly notable, as the structure's design was a collaborative effort between an architect and engineer, two discreet individuals and no longer a single master builder. Further, the two issues here presented—the production of components and their assembly directed via delineated details—would continue to be developed in both France and the United Kingdom, largely for utilitarian structures and often through the combined efforts of engineers and architects. This process would reach a high point at London's 1851 World's Fair in the design and construction of the Crystal Palace.

The commission for the Crystal Palace was won by a competition design by Joseph Paxton in collaboration with engineer and friend William Barlow. While there was nothing particularly novel about most of the parts that made up the great exhibition hall—many of its elements had been pioneered in the glass and iron conservatories of the 1830's and 40's—the scale and speed of construction and its process of production were wholly unprecedented. The scheme was predicated on the design of a few critical details, bringing together a relatively limited set of prefabricated, mass produced components to be assembled systematically on site (fig. 6). Here, the significant fragments that were the object of the practice of detailing were few, but their effect great. This powerfully instrumental set of construction details was designed in conjunction with an engineer, Charles Fox, and it embodied a modern technical-industrial ethos of precision and efficiency. Construction in iron was shifting the balance, at least to some degree, from ornamental to technical modes of detailing, but the relationship between these two poles would grow more complicated yet.





Figures 5 and 6: Details from Halle au Blé (left) and the Crystal Palace (right). (Sources: Belanger/Brunet and Paxton/Fox)

3.0 CONFLATION

While these various developments in the technology of construction were unfolding, the older ornamental traditions in detailing still had many adherents amongst architects. This seems clear as can be told from the practice of the *École des Beaux-Arts "alalytique"*, an ensemble in drawing of a project's ornamental fragments intended to convey the character of a work of architecture via the sum of its disembodied and recomposed parts, utilized in the training of architects well into the 20th century. This is also implicit in the wide practice in France and the UK of architecture in various classicist traditions. Thus, the detailing practices of the 19th century can be roughly characterized as a gradient, with constructive/technical detailing at one end and ornamental/aesthetic at the other, a crude dichotomy between the ethos of the engineer and that of the architect. But one will immediately realize that such an opposition is problematic, as technical and aesthetic concerns in detailing have almost always been bound to one another, even completely conflated in the practice of architects from at least the mid-19th century onward. An example of such a practice can be found in the work of the French architect Henri Labruste, particularly in his designs for the *Bibliothèque Sainte-Geneviève* (1843-50).

Labruste’s library is one of the earlier examples of iron-frame buildings typically cited in text books on architectural history, and it constitutes a very refined example of classical, Greco-Gothic ideals applied to new methods of construction in iron. Here, the designer’s attention was brought into focus upon a range of significant constructive fragments, treating each with the aesthetic attention and sensibility of a Beaux-Arts architect. In his carefully rendered detail drawings for the library, structural elements are richly articulated with decorative motifs, while also giving ample attention to the clear description of the modes of connection at each significant joint (fig. 7). Here, for the greater part, decoration is not merely applied to structure, but integrated into the members themselves—decoration adds depth to members, lightens them, and reinforces connections at discontinuities. Here, technical and aesthetic concerns are conflated, a slippage between approaches to detailing that would be increasingly common, one that would give rise to several other sub-approaches to detailing.

This evolution of the architect’s concerns in detailing is again rendered visible in the theoretical writings of Eugène-Emmanuel Viollet le Duc, particularly via his drawings of details in the first and second volumes of his *Lectures on Architecture* (1863-72). In lecture VII of the first volume, written in 1863, Le Duc refers the reader to a plate of illustrated ‘details’ in stone, clearly a set of ornamental elements, leaving behind questions of construction and assembly (fig. 8). However in the 1872 second volume, Le Duc refers to a different set of detail drawings, this time of construction in iron which, while clearly possessed of an aesthetic vision, is careful to describe and reveal all modes of connection and joinery as well (fig.9). Le Duc is often characterized as a staunch proponent of the rationalization of construction, an attitude toward building that would carry great currency among the pioneers and forefathers of the modernist movement.

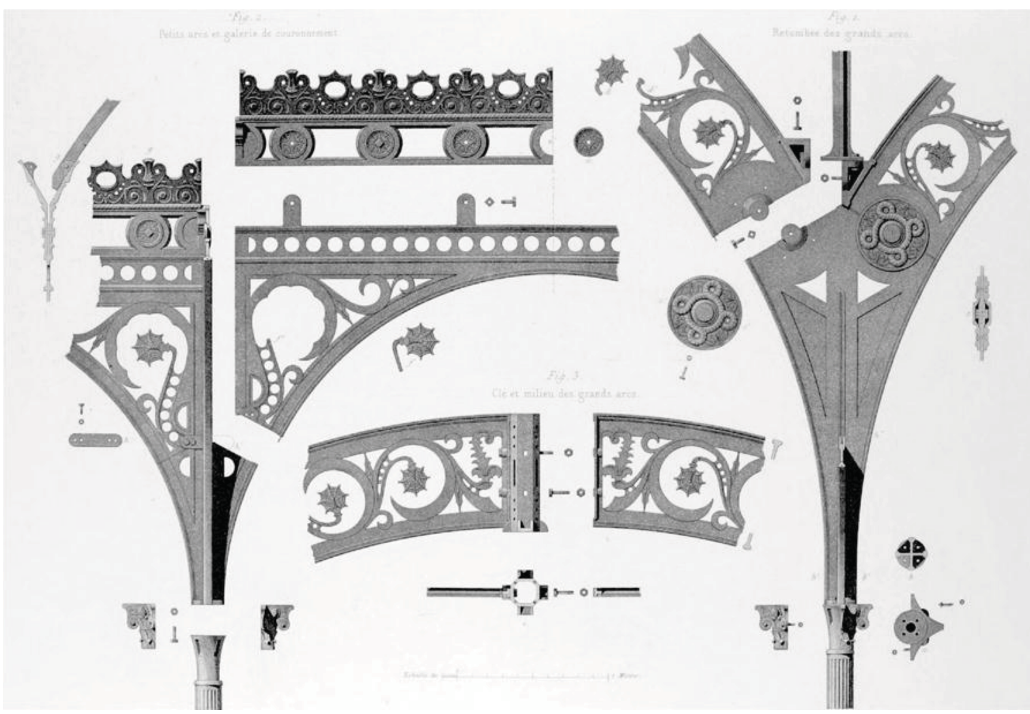


Figure 7: Labruste’s Details from *Bibliothèque Sainte-Geneviève*. (Source: Labruste)

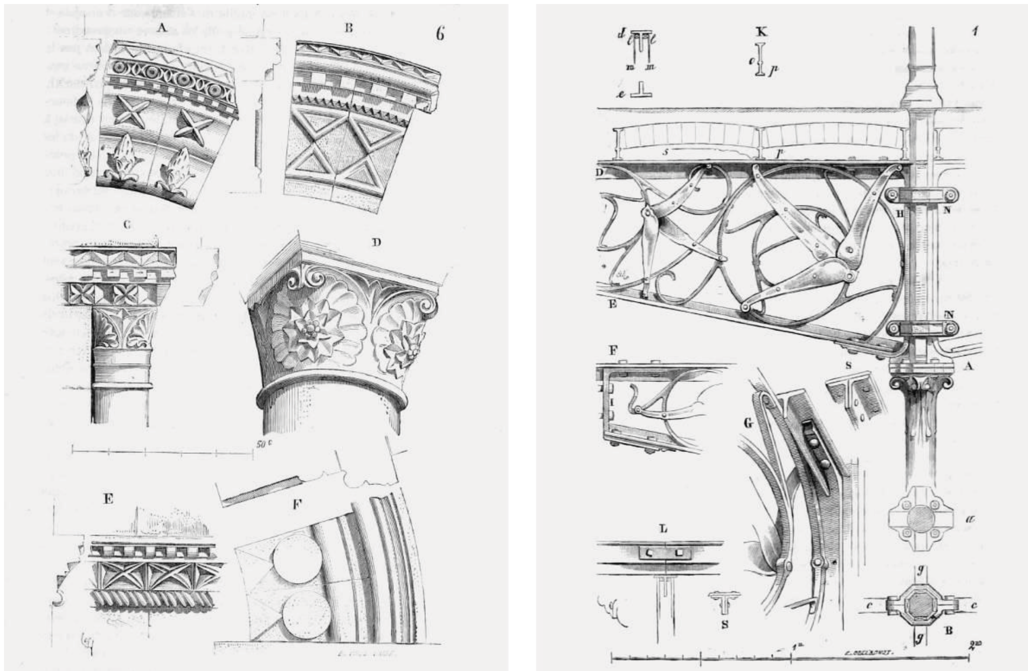


Figure 4: Le Duc's details in stone (left) and iron construction (right) . (Source: Le Duc)

CONCLUSION

This essay began with a commentary on the divergent meanings that the term detail carries in discussions about architecture. In the essay that followed, I have tried to describe what I believe are the origins of this contemporary condition in changing practices of drawing architectural "details" in the 18th and 19th centuries. While two contemporary meanings have been discussed—the ornamental and constructive—two other issues mentioned have yet to be fully addressed—the question of architectural meaning and the detail's supposed disappearance or absence in some architectural works. To risk a possibly oversimplified summary, the question of meaning seems caught between the communicative function of classical ornamentation and the elaboration of construction, an attempt to recover the purpose of the former within the process of the latter. And as suggested previously, the hope to erase the detail from a work of architecture seems more properly an attempt to suppress its expression in order to privilege the reading of the overall form of the work. Whatever the case, it's clear that while this essay ends in the late 19th century, the story of the detail continues to grow more complex over the course of the 20th century.

With the coexistence of these very different, and even at times contradictory meanings of detail, the real question lies in their similarity. What is it that unites them all as details? One answer would be that their common thread is the *act* that produces them—the *practice of detailing*.

Fundamentally, any practice of detailing begins with the identification of a significant fragment of a work and is followed by its development in relative isolation. What is isolated as a detail is sometimes a matter of necessity or convention while at others an issue of the designer's priority. In the latter case, the detail's identification is motivated, and the designer selects a fragment situated at some critical moment within the project, a decision that reveals, at least in some sense, the values of the designer in relation to the work. As we have seen, the mid-18th century architect might have isolated a cornice or the profile of a column capital, while the 19th century engineer might have isolated the riveted connection between two iron supports. In either case, both undertake the same fundamental activity—the design of the isolated particular, shaping it in response to the factors that they identify as valid influences upon its form. In the former case, the architect might have responded to the work's cultural context, relationship to the body of a viewer, and the character of the larger ensemble. In the latter case, the engineer might have calculated the loads and forces present at the connection and sought to maximize material efficiency. Historically, in either case, the act of drawing has played a critical role.

Because drawing has long been the primary medium of both development and communication in the production of built works, it has also been the primary means of operation for the practice of detailing. This is not to suggest that there can be no detailing without drawing, but merely that in most cases, it is central to the practice. Drawing provides easily for the isolation of the significant fragment and its development in an readily reproducible and communicable format, rendering decisions made visible and intelligible to those who would produce or assemble a given thing. The question that remains is that of the limits of what one might consider a significant fragment to be identified, isolated (if only for a time), developed, and delineated in detail.

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[2] Ben Van Berkel and Caroline Bos, "Sixteen Statements," in Detail Magazine, vol. 40, no. 8 (Dec 2000): 1437.
[3] I have in mind Edward R. Ford's *The Architectural Detail* (2011) and Michael Cadwell's *Strange Details* (2007).
[4] Peter Nicholson, *Architectural Dictionary* (London: J. Barfield, 1819): 383.
[5] Philibert de L'orme, *Nouvelles inventions pour bien bastir et a petits fraiz* (Paris: Federic Morel, 1561): 9.
[6] Jaques-Francois Blondel, *Cours d'architecture* (Paris, 1750) 256.
[7] Blondel, *Cours*, 266, 285, 299.
[8] For more on the relationship between design and construction before industrialization see: John Fitchen, *Building Construction Before Mechanization* (Cambridge: MIT Press, 1986).
[9] For an essay on the early stages of Iron's adoption in construction see: Bill Addis, "The Iron Revolution," in *Before Steel* (Zurich: Niggli, 2010): 33-46.
[10] Robin Middleton and Marie-Noelle Baudouin-Matuszek, *Jean Rondelet: The Architect as Technician* (New Haven: Yale University Press, 2007).
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Differentiation as a Form of Knowledge Production in Architecture

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ABSTRACT: Architectural models and photographs, foreground some perceptual aspects of architecture while minimizing the presence of others (Bermudez & King, 2000; Boge & Sullivan, 2006). Photographs highlight the value of a point of view, framing, and cropping. Digital models also embody points of view, as well as less obvious attributes such as the sequential order of construction (which may or may not correlate to the order of construction of the building being modeled).

Using Villa Savoye as a test case, we examined the degree of differentiation between online models, and how these differences can be mapped and extrapolated to illuminate conditions potentially suggestive of architectural significance in themselves – independent of any consideration of the models' verisimilitude. We then asked: Are there limits to how "wrong" a model can be and yet still be capable of provoking significant insight? In reflecting on our processes, we questioned how the tools we have developed may facilitate forms of knowledge production historically essential to architectural epistemology but often overlooked in a contemporary discourse dominated by hyperaccurate models, predictive simulations, and photorealistic renderings.

Our questions are aimed at making visible that which is essential to a critical architecture in which processes and tools generate and sustain a non-destructive environment for architectural research.

KEYWORDS: architecture, Villa Savoye, differentiation, models, photography

INTRODUCTION

Generative design approaches in architecture use algorithms to generate multiple iterations for evaluation with respect to stated criteria. In such approaches, it is usually assumed that criterion-driven selection processes will result in optimized forms, provided the algorithms are robust and the criteria are well-defined (Caldas & Norford, 2002; Terzidis, 2006). Differentiation is understood as a generative process which occurs over multiple iterations.

By contrast, in this research, we are interested in differentiation as a process of reading, as a trajectory within the larger project of architectural epistemology. Beginning with a set of 45 digital models of Le Corbusier's Villa Savoye (Figure 1), we considered differentiation of two types. Type 1 differentiation asserts that each of the models differs in more-or-less significant respects from the built Villa Savoye: any given model contains inaccuracies with respect to the actual house, affecting the model's value under certain conditions. For example, supposing a model is used for the purpose of producing accurate photorealistic renderings of Villa Savoye, its fidelity to the referent (in terms of sizes, proportions, materials, and so on) is a major concern: an inaccurate model would result in inaccurate renderings. As software developers strive to produce tools that not only enable one-to-one correspondence between models and referents, but that also attempt to make this correspondence as efficient as possible (Gomez, 2007), and as digital models are expected to support ever more-demanding interpretative and simulative performance requirements, it follows that reducing Type 1 differentiation has obvious value.

In our work, we assert that a high degree of Type 1 differentiation between an existing building model and its referent is a rich source of interpretation. Stated differently, the existence of a "mismatch" allows the model to be an "interpretation of" the referent rather than a "description of" the referent. It follows that the differences between one model and another offer potential value to interpretation. Thus, Type 2 differentiation registers the differences between the models in a collection. For example, consider a subset of models, each member of which exhibits a unique configuration for Villa Savoye's internal ramp. Type 2 differentiation does not consider which of the modeled configurations is "correct," but rather recognizes the extent of disruptions and discontinuities among the subset. The significance of Type 2 differentiation is not obvious, and with the goal of exploring its characteristics and ramifications, in an effort to illuminate the value of information that might be considered different, imprecise, or even erroneous, we set out to identify and highlight its extent within a set of models.

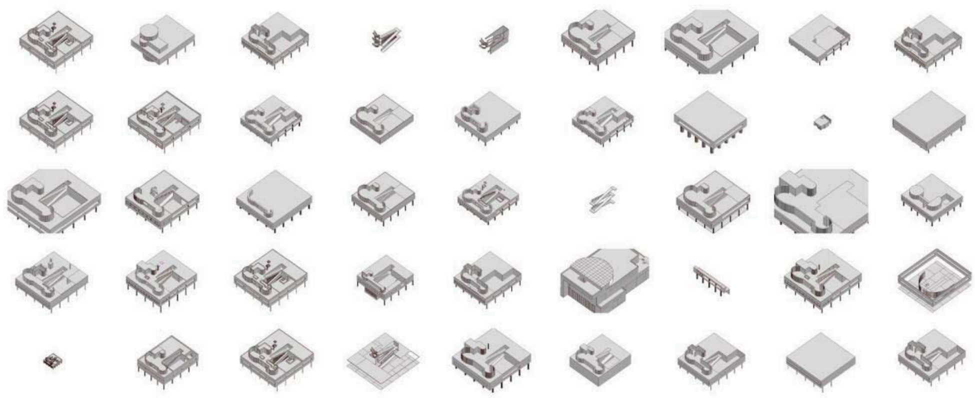

Figure 1: 45 models of Le Corbusier’s Villa Savoye.

1.0. MAPPING DIFFERENTIATION

We built our set of digital Villa Savoye models with an online search limited to freely available models in a common format (Trimble 3D Warehouse). The models, constructed by various authors over time, ranged from highly detailed and documented representations of the actual building to geometric configurations hardly recognizable as Villa Savoye. In order to identify differentiation between the models, we first categorized them by the number of times they had been downloaded – citations indicating the models’ apparent worth or popularity to the online community. We then stripped the models of populated content, that is, anything not physically part of the referent (i. e., people, cars, trees, ground, etc.). This homogenizing of the models allowed us to view them through an identical lens in order to discover their individual peculiarities and differences in a consistent manner. No building geometry was added, removed, or distorted in the homogenizing process. After achieving a desired level of homogeneity, we generated three views (top, front, and isometric) of each model for evaluation.

Unsurprisingly, the models that appear to most closely represent a one-to-one relationship with the actual Villa Savoye - i. e., those that minimize Type 1 differentiation - also ranked the highest in terms of online downloads (Figure 2, top). Presumably, authors and users of these models share the goal of eliminating imprecision and inaccuracy so that the possibility of (mis)interpretation is reduced. At the opposite end of the spectrum, where models are nearly indistinguishable offspring of Villa Savoye, the intent and purpose of the models becomes far less obvious. Some of these deviations (Figure 2, bottom) include radical distortions of geometry and severe generalization of specific building elements.

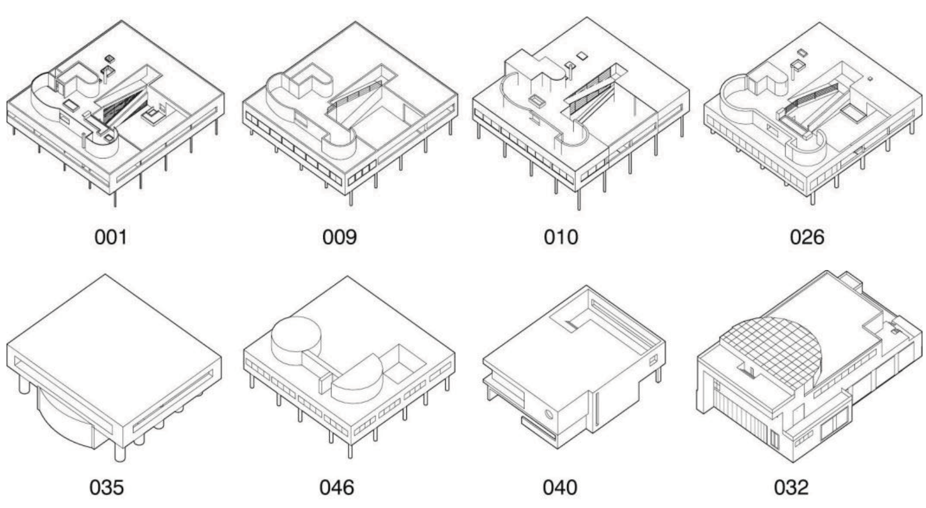

Figure 2: Villa Savoye models with low Type 1 differentiation (top row) and high Type 2 differentiation (bottom row)

1.1. Mapping differentiation: Isovists

Two-dimensional isovists (Benedikt 1979) provide a way of registering the planar permeability of a space as perceived from a fixed station point. We relied on a combination of software applications to construct isovists as a means of revealing differentiation among our set of models. Beginning in Sketchup, we sectioned each model at a consistent level of six feet above the second-floor terrace level, with the intent of representing the locus of human eyesight. We exported each section in .dwg format, and using AutoCAD, we converted the sections to polylines, re-saved them and opened them in Rhino 3d. We used a Grasshopper script to create a circle based on a fixed station point (in this case, the approximated center of the second floor terrace); the script has a built-in query to detect polylines as boundaries (in this case, the walls of the section cut). The result is a two-dimensional isovist that can be updated in real time and exported in many formats. Isovists reveal a kind of differentiation that is not immediately obvious from inspecting or comparing the models from their exterior (Figure 3).

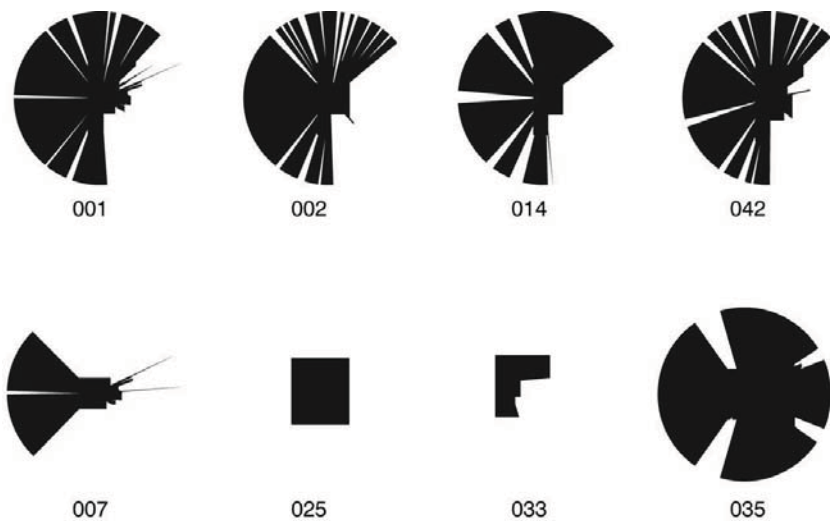

Figure 3: 2D isovists at second-floor terrace of Villa Savoye

The isovists for several models – for example, models 001, 002, 014, and 042 - indicate a common bias in visual permeability, suggesting that if the models are viewed from the station point inside the terrace, visibility would be largely unobstructed to the upper left sides of the isovists, while being blocked on the right side. These near-identical isovists indicate correspondence between their respective models, at least as far as visual permeability of the terrace is concerned. (Without comparing them to the referent, however, their "accuracy" is not guaranteed.) Other isovists, such as the ones corresponding to models 007, 025, 033, and 035, are relatively unique within the set of models. Even assuming that the unique isovists are likely to differ significantly from a hypothetical isovist resulting from an accurate model, their apparent inaccuracy does not preclude their utility in prompting speculations about Le Corbusier's approach to horizontal visibility. For example, isovist 007 heightens the symmetry between the two sides of the terrace, while isovist 025 prompts us to consider the terrace as completely impermeable to vision. Isovist 033 can be seen as a refinement of isovist 025, while isovist 035 inverts it, appearing to represent a fully permeable terrace where visibility is blocked only by corner columns. These apparently inaccurate isovists, considered in comparison with each other, are capable of highlighting possible interpretations of the space - interpretations that are latent within but obscured by the more accurate models. This ability of architectural mediating artifacts to highlight latency brings to mind David Leatherbarrow's proposition that "the purpose of architectural drawings is to discover and disclose aspects of the world that are not immediately apparent and never will be" (Leatherbarrow, 1998).

1.2. Mapping differentiation: Parametric model

To further examine differentiation between online models we created a digital model of our own. Our sampling of free digital models were analyzed and indexed on several building elements such as floor dimensions, ramp configuration, percentage of glazing, and column thickness to name a few. Building data were collected from a consistent (x, y, z) format aligned respectively to the building's orthogonal axes. Information was recorded only where possible. For instance, in the case of model 032 (Figure 2), no data were added to the index since it was not identifiable with the larger population. To visualize the degrees of differentiation between the available models, we developed a Grasshopper script (Figure 4) that generates a simple massing model of Villa Savoye based on the entire range of sampled dimensions. We chose to limit the script to generate a mass for the first floor, the second floor, as well as the columns and their given thicknesses. The script will generate variations in dimension, but not variations in topology. It represents an agreed-upon arrangement of parts from its model authors.

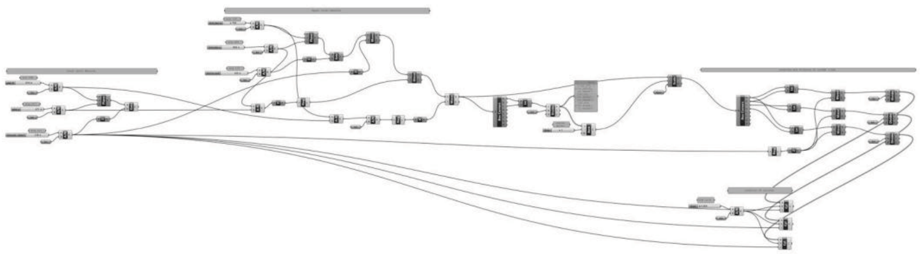

Figure 4: Grasshopper script for generating massing models

The model's dimensions are placed on a parametric slider and are able to update in real-time. This comprehensive parametric model is thus able to represent all of the dimensional values from our entire sample of online digital models as well as "in-between" dimensions (Figure 5). Not only can the model display unique values from unique model authors, the values can also be combined to generate new building geometry and configurations. The models in Figure 5 were created at 4 different values: the most popular (the values from the most downloaded model), the average values of our entire sample, the maximum values, and the minimum values.

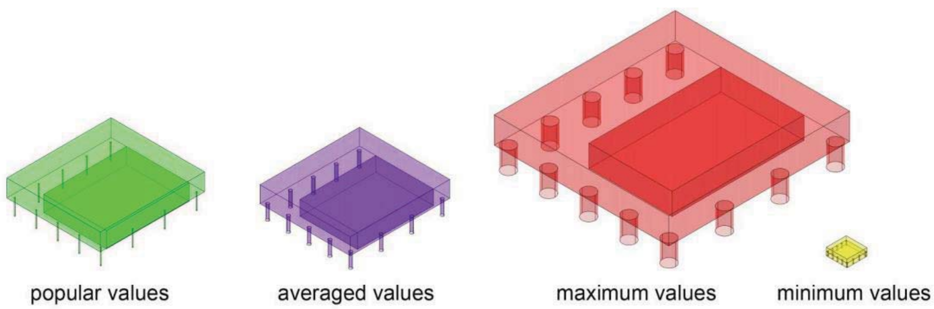

Figure 5: Generated massing models in 3D

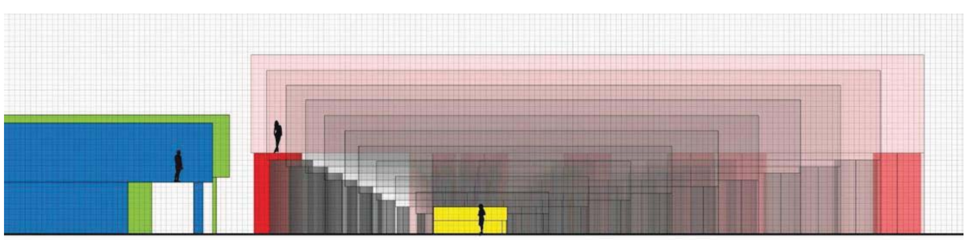

Figure 6: Sections of generated massing models

When juxtaposed, the degree of Type 2 differentiation reveals that the most popular model and the averaged model are very close to the same with the averaged model being only slightly smaller in massing but having thicker columns. This supports the notion that the majority of online authors strive for a one-to-one correspondence (minimizing Type 1 differentiation) between their model and the actual building. In contrast, the degree of Type 2 differentiation between the first two models and both the minimum and maximum value models is quite large. Furthermore, the degree of Type 2 differentiation between the minimum and maximum value models is even more drastic. Since the models represent an agreed-upon topological arrangement of parts, the most interesting differentiation is the degree to which some model authors are willing to disregard Type 1 differentiation in reference to the scale of specific elements (even to the point of modelling a non-liveable structure) while still being conscious of an the overall configuration of the building. In these models' most drastic levels of dimensional inaccuracy, their specificity in building topology is still able to highlight particular aspects of Villa Savoye such as column arrangement and floor configuration. Since the script allows us to visualize the entire range of both Type 1 and 2 differentiation, we also generated a range of models at equal intervals from the maximum to minimum values (Figure 6). This section image revealed the way different model authors may have been exploring the building's scale and how it relates to the human body.

1.3. Mapping differentiation: Initial views

When a model is opened in Sketchup, the most recently saved view is displayed. These initial views, because they are the first thing seen upon opening the models, have the potential to shape how the model is subsequently used. Assuming that the model authors are responsible for determining this initial view (along with any other preset cameras within the models), we considered the views as a significant feature of the models. As described elsewhere (Christenson 2011) a set of photographs of a given building can be mapped into a composite representation of photographers' positions, fields of view and directions of view, described as a point-of-view/field-of-view map, or POV/FOV map. We used a similar methodology to register the simulated photographs associated with viewing our set of digital models in simulated space (Figure 7).

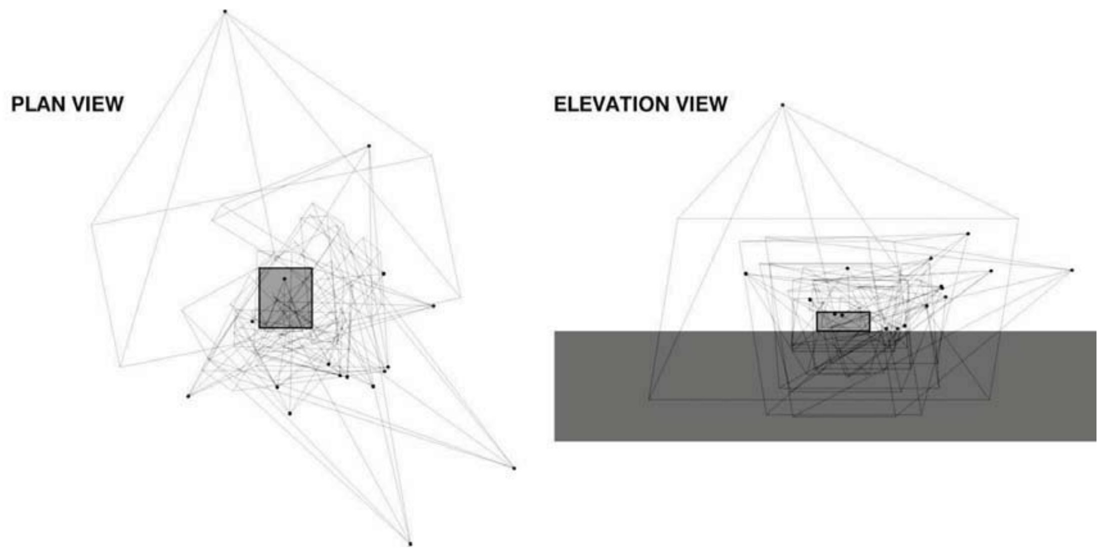

Figure 7: POV/FOV map of initial views for the first 20 models in our set

However, not all of the initial views were mappable in this format. Specifically, we excluded a handful of models with initial views in orthogonal format (plan, elevation, or isometric). Also, a few models with exceptionally large Type 1 differentiation (such as model 032, illustrated in Figure 2) could not be reliably oriented to correspond with the other models or the referent, and so were excluded from the map.

The plan POV/FOV map (Figure 7, left) of the initial views of the first twenty models shows that the station points tend to cluster around the point in the models corresponding to the northwest corner of Villa Savoye, facing the rounded entry wall. In contrast, just one of the mapped views is stationed on the opposite corner of the models, providing a wide, distant view. Model authors apparently have a clear preference for viewing the Villa Savoye models from the northwest corner. Moreover, the elevation POV/FOV map illustrates that most of the initial views cluster around a height of approximately two to three times the height of the model, looking down on it. Thus, most of the simulated views do not attempt to recall or predict a visual experience of Villa Savoye but are rather more like the experience of viewing a small physical model of the Villa displayed on a table. There are also a small number of initial views situated within the models.

Interestingly, the models which exhibit the lowest apparent degree of Type 1 differentiation - i. e., the most "accurate" models - do not show a trend for simulating visual experience through their initial views. Stated in another way, although many model authors may strive to accurately construct model geometry, those same authors appear to be less concerned with guiding others to understand the model as a device for simulating specific, achievable views. Just as often, model authors with an apparent lack of concern for strictly accurate geometry have chosen to present their models as if viewed from achievable viewpoints. We proceeded with the understanding that whether or not the growing database of online information as well as the mental images they create are able to alter the direct experience of an architectural work through the establishment of preconceived assumptions, they offer an increasingly rich amount of content to study architecture from remote places.

1.4. Photo-mapped height field model

Three-dimensional height field models are generated by assigning a given rasterized pixel color a specific dimensional 'height'. Commonly used by cartographers for modeling terrain, the same tools have been integrated into various software programs to generate 3D forms from any rasterized image. The tool was of specific interest to our research in that it allowed us to transpose photographic coverage of a building into three dimensional geometry. Figure 8 (left) shows a potential opportunity for digital modeling afforded by the combination of our comprehensive parametric model as well as the available photographic coverage of Villa Savoye. We began by generating a massing model of Villa Savoye using our script and proceeded to apply height field data to identifiable facades. The roof is modeled from a height field of our 'most popular' model's top view. For our images, lighter values were interpreted as higher heights, and darker values were interpreted as lower heights. Thus our top view required a color inversion to be accurately interpreted. The two vertical facades were modeled from height fields from a Google image of the building taken from the most popular vantage point as determined by our POV/FOV maps. The facades also required some manipulation to make them orthogonal. They were then placed onto their respective facades in Rhino, converted to height field surfaces, and scaled to fit our massing model. Although our model was generated from content based on a national monument and icon of modernism, it is plausible that the ever-increasing amount of online imagery and models could yield similar results for any building in the world. The use of Google Street View, bird's eye Bing maps, and various user-uploaded photo websites already constitute an enormous source of content for such an endeavor.

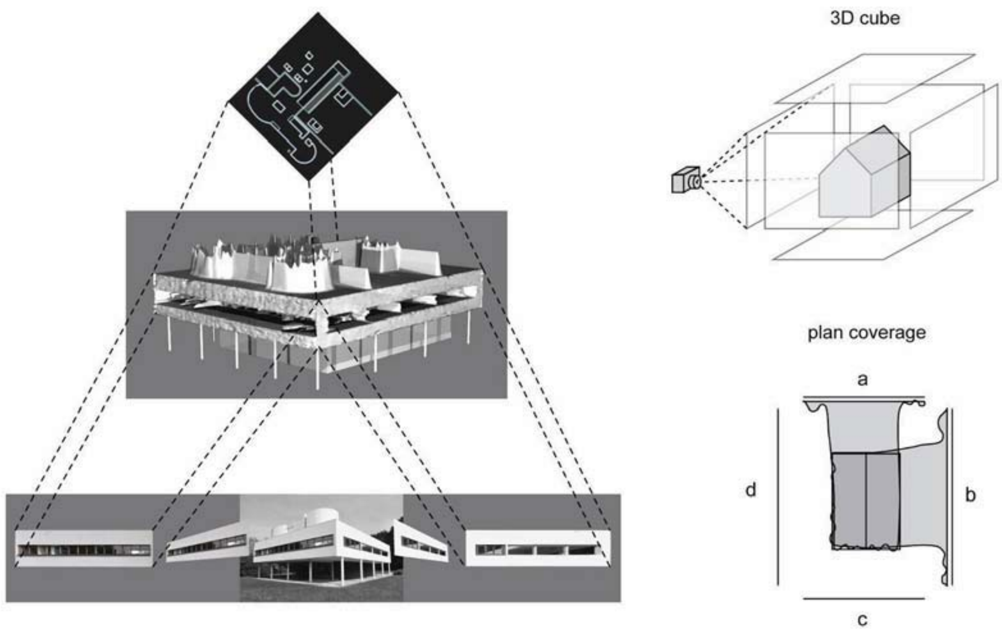

Figure 8: height field model and diagram

For our height field model, no one source (digital models, photos, drawings, etc.) could effectively construct the form. It required the combination of multiple forms of representation. This may not always be the case. Figure 8 (right) shows the potential for a generalized tool that could model a form from height fields alone. Assuming that every building could hypothetically fit inside a cube, and a photograph could be taken from all but one plane, a simple set of rules could be set up:

If *geometry 'a' intersects with geometry 'b'*
then *create intersection 'a + b'*
else *delete*

An automated tool as described could potentially produce a crude model of an entire city. Such a model would require information that might not be 'popular' or in support of mental images that have been established. Due to the nature of height field modeling, the resulting geometry would be inherently anexact - working more interpretive geometry through a set of rules than exact one-to-one tracings. As we have shown, these inherent inaccuracies would not be downfall of the proposed tool but rather a specific method of study that has the potential to create new ways of seeing.

CONCLUSION

Throughout our work, we've found ourselves confronting and challenging a prevailing assumption that accurate models (i. e., models with low Type 1 differentiation) are more valuable to architectural knowledge than inaccurate ones. While this assumption is certainly valid in many cases for obvious reasons, we proceeded with the understanding that architectural representations, whether in the form of diagrams, maps, or drawings, derive a unique kind of value not from their ability to trace what is already known, but in their ability to open the possibility of new worlds. Their generative potential is created through their distinctness from that which is being represented rather than their replication of it (Allen, 1998; Corner, 1999; Evans, 1997). By examining digital models in light of their distinctness from their referents, we can begin to speculate about their intention and purpose independently of the architect's own purposes, design approach, or intentions. (It is for this reason that we deliberately chose to focus our research on 'representations of Villa Savoye' rather than on the building itself, or on Le Corbusier's unique design approach.) While it's possible to associate distortions, generalizations, and inaccuracies in models with a lack of competence on the part of model authors, it's also possible that the authors may be attempting to disclose latent architectural attributes or features which are obscured in more comprehensive, 'realistic' models. Whether intended or not, what the authors of these models have created is an opportunity for their audience to read the models in a different way - to open up possibilities for generative interpretation.

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Toward a Rational Architectural Practice: The Particular Case of Giorgio Grassi

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ABSTRACT: This paper provides an historical examination of Giorgio Grassi's singular methodological approach to architecture, which is primarily based on a self-questioning rigorous framework that reflects on the autonomous nature of architectural production. From an operative point of view, Grassi's work has been characterized by an uninterrupted methodological continuity that sought coherence and rigor as ultimate form of expression. In Grassi's view, architecture is defined as a rational discipline that prioritizes reason above form in order to avoid a return to rhetorical formalist models of architectural production.

In order to underline this intelligible rational methodology, my paper will attempt to deconstruct Grassi's practice by elucidating his ideological association with the Italian *Tendenza,* and by critically breaking down his most compelling work, *La Costruzione Logica Dell' Architettura.* This system of inquiry will underline particular methodological components such as the reductive qualities of typological classification, the logical and autonomous foundations of architecture, and, consequently the recognition of its rules and limits. Accordingly, those cyclical constituents will be historically and critically exposed to emphasize those methodological characteristics that advocate the establishment of an architectural discourse, which is ideologically based on the idea of pure rationality.

In Grassi's case, the originating premises of rational epistemology - and the ultimate search for knowledge - propose a newfound interest in everything that can be logically classified. Rationalist principles indeed address cognitive issues related to the historical zeitgeist of architecture that privilege reason above experience, logic above instinct, and idea above form. Thus, according to Grassi, architecture should never be understood either aesthetically or morally, but it should be conceived as the only answer to real problems. Eventually, Grassi's desire to establish a theory based on the triumph of reason over the image emerges as the most definitive methodological model of architectural production.

KEYWORDS: method, rationality, typology, autonomy.

INTRODUCTION

Although generally label as overly reductive and austere, the work and methodological practice of Giorgio Grassi appears to be far from simplistic. Inherently related to the ideological trajectory of *Tendenza*, a group of Milanese architects in the Italy of the 60s, Grassi's practice is framed by a deeply rationalist methodology that explores architecture as an analytical design practice. This particular understanding is strictly related to a specific disciplinary research established in Italy at the end of the Second World War; this was when the term Rationalism and its theoretical body of work had acquired renewed prestige replacing the ephemeral aesthetic of the modernist movement with a grounded discourse based on a deep understanding of the city as background of all architectural artifacts.

Yet, before tackling the methodological question of rationality evident in the work of Giorgio Grassi, I believe that it is important to historically frame the Italian context of the 50s and 60s in order to understand the importance of *Tendenza* as an heterogeneous architectural movement that aimed to overcome the failures of modernity, and, most importantly, to locate the operational methodology of Giorgio Grassi who indeed happened to be one of the major ideological advocate of such a rational framework.

1.0 HISTORICAL CONTEXT: ITALY AFTER WORLD WAR II

> After the end of the Second World War, architects who were obliged to respond to the new Italian reality were faced with a difficult dialectic between knowledge and action – difficult because of the contradictory foundations underlying the tradition of the discipline, but also because of the many levels imposed on such knowledge. This was all the more true given that most competent members of the profession took it for granted that there could be no knowledge divorced from action: an encounter with active politics seemed imperative (Tafuri, 1990, 3).

Regardless of ideological and political implications, the description given by Manfredo Tafuri in his introduction to *History of Italian Architecture, 1945-1985* was exceptionally accurate. After the Germans retreat, entire historical neighborhoods, monuments and other civic landmarks had been destroyed, creating new urban conditions dictated by a fragmentary sense of unevenness. Additionally, most of the influential thinkers of the Italian architectural intelligentsia had fallen victim of Mussolini and his totalitarian Fascist regime. Giuseppe Pagano, editor in chief of *Casabella*, arguably one of the most influential Italian architecture magazines, had died in a concentration camp along with Raffaello Giolli, Gian Luigi Banfi of B.B.P.R., Filippo Beltrami, and Giorgio Labó leaving the architectural discourse in total disarray (de Seta, 1981).

As a result of this unfortunate scenario, Italian architecture had ended up falling victim, once again, of those conservative academics that had ruled the universities and the profession of architecture during the fascist years, desolately returning to an elitist framework controlled by the upper class. Thus, post war reconstruction became contaminated by a politically driven process that ended up legitimizing the rightist catholic middle and upper class, which was more interested in building quantity rather than quality (Tafuri, 1990).

Within this political framework, major architectural interventions had to include the decentralization of industrial areas, consolidation of historical centers, and the design of new residential areas, which would be functionally and morphologically integrated with the existing urban fabric. New plans had been developed in order to guarantee connectivity between the inner historical cores and the peripheral outskirts. However, this strategy, mostly based on the functionalist agenda of CIAM, did not result in compatible models, but it ended up creating fragmentary urban conditions that still remain a major problem (Benevolo, 1988).

Nevertheless, Ernesto Rogers, a prominent Milanese architect and academic had tried, through a series of sharp and brilliantly written editorials for the architectural magazine *Casabella,* to reopen the debate on reconstruction, suggesting to break away from this technocratic functionalism that prioritized modularity, serialization, and mass production. While extremely critical of this quantitative framework, Rogers proposed the establishment of an alternative tendency, a methodology based a rational model typical of the residential schemes of German *Siedlungen,* which seemed to offer a methodological model more socially and architecturally compatible with the Italian landscape (de Seta, 1981).

2.0. TOWARD A COMMON TENDENCY

While cities were undergoing a process of unbalanced transformations, Aldo Rossi and Giorgio Grassi had been actively writing for the *Casabella* of Rogers, questioning the ideological nature of the functionalist city and proposing an alternative framework based on a morphological and typological understanding of the contemporary city which appeared to provide more urban continuity (Rossi, 1962). Between 1966 and 1967, with the publication of *L'Architettura della Città* and *La Costruzione Logica dell' Architettura*, Rossi and Grassi finally unveil their reevaluation of the discipline of architecture, which now ought to be grounded into an understanding of those primal forms (building types) that distinguish the modern European city. Both Rossi and Grassi asserted the inevitability of a rational methodology based on the generative qualities of dominant building types that would eventually set up architecture as the measure of architecture, elucidating its genealogy and future directions through a catalog of autonomous principles, mostly typological, which were particularly showcased in the San Rocco Housing Unit in Monza, Italy (Fig. 1).

Architecture was to be, in Aldo Rossi and Giorgio Grassi's words, an "autonomous phenomena" that required a disciplinary refunding; a tendency that rejected interdisciplinary remedies, and that did not pursue nor was immersed in the political, economic, social and technological events of the time (Hays, 2000). In so doing, architecture could reveal rather than suppress its own analytical creativity through focused interventions. Clearly, the methodological work of *Tendenza* seemed to offer an interesting case study of a design practice that focused more on an analytical understanding of the post war Italian cities and the implementation of a comprehensive urban plan based on the continuity of typological approaches.

Tendenza, originally formulated as a methodological response to the reductive aesthetic of the *International Style*, is usually associated to a Milanese group close to Aldo Rossi and Giorgio Grassi. While looking at its linguistic roots, the Italian word *Tendenza* underlines an attitudinal predisposition to act and behave in a certain ideological way; thus, the term itself implies the existence of a very well defined programmatic orientation driven by a common idea or methodological practice. This definition certainly provides the basic principles of this critical discourse, which was characterized by a rational impulse shared by many architects.

The Italian *Tendenza* was not a homogeneous movement that produced a particular architectural style; on the contrary, *Tendenza* listed a very heterogeneous number of practitioners and academics that shared a similar interest toward rationality only as a methodological framework. Interestingly enough, the term *Tendenza* was rarely used by this group of architects as it implied, in a sort of reductive way, a common and generalizing formal production, but it was always understood as a procedural propensity indicative of a certain tendency that elucidated a rational architectural practice based on the understanding of dominant urban events (*fatti urbani*) and their processes of building/tectonic logic (Hays, 2000).

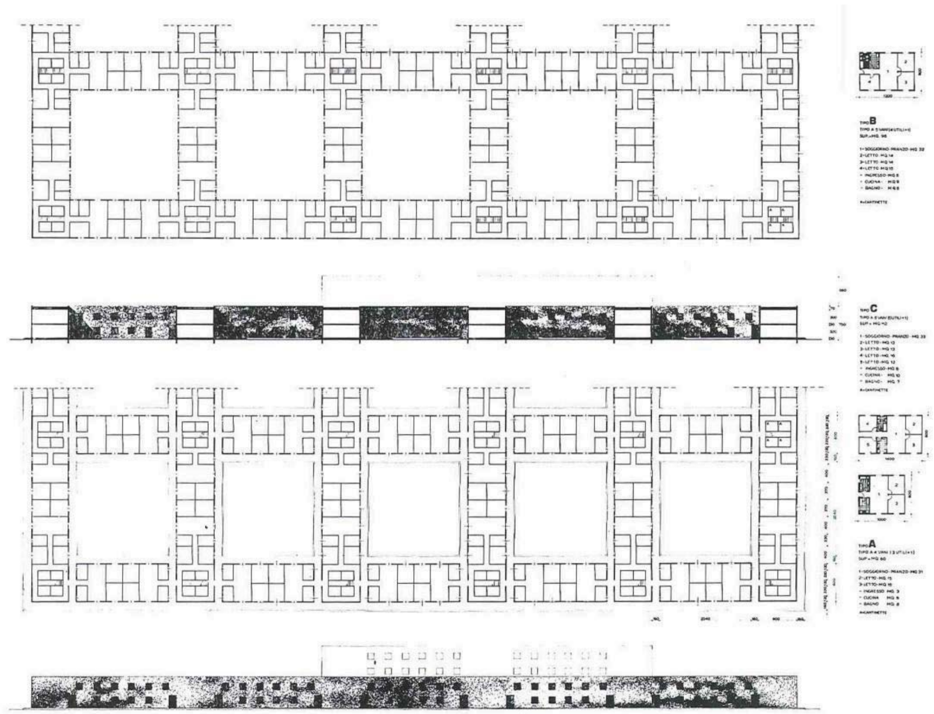

Figure 1: Giorgio Grassi and Aldo Rossi, San Rocco Housing Complex, Monza, Italy. (Giorgio Grassi, 1970)

Its heterogeneous, yet articulate, principles are often and mistakenly attributed to the audacity and talent of Aldo Rossi; yet, this rational tendency as well as its historical, urban, and didactic components, were rather the result of an intricate chronological process that saw the active involvement of other architects such as Giorgio Grassi, who particularly aimed toward the search for an appropriate design methodology that would characterize the rebirth of a discipline whose ideological and professional premises had been profoundly damaged after World War II. Pre-existing contextual components, the crucial role of history as a repertoire of architectural possibilities, the tradition of the European city, its urban fabric, and the intellectualization of the role of the architect are all characteristics of a discourse that defines the ideological premises of *Tendenza*, and consequently the work and practice of Giorgio Grassi.

3.0. GRASSI’S BUILDING LOGIC OF ARCHITECTURE

Giorgio Grassi graduated from the *Politecnico* of Milan in 1960, a year after Rossi. In 1961, Grassi becomes a key member of the editorial staff at *Casabella Continuità* until 1964; this is when Ernesto Rogers was forced to leave his editorial role to Gian Antonio Bernasconi. While at *Casabella*, Grassi becomes immediately very critical of conventional mainstream architecture; his early articles are based on an analytical reassessment of Tange’s Tokyo’s Plan, and Berlage’s work in Amsterdam, which are both analyzed in terms of their typological and morphological qualities (Grassi, 1961).

In addition, Grassi shows a particular interests toward the ideas and work of German Proto-Rationalist architects Ludwig Hilberseimer and Heinrich Tessenow, who had developed an interesting process of formal recognition based on austerity and simplicity which aimed to reduce architectural form to the most basic condition (Lahuerta, 2000). There is indeed an increasing interest in defining those fundamental design principles that could consolidate an ongoing discourse, a tendency based on the understanding and complexity of the city and its embodied relationship between typological variations overtime. After the first methodological explorations of the early 60s, Grassi feels the necessity to overcome this recurring processual anxiety typical of young architects by putting together a treatise that would explain his particular theoretical approach.

Thus, *La Costruzione Logica dell' Architettura* was published in 1967 with the intent to set up a rational framework based on the necessity of a general rational-logical model that would elucidate a general theory of architecture. Grassi sees architecture as the sum of all architectures of the past; therefore, its prerogatives have to be found within its disciplinary domain. Architecture is also understood as a discipline where theory merges with practice in a sort of systematic process, and where its rules are inherently defined by architecture's inner logic, which ought to manifest itself typologically (Grassi, 2008). Architecture has to be understood as the product of a fabrication process, which involves a historical and material awareness absolutely free of any sort of formal ambiguity. Formal expressions have to be contained to the basic premises of architecture, where formal ambiguity is not a programmatic necessity.

Within this framework, Grassi describes and proposes certain theoretical and technical systems of investigation based on the collection of analytical urban data. This process generates a catalog of processual techniques that can be identified in particular building types, and that can be systematically classified and then analyzed to discover their general programmatic methodology. Grassi states that:

> The line of thought to which I refer is that of Rationalism. And I will say right away that I intend to designate the term Rationalism as a particular processual attitude (Grassi, 2008, 21).

First and foremost, a rational methodology is strictly connected to an understanding of the term *architetti della ragione*, or architects of the reason, such as Boullèe, Ledoux, and Durand who had tried to synthesize new formal solutions by combining elementary forms, also proposing a methodological system based on the meaning of historical and typological significance. In this context, Grassi defines rationalism as a particular cognitive attitude that informs methodological design choices (Grassi, 2008).

Additionally, architecture can't be reduced to a style, but it can only undergo a methodological classification that reflects a typological analysis; it is wrong to label a building or any piece of architecture rational because of its aesthetics. Grassi emphasizes this concept by looking at theoretical frameworks that underline the importance and absoluteness of reason above all, a necessity generated by an innate desire to locate fixed design variables that can be set as methodological rules (Grassi, 2008). It is essentially a deductive way of producing a system that demarcates the domain of architecture, or what Grassi calls 'the limits of architecture,' which set aside those disciplinary aspects that govern the options available for the architect (Grassi, 1982).

> Architecture is the architectures, so there is no theory of architecture that is not embodied into the experience of architecture…design can not be tautological with respect to the experience of history Grassi, 2008, 83).

The rules have to be found within the discipline of architecture itself, which is understood as autonomous in its forms and techniques, yet it cannot be tautological and thus repetitive of a historical condition that has clearly changed overtime time. This is unmistakably true when Grassi looks at significant form; we cannot propose identical architectural expressions, but we have to strive for a process that shows analogous methodological guidelines. Again, the best approach toward this rationalist direction is characterized by typological description and classification, which both define the objectives of architectural analysis. Grassi explains the process of description and classification as a preliminary way to recognize common traits or characteristics that are the expression of determinate technical and formal choices. This process is implemented to compare and contrast a specific object and its internal qualities with the scope of representing them in a diagrammatic way, which is immediately intelligible and applicable (Grassi, 2008).

Consequently, simplification is attained in order to increase architecture's disclosure of its regulatory system. It is a didactic way to undress architecture of any rhetorical and abstract meaning, exposing its bare foundations of design rules and norms. Ideally, form should be expressed with rigorous clarity. Thus, a process of classification is necessary, not to generate a repertoire of formal solutions, but to craft a method that exposes particular generative rules. It is not a point of arrival, but it is a point of departure. It is also a limit in a way that forms have already been set up for a particular building type, although variations are still possible under specific contextual conditions (Grassi, 1992). For instance, if a specific building type has already displayed, through a process of typological analysis, specific variations of form overtime, than further formal explorations are no longer necessary. Within this framework, we can still extract the original form uncovered from our preliminary analytical research and manipulate its distributive or programmatic qualities, generating new solutions by use of the original.

Grassi is openly not interested in formalist explorations, but he is also not an advocate of professionalism because that attitude supports a capitalistic view that needs to be detached from the architectural discourse. Grassi states that:

> I am not interested in professionalism since it represents the adhesion of the city to capitalism; I am interested in those experiences within the city that refuse the city itself and its capitalistic structure. I believe that this juxtaposition can't be solved by repeatedly using a rather rigorous formalistic approach. This extreme experimentalism must terminate. There is too much *kunstwollen* (Grassi, 1999, 176).

Interestingly enough, Grassi distances himself from a rather simplistic approach, even though he supports a certain straightforwardness of design methodology. To clarify his understanding of building types, he refers to Quatremère de Quincy who said that:

> *The word type represents not so much the image of a thing to be copied as the idea of an element that must itself serve as a rule for the model.... The model, understood in terms of the practical execution of art, is an object that must be repeated such as it is; type, on the contrary, is an object according to which one can conceive of works that do not resemble one another at all. Everything is precise and given in the model; everything is more or less vague in the type. Thus we see that the imitation of types involves nothing that feelings or spirit cannot recognize (Lavin, 1992, 78).*

It is important to note that types can be conceived as conceptual tools that identify the connections between new and old structures. While looking at Alexander Klein's research work on the most favorable dimensions for particular floor plan types, Grassi tries to understand the relationship, both formal and functional, between different typological schemes, which are underlined by subtle distributive and formal variations. Similarly, Grassi analyzes the work of Pierre Le Muet who, in *Manière de bait pour toutes sortes de personnes,* had analyzed how particular residential types change their architectural character according to their placement within the urban fabric (Grassi 2008). Thus, plans, sections and elevations are used to show how cadastral conditions have altered urban and architectural form by allowing a specific typological solution to emerge and consolidate itself overtime. The most important characteristic of this analysis is the simplification of a process that reduces residential types to simple diagrams that can be formally and functionally evaluated in their distributive and programmatic characters.

This is a clear representation of a rational and logical methodology that proposes a specific solution inherently responsive to precise contextual conditions. Rationality is thus seen as a way to order architecture in its internal building logic by giving it a consistent methodical structure. Grassi uses four different degrees of intentionality: transcription of tectonic necessities that influence form; description of typological variations due to technological and tectonic characters; representation of those changes through matrixes of classification; expression of specific contextual conditions both morphological and typological. In the end, Grassi's theoretical framework becomes the quantifier of the architect's practice. Interestingly enough, Grassi's methodology will remain rather consistent over the years, advocating the importance of a rational process that evolves without contaminating itself in extreme formalizations.

CONCLUSIONS

The methodological practice of Giorgio Grassi has indeed showcased some interesting qualities particularly because his approach has been intrinsically underlined by a rigorous process that achieved visibility through normative production; indeed, such a methodology was only possible through the development of a rational approach that reflected on the nature of the limits of architectural production. In Grassi's work, most of those limitations are based on fixed moral and social connotations, which have been investigated in his other writings and essays collected in *L'Architettura come Mestiere ed Altri Scritti* in 1979, *Architettura Lingua Morta (Architecture Dead Language)* in 1988, *Progetti per la città antica* in 1995, and *Scritti Scelti* in 2000. Again, resilient to avant-gardism and its ambiguous formal explorations, Grassi's practice is still outlined by the same indivisible logic that avoided formalism by opting for a rational framework that elucidates the logical rules of architectural composition. Interestingly enough, Grassi's architecture still focuses on the conventional and ordinary conditions of architecture; his buildings are generated by a vocabulary of severe forms and signs that show no ambiguity or witty reference to historical or formal explorations.

From the students housing complex in Chieti, to the redesign of the historical center of Teora in Italy; from the restoration and rehabilitation of the Sagunto Roman Theater in Valencia (Fig.2), to the Potsdamer Platz complex in Berlin (Fig.3), Grassi's work has displayed a rigorous characterization of architecture constantly treated as a primordial collage of pure forms and volumes. While certainly isolationistic as a methodological attitude, Grassi's architectures have always remained the sum of all architectures from the past, and the inevitable accumulation of forms, solutions, and building types (Grassi, 1992).

The relevance of such a framework is recognizable in its method. By understanding Grassi's method, we should be able to look at the architectures of the past as a way to understand the building and design logic behind them, which should advocate for an autonomous methodology that refuses interdisciplinary solutions to its own crisis. Yet, it is not by replicating the past that we achieve autonomy, but it is by understanding its technicality and practicality that we will only be able to achieve modernity and continuity. Materiality and tectonics are understood as a primary factors in Grassi's methodology, a peculiarity that allows him to delegitimize form (Grassi, 1992). Again, Grassi's methodological process is based on the recognition of the limits of architecture and in the dichotomy between analysis and design process, which are understood as modes of architectural cognition. Yet, both are strictly related to this idea of architecture as a repository and collection of architectures. Grassi denies the utility of interdisciplinary solutions since those experiments are more focused on lateral explorations that end up distorting what Grassi calls *"forms of reference*" (Grassi, 1999).

Figure 2: Sagunto Roman Theatre, Valencia, Spain. (Pasquale De Paola, 2006)

Figure 3: Potsdamer Platz, Park Kolonnaden, Berlin, Germany. (Pasquale De Paola, 2002)

In conclusion, Grassi's methodological work has to be deconstructed and analyzed by looking at his didactic and pedagogical qualities; although Grassi's buildings have proven to be somehow austere and rigorous, his method has always been characterized by the same coherent recognition of architecture's own norms and rules. Furthermore, his interest in rationality has to be grasped by looking at typological analysis merely as a diagrammatic process of schematic and programmatic simplification. Indeed, Grassi offers a different methodological prospective that removes originality through scientific meticulousness while responding to conditions of disciplinary necessity. Upon reading this paper, it becomes rather apparent that for Grassi architecture should not be judged nor generated upon stylistic expectations, but it should be based on a coherent methodology that underlines the importance and absoluteness of reason above all, even above form. Considering the ambiguity of contemporary architectural production, perhaps too narcissistically immerse into digi-bio-techno ornamental models, Grassi's methodological rigor appears to be quite a refreshing return to the basics.

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Fort Proctor: A Conditional Preservation

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ABSTRACT: The preservation and sustainability of building cultural heritage in indeterminate landscapes and sites at extreme environmental risk raises several questions regarding methodology.

1. What are the priorities for preservation of built works where degradation is accelerated by global environmental shifts?
2. What does one preserve of past cultures when the physical ground it once occupied is gone?
3. What are the methods for Historic Preservation when to preserve means much more than stabilizing a built project in time but also includes the preservation/sustenance of the land, the environment, and the cultural relevance?
4. If one cannot physically preserve does that mean its presence and cultural significance is nullified?

To investigate these questions, the research team selected Fort Proctor, a NHRP site at extreme environmental risk. Fort Proctor is one of several forts built along Lake Borgne in Southeastern Louisiana following the War of 1812. Since then, Fort Proctor has remained in a fluctuating landscape as a static marker or datum, recording major ecological changes within the dynamic coastal environment. To understand the structure's deconstruction and degradation as well as the changing Gulf of Mexico ecologies, a rich historical context was assembled from a complex array of disparate datasets (physical site and geographical condition surveys, material analyses, photogrammetric and photographic documentation, and GIS mapping.) From the data, the researchers developed time-based animations that explore the test site in four time-scales; one day, one year, 200 years, and geologic time. The animations present perspectival visualizations that illustrate the aesthetic and atmospheric qualities for each scale while overlaying analytical data and historical facts. They create a composite temporal framework allowing the viewer to digest the disparate datasets as single narratives. These animations and the procedure for their composition present a new preservation methodology for sites where physical preservation is prohibitive and loss unavoidable: "*the conditional preservation.*"

KEYWORDS: preservation, coast, at-risk, Fort Proctor, animations

Figure 1: Fort Proctor (Fort Beauregard), Shell Beach, St. Bernard's Parish, LA. 29°52′2.3″N 89°40′41.82″W. Source: (Author 2012)

INTRODUCTION

The preservation and sustainability of building cultural heritage in indeterminate landscapes and sites at extreme environmental risk raises several questions regarding methodology.

1. What are the priorities for preservation of built works where degradation is accelerated by global environmental shifts?
2. What does one preserve of past cultures when the physical ground it once occupied is gone?
3. What are the methods for Historic Preservation when to preserve means much more than stabilizing a built project in time but also includes the preservation/sustenance of the land, the environment, and the cultural relevance?
4. If one cannot physically preserve does that mean its presence and cultural significance is nullified?
5. How does the preservation of sites influence /modify/conflict with the reconstruction of sites (particularly when a historical site requires new land to be constructed)?

To investigate these questions, we selected Fort Proctor, a NHRP site at extreme environmental risk. Fort Proctor (Fig. 1) is one of several forts built along Lake Borgne in Southeastern Louisiana following the War of 1812. The fort was designed and construction commenced in 1856 but was halted in 1859 because of a hurricane and events associated with the beginning of the US Civil War. Since then, Fort Proctor has remained in a fluctuating landscape as a static marker or datum, recording major ecological changes within the dynamic coastal environment. To begin, a multi-disciplinary team[1] assembled a rich historical context to understand Fort Proctor's deconstruction and degradation as well as the changing Gulf of Mexico ecologies. From this complex array of disparate datasets (physical site and geographical condition surveys, material analyses, photogrammetric and photographic documentation, and GIS mapping) the researchers developed time-based animations that explore the test site, Fort Proctor, in four time-scales; one day, one year, 200 years, and geologic time. The animations present perspectival visualizations[2] that show the aesthetic and atmospheric qualities of each environment while overlaying analytical data and historical facts. The animations allow the viewer to digest the disparate datasets as single narratives creating a composite temporal framework.

The research has generated a new procedural methodology for preservation of sites at extreme environmental risk. In the test site of Fort Proctor, both the building and site exist in a state of decay. To preserve the architecture requires the preservation of the environment and that is not only cost prohibitive but also disproportionately scalar. As the world's global environment continues to shift, more and more preservation sites will face similar dilemmas. We argue this does not preclude preservation however but instead changes the methodology and resultant. In museum conservation ethics there exists a precedent for our methodology; reformatting unstable media. When a media is unstable and/or threatens the existence of other media the secondary form of preservation is reformatting. The goal is to capture the information from the media but not to preserve said media. Thusly, in cultural heritage sites where physical preservation is prohibitive and loss unavoidable, we propose "*the conditional preservation.*" Beginning with the traditional HABS methodology we have elaborated on that documentation procedure to create a more experiential and holistic preservation method for at-risk sites. The innovation of this research lies in the combination of addressing the sustainability of building cultural heritage in conjunction with the sustainability of a coastal ecosystem. This paper will elaborate on this procedural methodology and present via the animations, the methodology employed on the test site, Fort Proctor.

1.0. TEST SITE – FORT PROCTOR

This research project utilizes Fort Proctor as a test site for the aforementioned preservation questions the Louisiana Coast (and other world coasts in similar states of erosion) faces. Fort Proctor (also known as Fort Beauregard or Beauregard's Castle) was built in the 1850's as a fortification to protect the water routes leading to the New Orleans. Designed by the architect J.G. Totten with the most current military guidelines of the time damage from a hurricane and events associated with the commencement of the Civil War kept it from being garrisoned. It is currently listed on the National Register of Historic Places (NHRP # 78003067) because it was part of the United States' coastal fortification system prior to the Civil War and also because of certain architectural features which were unusual in the design of American forts.

In the years following the War of 1812, Congress authorized the development of a permanent national system of forts to defend routes which could be used for invasion. Regional fortifications for the defense of the city of New Orleans were conceived as integral links of this extensive national system. The board of engineers, led by Simon Bernard, recommended that a chain of forts and batteries be constructed at strategic locations around New Orleans to prohibit potential invasion routs to the city. For the approach up the Mississippi River, a fort (later named Fort Jackson) was proposed for opposite Fort St. Philip (the only colonial fort to be utilized in the system.) To protect the northern approaches to the city through Lake Borgne and Lake Pontchartrain, forts were projected for Rigolets Pass (Fort Pike) and Chef Menteur Pass (Fort Macomb) and Lake Borgne (Fort Proctor). To protect the western approach at Barataria Bay, Fort Livingston was proposed at Grand Terre Island. Finally, to defend the pass used by the English in 1814, a battery was proposed at Bayou Bienvenue and a tower was proposed at Bayou Dupre.

It was not until the 1840’s that Proctor’s Landing began to garner attention as a possible invasion route. At Proctor’s Landing there was Bayou Yscloskey. The bayou led inland towards the Mississippi River and besides the bayou was a shell-surfaced road. New developments in naval architecture had led to more shallow draft steam vessels and as a result, new sites previously considered too shallow for invasion routes were added to the New Orleans defense system. Fort Proctor was prioritized and the site was surveyed in 1845 by Second Lieutenant Paul O. Hebert and appropriations for the work at Proctor’s landing were requested in 1847. They were not allocated however, for almost ten years due to skepticism over the strength of the overall defense system and issues concerning ownership. Finally in 1856 it was decided that the internal systems development should be continued and 100 acres adjacent to Lake Borgne were purchased from Mary Screven, Stephen R. Proctor’s widow, for $10,000 and construction began.

The architecture of the fort is unique embodying two innovations in military fortification design. The first is the inclusion of living quarters for the soldiers including bathrooms and the second innovation is the use of structural iron. It is constructed in the Renaissance Revival style and was designed as a two-story square plan tower with four main guns mounted on a roof terrace. The first story was dedicated to the magazine and the soldiers living quarters. The second story, which was never constructed, would have been dedicated to military operations and the gun mounts. The foundation of the structure is a spread foot base with cisterns below. Rising from the base are sixteen brick piers which would have supported the large groin vaults required for the gun platform. This relatively typical masonry construction, used in conjunction with the cast iron beams which are I-shaped and resemble modern steel, makes this military structure unique.

The architectural significance of Fort Proctor is complimented by the historical site significance. Fort Proctor was originally located on the southern shore of Lake Borgne at the terminus of a road along Bayou Terre aux Boeufs. When construction began, the site of the fort was one hundred and fifty-feet inland with levees protecting the land from Lake Borgne’s waters. The fort was designed to sit in a moat with outhouses surrounding the outer terreplain wall. When Hurricane Five crossed Louisiana’s coast in 1859, construction halted. After the hurricane, changes in marsh sizes were visible, though not extreme. Before construction could resume however, confederate soldiers blew the levees allowing for water to move its way into the fort and its site. The site of the fort sat stagnant for 109 years. Even though the fort was never used for its true purpose, its origin and siting as part of the Mississippi River access and US coastal fortification system make it historically significant to the military history of Louisiana and the United States. In 1965, the U.S. Army Corps of Engineers dredged the Mississippi River Gulf Outlet between the site of the fort and Shell Beach. Since then, the salt water from the Gulf of Mexico and repeated storm action has slowly eroded away the marshy landscape. Now Fort Proctor is currently 230 feet off the coast into Lake Borgne separated from the mainland and preserved from modern development. Presently there is a rock berm in place to mitigate wave action but the future existence of the fort is clearly at peril. It is at guaranteed risk of being completely destroyed by future storms and predicted sea water rise. The integrity of the fort (structural, material, and detail) is threatened by the deteriorating conditions at the site and it is this contemporary condition that stipulated it as a perfect test site for this research project.

2.0. RESEARCH METHODOLOGY- THE CONDITIONAL PRESERVATION

The “conditional preservation” research project commenced in the fall of 2011 with one year of funding from the National Park Service and the LSU Coastal Sustainability Studio. A student research team was dedicated to each funding source but all were supervised by one principal investigator. The teams worked collaboratively throughout the grant period yet retained distinct research goals. The NPS grant had a single principal investigator, the author, while the CSS grant was supervised by the principal investigator (architect), a landscape architect, and a structural engineer. Both teams collaborated with consultants from mathematics, preservation technologies, coastal studies, and civil engineering. The “conditional preservation” was not the original goal of either grant but materialized from the discourse between the teams and the consultants. [2]

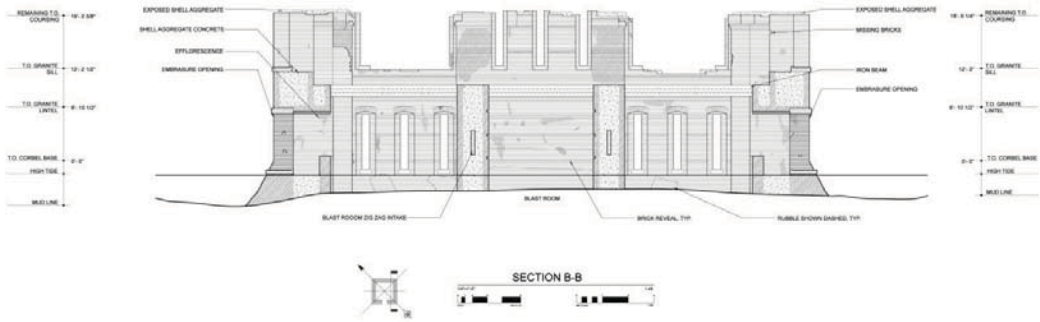

Figure 2: Fort Proctor HABS LA-199, Measured Section Drawing. Source: (LSU HABS team 2012)

The NPS sponsored research began with a Historic American Building Survey (HABS) of the test site. In 1935 the Civil Works Administration Act established a policy

> to preserve for public use historic sites, buildings and objects of significance for the inspiration and benefit of the people of the United States" (*Historic Sites Act of 1935*, 16 U.S.C. 461 to 467, Tyler 2009, 40).

To employ this policy, in an agreement between the American Institute of Architects, the Library of Congress, and the Department of the Interior's National Park Service, the HABS program was created and the NPS established rigorous documentation standards and provided administration.

> The survey shall cover structures of all types from the smallest utilitarian structures to the largest and most monumental. Buildings of every description are to be included so that a complete picture of the culture of the times as reflected in the buildings of the period may be put on record"(HABS, 1999).

The documentation for HABS includes field notes, historical narrative reports, measured drawings, and large format photographs. All documentation becomes part of the National Archives and are housed, serviced, and maintained in the Library of Congress. Over 35,000 buildings and sites have been documented since the program began and presently digital access to the archive is available.

The documentation of Fort Proctor per the NPS survey guidelines provided much of the physical measured data required for this research project (Fig. 2). The precise measure and cataloguing of the structure with drawings and photographs created a visualization of the structure's present condition while the historical narrative constructed a timeline of its existence. For the researchers' however, a substantial disconnect lay between the static and momentary visual documentation of the present and the linear and perpetual historical narrative. Not only did the data seem disjointed but it did not accurately reflect the conditional environment of the fluctuating landscape against the structure. This conditional characteristic needed to be captured so that the preservation questions could be addressed.

In collaboration with the HABS research team, the CSS research team compiled the necessary data to quantify the dynamic condition of the test site. First, they collected all quantifiable environmental data. Utilizing GIS for the contemporary data and written documents for the historical, an environmental timeline was constructed. Secondly, using Google Earth and historical maps, a coastal edge timeline was constructed. Both of these data sets the teams supplemented with "significant event" data such as storm systems and infrastructural adaptations that modified the coastline and salinity levels. To correlate the environmental and landscape fluctuations to the fort structure, multiple three-dimensional digital models were made of the fort and its landscape. To construct the building models and reflect change over time, the team used the original construction drawings by J. G. Totten, early photographs, and the present HABS documentation. This measured visual data was informed by the structural analysis of the brick and mortar: a numerical dataset produced from an investigation of the materials' strength, decay, and rate of decay relative to time, storm effect (wind, waves, dynamic pressure), and salinity exposure. All of the data the teams collected combined into multiple digital models built with Autocad, Autodesk Revit and Revit Structure, 3DStudio Max, and Adobe.

It was at this point in the research, that some of the preservation issues became clearer. The visualized models of the test site throughout time determined the unavoidable loss of both fort and landscape. They also identified the period of significance, a determination required for defining preservation requirements. The NPS defines period of significance as

> the span of time in which a property attained the significance for which it meets the National Register Criteria" (Workflows Definitions, 2013).

Although the 1978 NHRP nomination form declared the site's period of significance 1800-1899 the researchers concurred the more significant period was from the beginning of the construction period (1856) to present. The static structure and its siting on the dynamic Louisiana coast served and perilously continue to serve as a datum to measure the fluctuating environment and major ecological changes. Simultaneously the structures deconstruction and degradation identifies issues faced by historic sites found in indeterminate landscapes and at extreme environmental risk.

Based on the aforementioned determinations, it was concluded to employ one of the typical preservation methodologies for this site was not appropriate. Protection, rehabilitation, reconstruction, restoration, or stabilization treatments (as defined by the NPS, Dickenson 1983) were deemed not only cost-prohibitive but also impossible. For any of those methods to have any preserving effect would require modifying the global environment. Thusly, the team researched other preservation methodologies outside of the stated historic building and landscape treatments. Libraries, archives, and museums are all concerned with maintaining or restoring access to artifacts, documents and records through the study, diagnosis, treatment and prevention of decay and damage. Besides preservation they also practice conservation which refers to the treatment and repair of individual items to slow decay or restore them to a usable state. For example, the Library of Congress established in 1967 the Preservation Directorate. Composed of the Office of the Director for Preservation (which includes the Mass Deacidification Program) and four divisions, the Binding and Collections Care Division, the Conservation Division, the Preservation Research and Testing Division, and the Preservation Reformatting Division, the directorate is responsible for all of the Library's holdings (over 125 million items). This vast, diverse, and unique collection (books, recordings, photographs, maps, manuscripts, etc.) requires the Library to employ all preservation methodologies, including even the process of reformatting. Reformatting is used to preserve materials that are on an unstable media and/or the material threatens the existence of other media. The goal is to capture the information from the media, through replacement or provision of surrogates, so that the content will be accessible and usable. It is often determined as the preservation method "of last resort" and "priority is given to high-value, at-risk materials of national interest" (Preservation Digital Reformatting Program 2012).

As the research project focused on the investigation of building cultural heritage in indeterminate landscapes and sites at extreme environmental risk the preservation method of reformatting seemed applicable. The material (Fort Proctor) is on an unstable media (Louisiana Coast) and the dynamic coast threatens the existence of the fort. The reformatting methodology would first dictate the provision of a replacement, an exact copy. However as a building is a unique structure found in a singular location that is not possible. Thusly, the research team decided on the provision of a surrogate, a substitute for oneself. At the Library of Congress, preservation surrogates include microfilm, paper-to-paper, and most recently digitization. Microfilm and paper would suffice if the item was two-dimensional but a building is not and as previously stated for this project, nor is it static. The fort's period of significance is its position as a datum, a marker of time. It persists, recording major ecological changes within the dynamic coastal environment and the influences of those changes on the structure. This inclusion of time in the preservation dictated digitization be the surrogate for it is the only surrogate that might be able to record time. Digitization also provides a means of capturing three-dimensional data with such modeling programs as Autocad, Revit, and 3DStudio Max. Acknowledging that actual physical preservation was not applicable for the conditions researched and two-dimensional preservation would exclude valuable information, a digital surrogate was employed

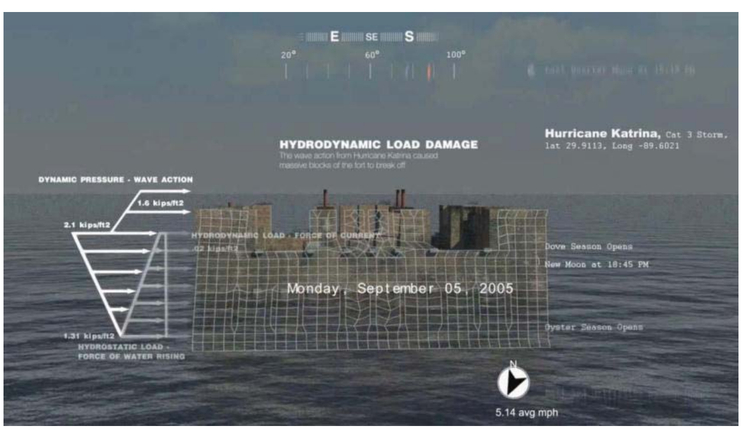

Figure 3: Single year animation still. Source: (Author 2012)

The digital surrogate was used to create the “conditional preservation” and is the determination of this research project. Assembling the complex array of data gathered by the team, including the multiple digital models constructed of the fort and landscape from its design conception in 1846 to its present day realized condition, the team developed a series of time-based animations. Utilizing historical drawings, maps, photographs (past and present) and current field surveys and GIS data, these models were constructed in a symbiotic digital environment of AutoCad, Revit and Revit Structure, and 3DStudio Max. These digital models then became the base structure for the animations. The goal of the animations is to present “a complete picture of the culture of the times as reflected in the buildings of the period” (HABS, 1999) through perspectival visualizations of the test site. To create the complete picture, the team identified four critical time-scales to animate for the fort: a single day, a single year (Fig. 3), 200 years, and geologic time. Geologic time to illustrate the dynamic condition of the Louisiana Coast, 200 years to document the full life of the building and the changes upon it and its site, a single year (2005) to capture its condition in an environment of extreme risk, and finally a single day to present its architectural condition. Each animation, through the myriad of changes they exhibit, frames each time-scale’s analytical focus and also presents the aesthetic and atmospheric qualities of each environment complete with overlays of analytical data and historical facts. The animations allow for the viewer to digest the disparate data as single narratives creating a composite temporal framework. They also preserve, at a minimum, the visual experience of a building and its environment.

These animations and the procedure for their composition present a new preservation methodology for sites where physical preservation is prohibitive and loss unavoidable: “*the conditional preservation.*” Historically and currently humankind has inhabited the coastal environments of the Earth (40% as of 2007). Simultaneously, sea level rise and global climate shifts continue to exert changes upon these environments.

> To preserve for public use historic sites, buildings and objects of significance for the inspiration and benefit of the people” (Tyler 2009, 40)

that are found in such dynamic, at-risk environments has become a significant concern and is somewhat contradictory. Fundamentally the preservation and sustainability of building cultural heritage advocates to keep or save from destruction and to establish a singular period of significance to be maintained. As this is not always feasible (nor completely indicative of a building’s significance) we argue that similar to libraries, museums, and archives, reformatting provides a methodology for ”a conditional preservation.” The rigor of traditional historic preservation documentation creates a model for reformatting and the creation of a surrogate. The documentation, similar to most representational processes, is both a reformatting of current data and a heuristic process that speaks to future physical interventions.

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ENDNOTES

[1] The NPS sponsored team consisted of the principal investigator, Ursula Emery McClure and the student team of Taylor Alphonso, Annette Couvillon, Lindsay Boley, Cody Blanchard, Christopher Peoples, and Sarah Kolac. They prepared the HABS documentation and were awarded the 2012 Peterson prize for their archival work of the Library of Congress. The CSS sponsored team consisted of three principal investigators, Ursula Emery McClure, Bradley Cantrell, and Michele Barbato. The student team was Ben Buehrle, Audrey Cropp, and Claire Hu.

[2] http://vimeo.com/channels/392545

Mapping as Applied Research

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ABSTRACT: Cartographers, geographers, and cultural historians acknowledge that existing frameworks for creating and understanding relationships through the map began to change in the mid-twentieth century. Terms like zoning, boundary condition, and master plan no longer adequately describe, catalog, or represent what are now understood as complex, culturally specific contexts and information networks. Additionally, new forms of mapping and new tools for representation allow faster and more data-intensive maps to be assembled. When used as an applied research method in design, mapping reveals a complex of relationships between representation and thinking, technology, culture, and aesthetic practices. With the aim of developing more effective ways to employ mapping, I offer a mapping course to students across disciplines that looks at maps in relation to the cartographic histories associated with different forms of the map and the relationship of these maps to an idea or place. This paper shares a method for mapping that emphasizes an understanding of the map as a strategy for the visualization of data and ideas. I show examples of student work using the tools learned in the course. Embedded in the pedagogy are terms used to organize effective maps that construct varied possible worlds by translating from one set of conditions, or constructs, to another through correspondence. Addressing maps as texts, objects of historical explanation, projections of new worlds, and a form of research, students gain a better understanding of spatial and ideational practices.

KEYWORDS: Mapping, Data Visualization, Representation, Design

INTRODUCTION

The term ’mapping’ travels across disciplines, acquiring varied definitions and, therefore; utilities. The question is, how can we define and instrumentalize mapping in design? A quick review of current theory in map–making and mapping provide some insight, but as with all experiments, reliability and testing are in order if we want to be able to transmit a working method. This paper will review the idea of mapping, propose a working definition, and share a methodology tested over the course of six years in design studios and a seminar on applied mapping. Definitions of the term mapping range from early usage in surveying as a synonym for plotting or protracting to mathematics where mapping is the correspondence between each element of a given set with each element of another. Similarly, in linguistics the emphasis is on the correspondence between associated elements of different types. In the humanities the spatial turn of the late 1960s inaugurated revisionist histories leading to a revaluation of context or place as the site of events lead by French theorists Michel Foucault, Maurice Merleau-Ponty and Paul Virilio who formulated an instrumental relation between place, people and power. In geography and eventually cartography, the emphasis shifted to "territoriality" and theories of power and space. Cultural historian Denis Cosgrove differentiates maps and mapping: the latter, once understood as a weak synonym for cartography, is more recently defined through process, specifically the process of projection. Mapping is an act that creates, visualizes, and conceptualizes a possible situation, as much as it records, represents or describes one (Cosgrove, 1999) or as Jean Baudrillard notes the territory no long precedes the map, nor does it survive it, ’the map precedes the territory’ (Baudrillard, 1994). The generally accepted definition of mapping in geography and cartography is ’a description of the milieu’ easily applied to genetic code, certain mathematical concepts, or sonar maps that create a correspondence between sound and the rise and fall of a seabed topography (Robinson and Petchenik, 1976). As a ’graphic representation of correspondence between two spaces, whose explicit outcome is a space of representation,’ mapping is, as Cosgrove reminded us, a deceptively simple activity (Cosgrove, 1999).

1.0 MAPS AS OBJECT OF EXPLANATION

Maps are parenthetical—that is, maps frame what you want to hold apart from the real in the world. The map does this by creating conceptual representations of the milieu by means of symbols and relations between symbols. This symbol correspondence is termed the index by cartographers, but it is the same representational strategy as correspondence, the difference only becoming evident when the map describes a spatial milieu. Unlike the symbols of language, the spatial map as a code derived from graphic symbols and it is from these that it’s particular ambiguity or indeterminacy derives. It is this indeterminacy that allows maps to operate as qualitative and/or quantitative research instruments.[1]

Borrowing from French theorist Roland Barthes semiotic strategy with language and myth, the following semiotic structure explains how the map can be both a sign and a signifier—that is, the map is a more of a strategy for signification than a collection of signs.

$$\begin{matrix}\text{Language}\\ \text{Maps}\end{matrix}\left\{ \frac{\left\{ \frac{(1_{Signifier}+2_{Signified}}{I.FORM}) + II.CONCEPT\right.}{III.SIGNIFICATION}\right.$$

(1) Semiotic Ordering (Author following Barthes, 2010)

In this organization signifier and signified equate to image, e.g. shapes of the continent in the northern hemisphere, while ‘concept’ is all possible meanings associated with that image: United States, Finland, Sweden for example. The second level of ‘signification’ is the way the image is construed once it is located in a context. Looking at Figure 1illustrates this difference: in the Mercator projection, the map effectively positions those countries as the center of the globe, thus the center of power.

Maps take signs, that is, anything that communicates (word, image film) with a literal meaning, and use them to stand in for something else such that the original sign becomes part of a new sign (Barthes, 1993). Using two different representations of the world map will illustrate the way this works. The Mercator projection (1569) by the cartographer Gerhard Mercator privileges ocean area. The Mercator map makes it possible for a ship’s navigator to use rhumb lines or constant sailing courses that cross all meridians of longitude at the same angle to navigate the worlds oceans (Fig. 1).

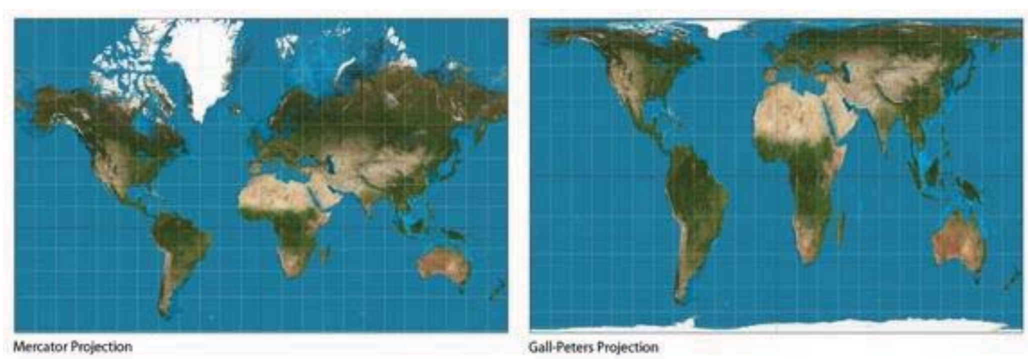

Figure 1: Mercator projection (left) and the Gall-Peters Projection (right).

The Gall-Peters map (1855) is an equal-area projection and privileges land mass. Continents in the Gall-Peters projection are arguably more correct for land area than the Mercator map. Both maps correspond to different features of the globe, but their utility as world maps is the same. The second level of signification is found in the utility of the maps as instruments of political power. The Mercator projection continues to this day as the normative representation of the globe, regardless of its original use (for sea travel), while the Peters projection remains relatively obscure. This is not surprising given that the western hegemony as the dominant territorial powers would be undermined somewhat by the Peters more accurate depiction of the southern continents.

For a moment let us take a phenomenological turn and borrow Husserl’s notion of *intersubjectivity* in order to understand how maps activate a relationship between two discreet conditions, sets, or domains. For Husserl, the term applies to the indeterminate relation between the subjective worlds of appearances for the individual–self and the shared subjectivities of other embodied subjects (Husserl, 1964). The world as a field of appearances is not a solitary realm, but a shared realm inhabited by multiple bodies in space. And it is these intersubjective relations occurring as spatially dependent phenomena between these bodies that we characterize as identities. That is, identities are always constructed in relation to. In mapping, these subjects become the subjects in the map and the world of the map re-creates these subjects through distinctions or differences, not through negation, but through a positive dialectics. That is, the context of the map is both the ’subjects’ in the map that the mapmaker brings into focus and the subjects used at the periphery to sustain the totality of the mapped representation.

2.0 KEY CONCEPTS AND TERMS

Colin Rowe introduced the figure-ground diagram (really a map) borrowed from Gestalt psychology as a way to reinforce the dependence of part-to-whole, or in the case of the city: object to field, solid to void. For Rowe the map represented the field of the city as *polis*, and the political sphere it implies, expressed as a dynamic relation between built/un-built, public/private (Rowe, 1978). It is in use now to describe urban density.

Building on Colin Rowe and others, including Kevin Lynch who introduced ’cognitive mapping’ into urban design (Lynch, 1960), Kenzo Tange’s use of photogrammetry in the Tokyo Bay Plan (1961), architects, urban designers and map-makers from a multitude of disciplines who instrumentalize the map, I developed a methodology for architecture students to use mapping as a strategy of secondary signification to build correspondences between their observations and real-world conditions, or their concepts and possible physical or perceptual analogues. The mapping methodology we use is not limited to the physical or material, but can applied as well to represent an idea or a concept. It allows students to calibrate their understanding through by translating from one idea or condition to another. Depending on the subject of their map, the data will be quantitative—that is, based on numerical measurement or qualitative which highlights a correspondence between *qualia* or the subjective properties of experience (Thomas, 2003).

The terms outlined in the following section are part of the representational structure of maps. They help identify key mechanisms imbedded in all maps. The presence of a structure also distinguishes maps from diagrams that are similar to maps in kind, but not degree. Diagrams do not quantify or qualify spatio-temporal relationships. Diagrams are ’simplified figures to convey essential meaning,’ whereas maps tend toward robust meaning relative to the subject (Hall, 1996). The symbols in a diagram have multiple significations until we specify, or point to their context using an index. They are themselves indexical, i.e. they point to something, but they are not indexed: they are not ordered or organized within a larger context, nor do they have a temporal or spatial scale.

2.1. Frame, Relative Scale, Axis, Index and Time

The five operative terms necessary to the organization of the map are: 1) frame, 2) relative scale, 3) axis of translation, 4) index, and 5) time. In order to explain the terms I will use examples from a variety of sources. In the Case Studies section of this paper we will look at specific examples in depth.

The first term is the frame or the literal and conceptual demarcation of the map: it denotes inclusion or exclusion. Making a map begins with an observation which is both a thought about thinking and the object of thought itself. The undifferentiated world cannot be apprehended therefore, all maps have a frame whether applied to a concept or a cosmography. This is one of the first principles of a map identified by the Milesian philosopher Anaximander (c.610-c.546 BC). The second term, relative scale is controlled through the geometries of projection and includes scale and all scalar relationships. All architecture drawings are by definition maps as they describe a milieu through and employ relative scale using geometries of projection. The third term is the axis of translation or the rotational plane at which the mapped representation is viewed. This is usually either horizontal or vertical. The former associated with rationalized spatial orderings like the orthographic geometries and the latter with perceptual or perspectival views. Not all maps include every term. For example, genetic maps do not depend on the axis of translation, protein sequences.

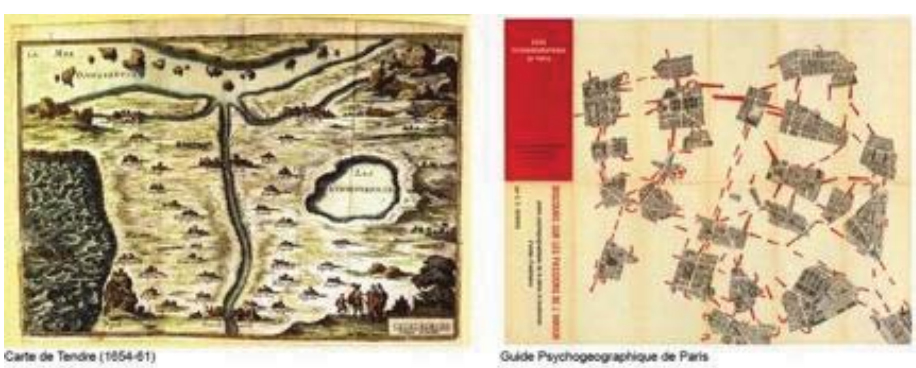

Figure 2: Comparison of the *Carte de Tendre* (left) and the *Guide Psychogeographique de Paris* (right) (Author, 2012)

The index, or forth term, is the legend or key of the map. These are the signs of the map that point to specific content. The *Carte de Tendre* (1654-61) is a thematic map describing the journey of love by pointing to or indexing geography of rivers, seas, and mountains to seventeenth century morays on love. It's contemporary equivalent is Guy Debord's *Guide Psychogeographique de Paris*: *Discours sur les Passions de L'Amour* (1957) (Discourse on the Passions of Love) that uses a graphic arrows and bits of a Parisian tourist map to describe the territory of aimless wandering practiced by the Situationist (Fig. 2).[2] Debord's map is also an example of a cognitive map similar to Lynch's, but rather than a utopian image of the city that reinforces a sense of place, the Situationists' map suggests a resistance to the underlying ordering structures of the city (Debord, 1973).

The fifth term is time and it can be either synchronic or diachronic in the map. The synchrony of time in the map is the date of the maps' creation and the time in the map, but it may also work diachronically where the map may also describe a temporal event. Kevin Lynch's cognitive maps from a *View from the Road* work this way. The cognitive map he projects in the Boston Highway project unfolds through the perceptual space of the viewer as they move through the city on the highway (Appleyard, 1964). This is a linear progression of experience and, therefore; controlled through time.

Figure 3: An example of the un-mapping exercise. The original map is the tourist map given at Disneyland, California. *Disneytopia* (Betty Ng 2008)

3.0 CASE STUDIES

The following are a series of case studies from an applied mapping course taught by the author. The maps students make range broadly between quantitative and qualitative analysis and include thematic, choreographic, ichnographic and topographic maps to name a few. The following selections illustrate the capacity of the map through measurement, however relative, to act as a scientific document. Mark Monmonier, famously showed that not only do maps lie, they must.[3] All maps are, by definition, reduced models of reality and as such, reflect a mapmakers dialogue with the world around them. The goal of the course was to teach students how to communicate effectively through the map. Exercises and readings focused on the necessary grammar and syntax of map making.

This is a graduate level course offered over the last five years in architecture. The format of the course is a seminar workshop meeting three hours a week. The emphasis is not on technologies used to make maps (GIS, mathematical projection, CAD programs), rather on maps as representational strategies. Students are encouraged to use whatever technology is appropriate to the subject of their map. Students read a variety of texts, from the history and theory of representation to specific cases of mapping in architecture.

Students complete two mapping projects over the semester-long course. The first project is a un-mapping exercise in which students 1) choose one of five pre-selected maps, 2) deconstruct the map to understand how it is organized, then 3) reassemble the map according to a particular thematic (FIG. 3). The final research project is the construction of a new map using a data set assembled by the student. There are no restrictions placed on the choice of data or how it is to be organized, but the final representation must conform to the terms outlined in the mapping methodology.

3.1. Orthographic Projection: ***Canopy_Florida_11.09.09, 10:00AM***

Sara Johnson's *Canopy_Florida* is a thematic map that looks at the density of foliage (Fig. 4). The map frames a narrow slice of Floridian understory at a particular time of day and then calibrates the density from light to dark. The goal of the map was to evaluate an existing natural condition in order to calibrate an artificial response, in this case, the design of a shading device.

The map outlines the sequence of translation from original canopy condition to reformulated density. Using a photograph, the student projected a rationalized grid in order to fix the position of the data. By translating the original photograph into a high-contrast image and then mapping the data on the grid, the map allows for the construction of a new value-set. The value-set is re-projected onto the grid using a set of predetermined parameters to inform an alternative reading of the relative density of light to dark in the original condition. Sara also tested an alternative reading of the density as a color mapping. Finally, the z-axis translation is projected as a 3-D lattice structure in the final translation of the original perceived densities.

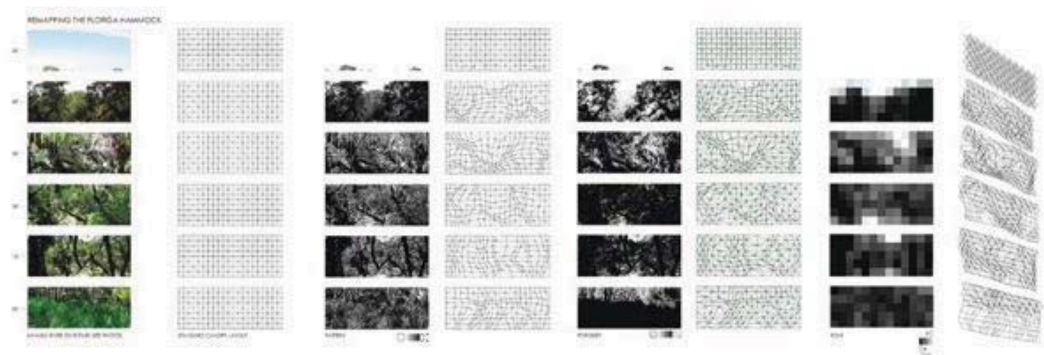

Figure 4: *Canopy_Florida_11.09.09, 10:00AM* (Sara Johnson, 2010)

The final mapping was used to inform the design of an artificial canopy intended to mitigate the natural canopy of the Florida site. The mapping is effective because the mapmaker is specific about the data and translations. Similar to sonar maps that translate one data set (sound) to another (graphical index) to describe a third condition (terrain) this map translates an original image made using light (photo) to a density reading and finally a three-dimensional representation of a new perceptual terrain.

3.2. Perceptions of Space: Everchanging Frame and GIS Data scape

The two maps shown focus on how we perceive space. The first uses two axes of translations: the plan-view that ordered by orthographic geometries and the perceptual view organized by the perspectival optics of the camera lens that captures what the observer sees through the lens. The second map describes the contours of a scene using a GIS data-set where the z-axis is given value in proportion to the amount of tone change from one color to another.

Everchanging Frame: One Lincoln Road Experience (Fig. 5) is one of 14 sheets from a folio. The analysis is a qualitative mapping describing the spatial frame on Lincoln Road in Miami, Florida. The data set is a compilation of 110 photographs taken at 20 pace intervals. Overlaying the frames is a conceptual screening of the positive and negative space of Lincoln Road shown in perspective enforces the compressive and expansive quality of the actual space.

The second map (Fig. 6) addressed the how it is that we perceive a scene using theories of perception from ecological psychology. The questions were 1) how are you seeing, and 2) how to measure what you are seeing. Cognitive psychology argues that visual perception is a function of an indirect and rationalized perception of reality. In contrast the work of psychologist James J. Gibson argued for a direct realist approach to visual information acquisition where the environment is understood to provide all the information necessary to specify it's properties (Gibson, 1979). Gibson's ecological approach emphasizes the direct experience of the world as mapped by the visual cortex. Using a similar approach Lysa Janssen's *GIS Data-Scape* map proposes that the raw data of a visual image (in this case a photograph) can be treated as a visual field of color to be re-projected using GIS software.

The first step in the process is the pixilation of the original image after which pixels are converted into bands of color abstracting the image to its most basic color data. A second iteration converts the pixilated image to a set of densities depending on a pre-selected range of values from light to dark. The new mapping translates one set of data (light) to a three-dimensional landscape. This is not a strictly ecological approach as intended by Gibson; rather it plays with data sets and demonstrates the malleability of our technologies and assumptions about the way perception operates.

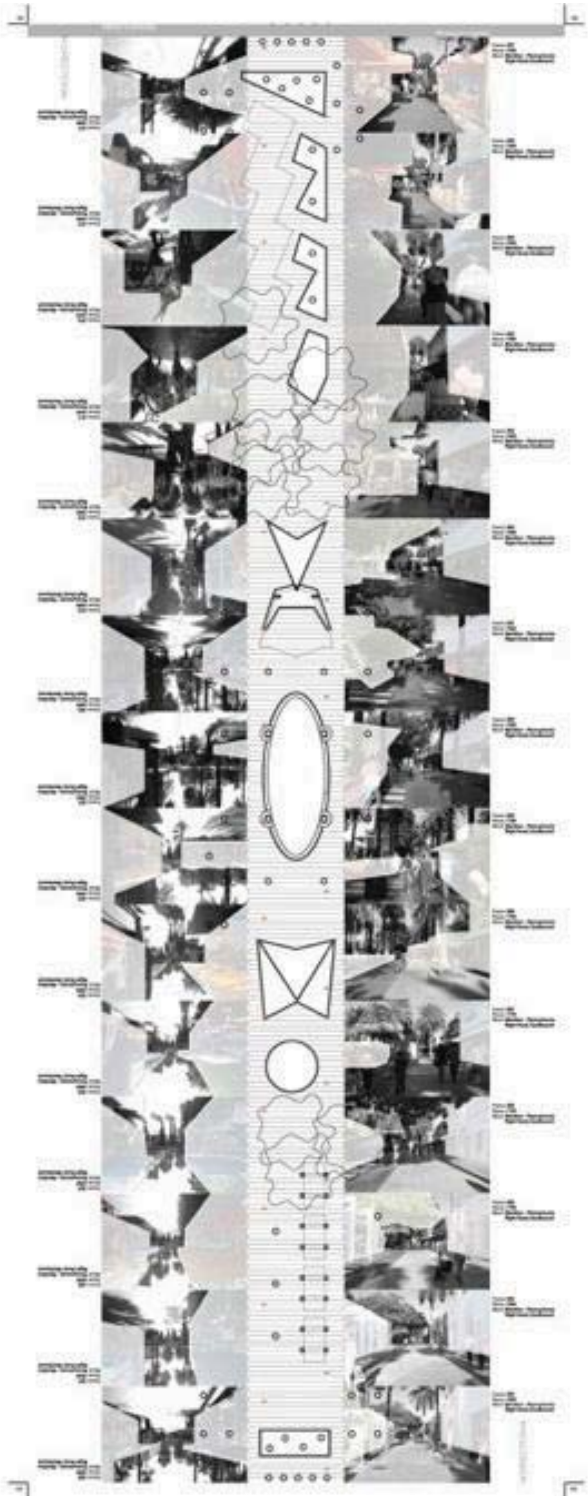

Figure 5: *Everchanging Frame*, The data for the map was collected on Lincoln Rd., Miami, Florida, 3/27/12 at 3:28-3:42 PM. (Daniel Alonso, 2010)

3.3. Thematic Maps: *Chronotope of Babel* and *Distributing Dynamics*

Gia Wolff's *Chronotope of Babel* is a thematic mapping of the short story "The Library of Babel" by Argentine author Jorge Luis Borges (Fig. 7) In the story the universe is presented as a vast library containing only 410-page books. Borges imagines the spatial organization as an infinite field of interlocking hexagonal rooms. Wolff's map chronicles the time-space of the narrative of the story or what literary theorist Mikhel Bakhtin designated a *chronotope*. The term describes the spatio-temporal link controlling the structure of any given narrative or speech act. All stories take place *somewhere* and in *sometime*. In the case of the "Library of Babel," the narrative unfolds in relation to the hexagonal units of a library as described by Borges' narrator, the 'traveller.' (Borges, 2000)

The underlying layer of the map is the text of the book "folded" corresponding to the overlap of the events of the story linked to the space in which they occur. The frame of the map is the limit of Borges essay or the internal time of the story in relation to its imagined space. Unlike the text in which the ordering principle is language and syntax, the map is ordered by the hexagonal figure of the library and the sequence of the story as told by the narrator. It was important that neither time nor space was privileged, as this is part of the definition of the chronotope according to Bakhtin and was also deemed important by the mapmaker. Ultimately the map is a translation of Borges dys-topic world in which neither space, time, or language are stable.

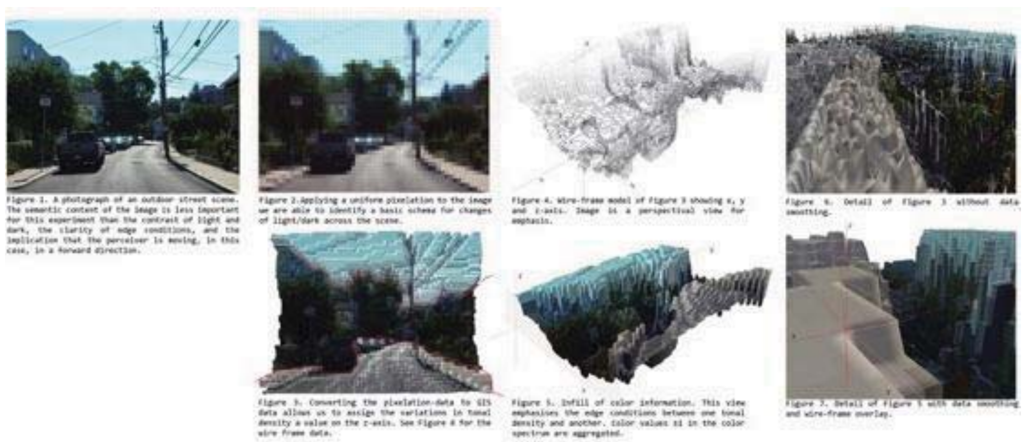

Figure 6: *GIS Data-scape*, (Lysa Janssen, 2008)

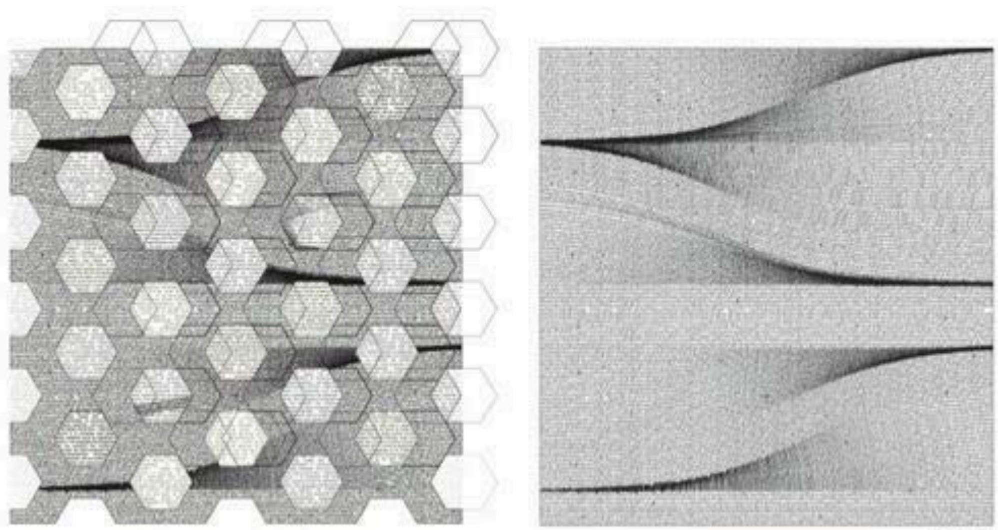

Figure 7: *Chronotope of Babel* (Gia Wolff 2008)

The map, *Redistributing the Dynamics of the World* explores the relationship between time and distance by reordering the world according to the time needed to travel from one location to another via the airplane (Fig. 8). Buckminster Fuller's *AirOcean World Map* (1946) proposed a similar reordering of the world based on the transport of goods and people through airplanes. But where Fuller used a new projection of the three-dimensional globe as sections of an icosahedron, Siliang Fu's map simply moves the existing landmass as a function of the time to distance relationship based on air travel and telecommunications. The map offers three versions of the world: past, present, and future. In this new world map, the world is not only perceptually smaller, but literally shrinking.

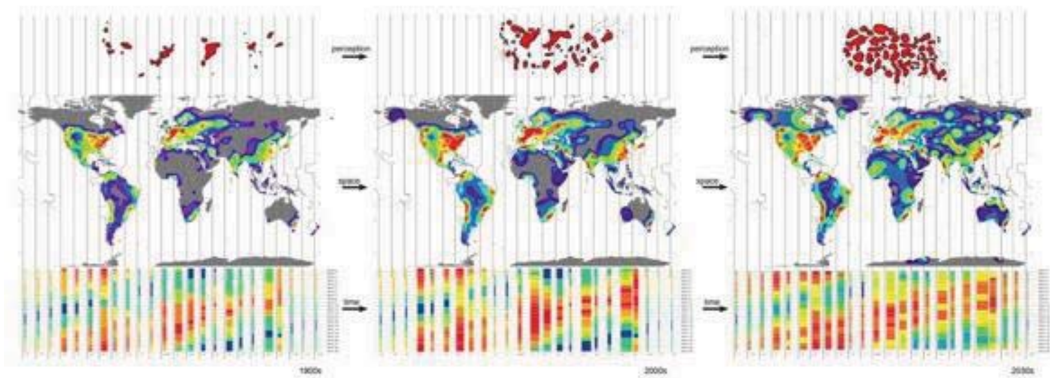

Figure 8: *Redistributing the Dynamics of the World* (Siliang Fu 2010)

CONCLUSION

Making a map begins with an observation which is both a thought about thinking and the object of thought itself. The undifferentiated world cannot be apprehended. The map can isolate data without fully disrupting imbedded relationship of that data to all other data. The map allows us to slip between whole and part, object and subject, point and field, or identity and non-identity on a continuum, rather than as sets or categories which are necessarily defined by contrast, or difference. This positions mapping as an effective tool for managing the complexity of observations often associate with design in the spatial disciplines. Maps organize qualitative and quantitative data according to the theoretical framework of the mapmaker. Mapping is the collective set of practices that structure correspondence between physical phenomena, lived experience, or conceptual frameworks. To paraphrase Lord Kelvin who famously noted that to measure something is to understand it; to map something is to structure it.

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ENDNOTES

[1] The argument for a 'multimethod' approach in the social sciences bodes well for using maps in combination with additional tools including surveys, experiment, and field observations. The key is to control the selection of method primarily by the researcher's theoretical formulation of the problem, and 'only secondarily by methodology.' See J. Brewer and A. Hunter. 2006. *Foundations of Multimethod Research: Synthesizing Styles*. Sage Publications: Thousand Oaks, Calif., pp. 64.
[2] The original map was an engraving by François Chauveau as part of a novel by Madeleine de Scudéry's novel Clélie (1654-61).
[3] M. S. Monmonier. *How to lie with maps*. University of Chicago Press, Chicago, 2nd ed edition, 1996.

Visualizing the Social Underpinnings of a Building Type & Widespread Adoption of Student Unions

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ABSTRACT: Using both found and created visual evidence, this paper will chart the origin and widespread adoption of Student Union buildings on college campuses in the United States from the 1920s through World War II. Original photographs, plans, and drawings of buildings – published or buried in archives – mount a story about the emerging building type that Student Union proponents and architects sought to establish on university campuses. Existing visual evidence provides important clues about the character and intent of the social spaces for college students, but this evidence does not explain the rapid adoption or the similarities among contemporaneous buildings, which were built by different architects under various campus administrations. New maps, however, are able to depict how ideas about the building type coalesced geographically through social connections, and why construction spread across the country as membership to the Association of College Unions grew. Although the history of Student Union buildings entails a range of topics that span how architecture supported social education and citizenship, conjured "home," and served to establish a broad middle-class culture after World War II, this paper focuses on how social processes and individuals, on behalf of an institution, established the building type through a social network. Specific historic factors visualized include directed travel for Student Union research, conventions, and membership to the Association of College Unions, as well as travel by Student Union professionals. The significance of this research is that it harnesses maps and visual media to explore when and how social connections – much like social media today – circulated ideological approaches to social education, and shaped the form and meaning of Student Union buildings themselves. Thus, this paper contributes to discourse on building typologies as it examines the potential of maps and visual evidence in architectural history.

KEYWORDS: college union, history, social network

INTRODUCTION

Establishing Student Unions on North American campuses during the first half of the twentieth-century was a task undertaken by numerous individuals who harnessed the social structure provided by the Association of College Unions, an institution that complemented efforts of university administrators to provide activities and spaces for student leisure. To convey the importance of the social structure and subsequent social networks which grew under the auspices of the Association, this paper combines existing texts and visual evidence with the geographical analysis of the institutions and individuals involved in establishing Student Unions as a building type. The approach illuminates where the building type originated, what the building became, and how ideas about Student Unions were transmitted during a period of United States history rich with social change and upheaval; when college age women increasingly attended coed institutions, business culture popularized going to college among young men, and when the imagination of college proponents saw organized leisure activities as an important part of the university experience.[1] Understanding the geographical impact of the first Union buildings, alongside its social import and early architectural development, illustrates how both official and unofficial social connections across geographical distances were crucial to the development and adoption of Student Union buildings.

1.0. The origin of student unions in North America

As an institution, Student Unions emerged out of the debating societies at Oxford and Cambridge University. But an association of students, where students and university administrators planned leisure activities, constructed dedicated Union buildings, and maintained intercollegiate exchange, is a relatively young, American, and twentieth-century phenomenon. The movement officially began in 1914, when members of the Student Union at Ohio State University invited a handful of administrators and student leaders to gather and discuss the possibility of forming an Association of College Unions (*Convention Proceedings of the Association of College Unions* 1915).[2] Because few schools at that time had dedicated Union buildings, school delegates turned their attention toward envisioning Student Union buildings and the mechanisms through which they could collect and exchange information about them. Buildings would be the topic and vehicle for the development of the Student Union idea.

The early meetings before and immediately following World War I proved to be a practical solution for far-flung student organizations in the Midwest and Northeast. The meetings gave leaders an opportunity to forge personal contacts, share ideas about student government and leisure activities, and visit College Unions (*The Bulletin of Association of College Unions* March 1933). Administrators, Union directors, and students, by way of the Association, thus cast chance correspondence aside by structuring how student leaders and a growing group of young Student Union professionals would air concerns, exchange solutions, and develop the Student Union idea. With a cooperative and collegial spirit, the Association became a celebrated organization through which students could practice self-governance, learn professional skills and leisure habits deemed important for society at large.

In the early years of the Association, the geographical reach of the young organization was largely defined by regional proximity and railroad interconnectivity among Midwestern and northeastern cities (Figure 1). These schools, Wisconsin, Illinois, and Michigan among them, mark a concentration of interest and the regional origin of the North American building type. But the initial social connections among Association members does not and cannot explain the eventual rapid and wide-spread adoption of dedicated Student Union buildings on university and college campuses, which occurred during the 1930s and 1940s (Table 1). Instead, underlying the wide-spread adoption was a concentrated effort to define the building type, which developed through both official and unofficial social networks put in place by the Association of College Unions and it members (Figure 2).[3]

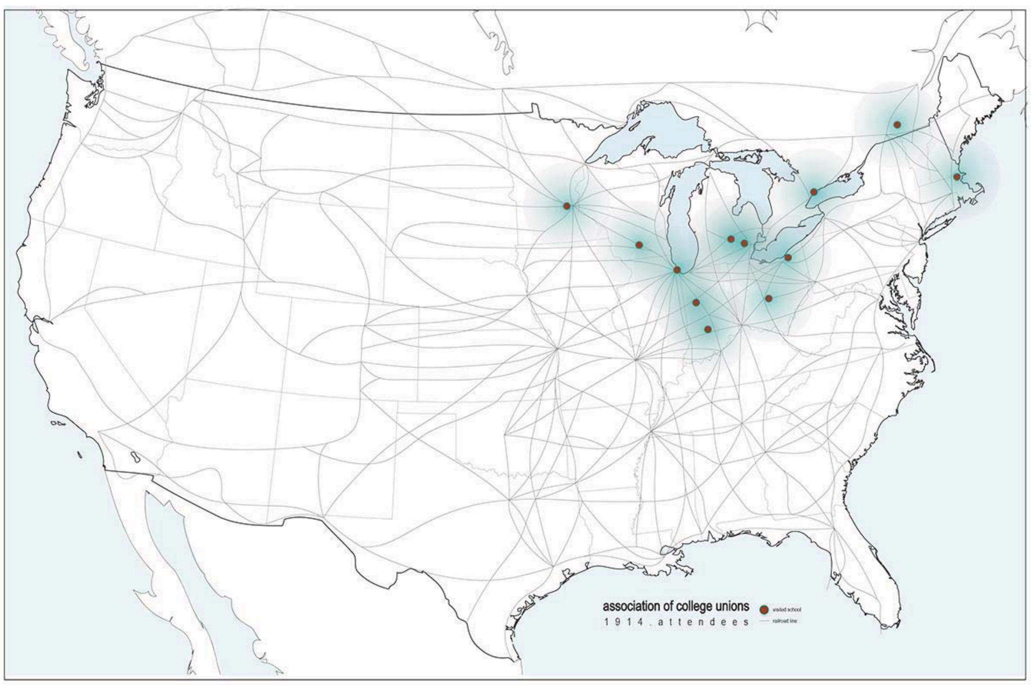

Figure 1. Schools represented at the first Association of College Union meeting in Ohio in 1914 shows a cluster of Midwestern interest in Student Union buildings and their railroad connectivity. Source: (Author, 2013)

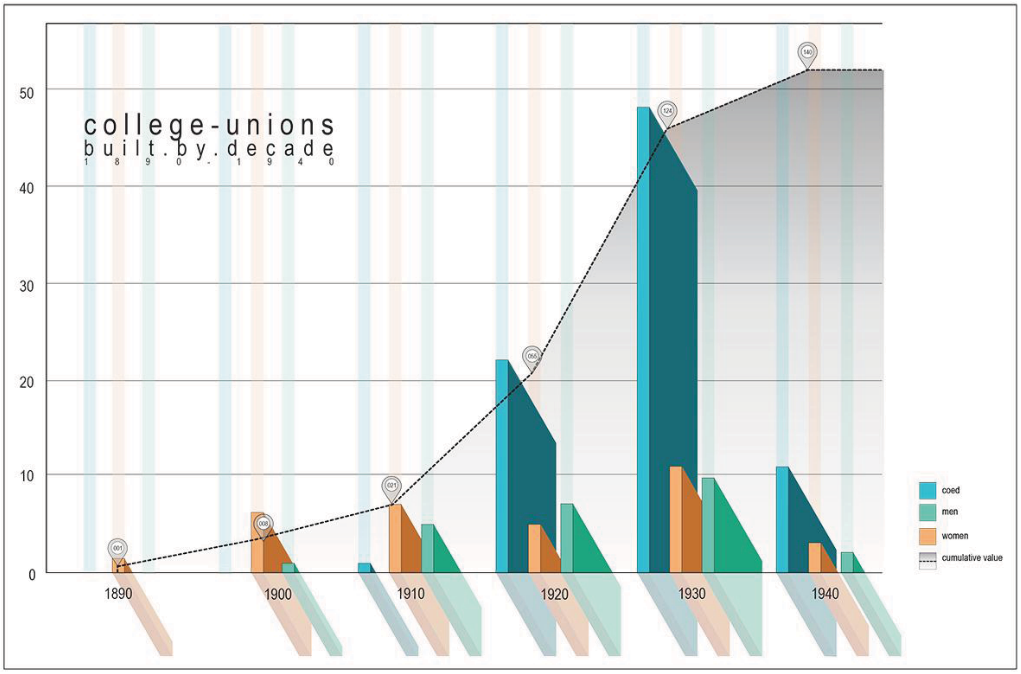

Table 1. The number of College Unions constructed by decade shows the significant increase in Student Unions built during the 1930s and 1940s as well as growing the popularity of coed buildings. Source: (Author, 2012)

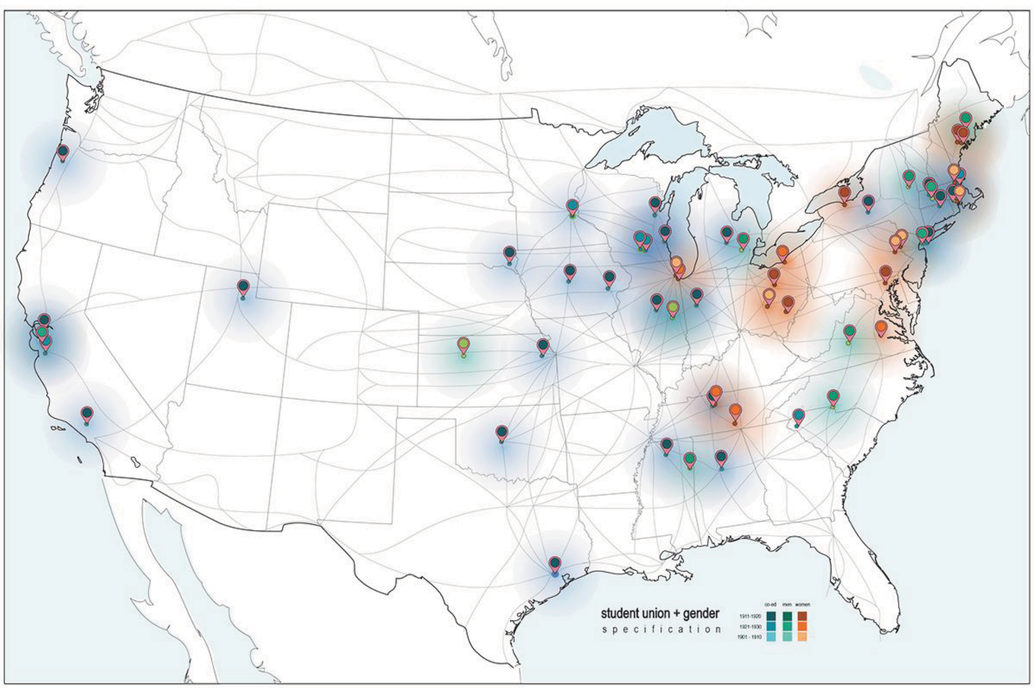

Figure 2. The completion of Student Unions in North America illustrated geographically shows a concentration of buildings in the Midwest and northeast and their adoption throughout the continent by the end of the 1930s. The distance between Student Union buildings posed a geographic hurdle for the social connections affording by the Association of College Unions, especially for many of the new buildings constructed in the west and south. Source: (Author, 2013)

2.0. Early architectural precedents offer a benchmark for Association members

Accounts of the origin of Student Union buildings came from a myriad of professionals who built Student Unions from the ground up. These men and women were active members of the Association of College Unions; they often served as conference speakers and authored publications about the benefits and the architecture of Unions. Their notions about Student Unions stemmed from a synthesis of various examples in the United Kingdom that Union proponents studied, if not visited, in Oxford and Cambridge.[4] But during the 1920s, founders of the Association of College Unions more often looked to North American examples. In particular, the Association recognized Houston Hall at the University of Pennsylvania as the first Student Union in North America. It had a store, a soda fountain, a barbershop, a post office, a billiards room, and several small reading and lounging rooms.[5] The Ohio Union, another early building, had a basement cafeteria, a small private dining room, a soda grill, and a kitchen as well as a large lounge, a billiards room, a game room, a reception room, offices, and a theater. Most Unions built just after the First World War contained lounges, cafeterias, game rooms, and offices but none were as comprehensive as the celebrated Hart House at the University of Toronto.[6]

The Hart House, unlike other North American Unions, provided students and faculty with a broad spectrum of activities that ranged from bible study, dining, and athletics. Completed in 1919, its rooms and activities had the purpose of serving "the highest interests of [the] university by drawing into a common fellowship the members of the several colleges and faculties" and to gather "into a true society the teacher and the student, the graduate and the undergraduate" (*Architectural Forum* January 1924, 12).[7] The unity of fellowship, against the backdrop of debate, music, play, casual reading, sports, and games, promised to mold the whole student and arm him with clarity of mind, depth of understanding, and moral objectives. The building's exterior resembled a monumental monastic cloister, but students inside partook of activities considered essential for the development of the modern man: physical fitness, entertainment, and casual socialization. For such a broad range of activities, the architecture firm Spratt and Ralph artfully designed different spaces, placing ornamentation in the rooms that demanded more refined student behavior and leaving the knock-about spaces relatively plain.[8] The overall grandeur of the building, made of rusticated stone, not only impressed administrators elsewhere but also gave physical form to a multipurpose Student Union. Discussion about the Hart House and many of the other North American buildings gave Union proponents a tangible project that stirred planning, if not building campaigns, for Student Unions on college campuses that would uphold the social and educational aspirations of Association.

The early precedents were instrumental but only the beginning of the movement. By 1925, the Association of College Unions published the *complete* Union program (*Convention Proceedings of the Association of College Unions* 1925).[9] Compiled from lists of all activities that any member Union had or deemed advisable, the Association crafted an *ideal*, although fictional, program for a Union. Desirable rooms ranged in size, number, and purpose, from alumni offices to barber shops, candy counters, dance halls, locker rooms, music rooms, post offices, radio broadcasting rooms, smoking rooms, and trophy rooms.[10] With art rooms and bowling alleys on the list, the scale and scope of Unions had far surpassed Unions in England, which at most, by 1925, had only seven types of spaces.[11]

The building type continued to change as college campuses constructed double and quadruple-sized buildings. Gone were buildings which merely provided lounges where students would gather to read, debate, and play cards. In their place came a variety of spaces with more specific programmatic purposes. Smaller rooms were for reading, games, and recitals. Larger rooms were for dances, lectures, and staged performances. Student Union buildings, dubbed "social unions" by Jens Fredrick Larson in his 1933 publication, *Architectural Planning of the American College Campus*, had become indispensable for extracurricular campus activates and a complex building proposition. *How did these changes transpire?*

3.0. Official sources for union buildings

An early, authoritative voice on Union buildings was Irving Pond, who designed the Union at Purdue and the Women's League at the University of Michigan and published the first professional article on Union design in *Architectural Forum* in 1931. His opinions about the importance of social education matched those of the Association of College Unions but he specified how architecture could express the ideological underpinnings of the organization. As an architect, he was primarily concerned with program and how to reconcile conflicting interests concerning the allocation of rooms and spaces. In his essay "The College Union," Pond argued the use and potential of lobbies, offices, check and toilet rooms, lounges, cafeterias, dining rooms, committee rooms, assembly rooms, kitchens, libraries, game rooms, barber shops and beauty parlors, quiet rooms, storage rooms, and theater facilities (Pond 1931). Through these environments, he painted a backdrop for the everyday and special celebrations that would reinforce social norms. Upholstery and wood paneling, much like the formal spaces of the Hart House, covered the furniture and walls of the lounges and large gathering spaces. These rooms, often with double-height ceilings, hosted formal occasions. Cafeterias and game rooms were stripped of expensive materials but not their power to foster collegial socialization. Informal spaces only reinforced social expectations harbored in more opulent settings. Thus, for Pond, it was the suite of spaces, not a single room, that bore the burden of social education. And it was from this that a particular combination of rooms became the signature of early Student Union buildings: lounges, game rooms, cafeterias or lunch stands, and sometimes a ballroom.

Although Pond put architectural ideas into circulation, two other factors defined and subsequently spread ideas about buildings: official publications and the travel of early Student Union professionals who sought to chronicle, understand, and disseminate ideas about the purpose and form of Student Unions. Porter Butts, who served as the Union Director at the University of Wisconsin and longtime Editor of Publications for the Association of College Unions, printed and mailed quarterly updates to Association members. The circulation of *The Bulletin of the Association of College Unions*, usually mailed quarterly, gave members periodic updates on issues and building campaigns. Through Butts, *The Bulletin* became a crucial communication device that welded a coherent ideological vision for the Association.

While *The Bulletin* circulated, so did Edith Humphreys, a young Student Union professional who undertook a study of Student Union buildings in North America in the 1930s and 1940s.[12] Because of her effort to travel among and chronicle the history and the state of College Unions on the eve of World War II, her widely publicized first-of-a-kind book *College Unions: A Handbook on Campus Community Center* (1946), codified many aspects of Union design for the larger community. Her study entailed the production, distribution, and analysis of questionnaires as well as personal visits to fifty-five institutions in the United States. Traveling by train and with sustained correspondence between Union leaders, she stitched the otherwise disparate locations of Student Union buildings together tightly (Figure 3).

The principal purpose of Humphreys' handbook was to suggest procedures for fulfilling the university's educational goals after the war. Instead of relying on lists, costs, salaries, and annual expenditures, Humphreys believed these facts and figures, sometimes quite specific to different institutional contexts, should not appear to be more important than the people for whom Student Union buildings were created. The social particulars of any given campus were therefore most important. The common belief among Humphreys' colleagues was that informal education enhanced the value of the Union as an educational medium in an academic setting. In this way, imagining the building as merely a place to meet, dance, have tea, or eat missed the potential of the Union building as an environment for life-changing experiences. Instead of viewing the Union as an unnecessary place for loafing or "bull," she argued that faculty and other members of the university community appreciated how the Unions of the 1940s could enable personal development and connections among fellow students. She also observed how Union staff no longer boasted about the beauty and grandeur of their building but instead prided themselves on how well the building served the recreational needs of its members. In this way, the buildings helped put in place a vibrant, local social structure for the Association.

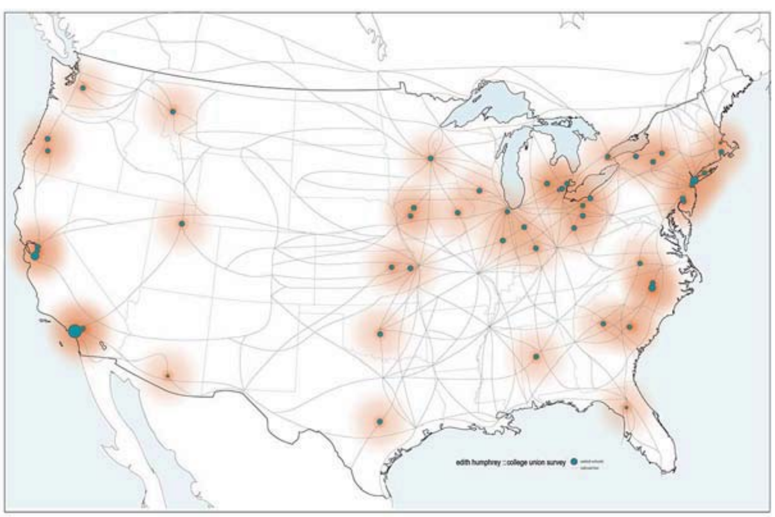

Figure 3. Edith Outzs Humphreys completed her study of Student Union buildings in two phases, visiting a total of fifty-five College Unions in the United States and Canada. Source: (Author 2013).

Through her book, Humphreys conveyed that recreation had broad social and cultural consequences and underscored the grown importance of the building type. She also specified how within the recreation center, activities and experiences were best if they were planned around the interests and needs of community members. Therefore, programs must be flexible, adapt to students, and offer choice in leisure activities. The varied activities, ranging from casual cokes at the soda fountain, to lunch and dinner in the cafeteria, to lectures in the lounge, needed not only the space but also institutional support – from the college and Association – to promote the desired values of the university.

Humphreys' book did not portray *how* unions spread but rather *what* union became, and emphasized the commonalties among Union buildings in North America. Thus, her journey to visit fifty-five Student Unions, and the survey many others, clarified a building type that had spread and the most prevalent features of them. She helped spread information by using the social structure afforded by the Association. Moreover, she physically inscribed a social network crucial to the Association and future member schools. Despite the book's attention to individual campuses and need, *College Unions*, reprinted in 1951 and again in 1960, was the official, most complete source for Union proponents throughout the postwar period. Official expertise, however, was not the only source of ideas. Unofficial social networks played an important role as well.

4.0. Unofficial social networks shape the building type

Unofficial social networks afforded by membership to the Association had a role in shaping the building type and its adoption across North America. Intercollegiate billiard and bowling tournaments are evidence of social exchange.[13] But ideas about Student Union buildings spread informally more often, and more specifically, in one of two ways: photographic exhibitions and the publication of Student Union buildings in school newspapers.

The Association maintained a collection of photographs which interested schools could borrow to publicize and spread ideas about Student union buildings. Members of the Association and Union proponents thus, on a rotating basis, could display the collection for an entire student body. More important, the exhibition on Student Union architecture brought the Union idea directly to students. Student leaders at Antioch, for example, pinned a collection of thirty Association photographs to a temporary colorful wall near their student executive offices (*The Bulletin of the Association of College Unions* December 1949). Comprised of both interior and exterior views, the collection not only showed students at Antioch and images of celebrated Unions but also incited a bit of competition. Students were first enticed to take a look at what other colleges were doing and then provoked to plan their own Unions.

In a similar spirit, it was also common for student government associations, who were interested in building or renovating Student Union facilities, to publish photographs of Unions elsewhere. The effect of this practice was to introduce college students in one area of the country to facilities in another area of the country. The photographs often depreciated older union facilities in favor of modern ones, with amenities such as bowling alleys and large cafeterias. Writers for the student newspaper at the University of California in Berkeley, for example, compared the old Union at Berkeley to newer Unions that were equipped with beauty parlors, barbershops, listening rooms, and lounges complete with modern furniture and stone fireplaces. Thus, as Berkeley was hosting the national Association of College Unions convention in 1953, students could view interior images of far-flung Unions at Ohio State, Oregon State, and Texas A&M and imagine a similar one of their own (*Daily Californian* May 1953). As Berkeley advanced Union plans, the schools newspaper attempted to further pique student interest by publishing contests. Prizes were awarded to the reader who could identify the Student Union pictured. Students with the correct answer won a cash prize that exceeded the proposed Student Union fee! (*Daily Californian* January 1955). Circulating images of Union architecture built knowledge and opinions about the type. In this way, school papers and the Association's traveling exhibition were a vehicle for college communities to share ideas about Student Union buildings.

CONCLUSION

By the 1940s, Union buildings had become the symbol and physical instrument for attaining the goals of a good community life. Historical texts and supporting visual evidence can depict a vivid story about the construction of Student Union buildings in North America. Geographic evidence – of meetings and member connections forged through official travel and informal collegiate connections – maps the origin, rapid adoption, and the spatial channels through which information about the building typed flowed. Combining traditional modes of historical research with geographic analysis more fully illuminates the regional origin of the building type and social framework necessary for its architectural development. Understanding the social underpinnings of the building type – and how discussions about Student Unions channeled common concerns – may be inferred without geographical analysis, but the flexible and adaptive social structure established across space and over time was crucial to the refinement and the pattern of wide-spread adoption of the building type.

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ENDNOTES

[1] For the popularization of college, see Daniel Clark, *Creating the College Man: American Mass Magazines and Middle-Class Manhood* (Madison: University of Wisconsin Press, 2010), especially his introduction and Chap. 5, "From Campus Hero to Corporate Professional." For the interest in organized leisure, see See Eugene T. Lies, *The New Leisure Challenges the Schools: Shall Recreation Enrich or Impoverish Life?* (Washington, DC: National Education Association, 1933); Paul P. Boyd, "Extra Curricular Activities and Scholarship," *School and Society* XIII (February 5, 1921); Donald S. Bridgeman, "Success in College and Business," *Personnel Journal* IX (June 1930); Delisle C Burns, *Leisure in the Modern World* (New York: The Century Co., 1932); Stuart F Chapin, "Extra-Curricular Activities of College Students: A Study in College Leadership," *School and Society* XXIII (February 13, 1926); Alzada Comstock, "Time and the College Girl," *School and Society* XXI (March 14, 1925); W. H. Cowley, "Explaining the Rah Rah Boy," *New Republic* XLVI (April 14, 1926); Irwin Edman, "On American Leisure," *Harper's Magazine* (January 1926); Christian Gauss, *Life in College* (New York: Scribner's, 1930); L. P. Jacks, *Education for the Whole Man* (New York: Harper's, 1931) and *Education Through Recreation* (New York: Harper and Bros., 1932); and Woodrow Wilson, "What is College For?" *Scribner's Magazine* Vol XLVI (November 1909).
[2] The Association was first founded at Ohio State University in 1914 but had several incarnations until the close of World War I, when members decided to name their organization the Association of College Unions. At the first meeting, Ohio was the only school represented with both a Student Union and a dedicated building (*Convention Proceedings of the Association of College Unions* (1915) National Student Affairs Archives, Bowling Green State University: 7).

[3] The dissemination of information and adoption of the building type on college campuses is not unlike YMCA buildings a generation earlier. See Paula Lupkin's book *Manhood Factories: YMCA Architecture and the Making of Modern Urban Culture* (Minneapolis: University of Minnesota Press, 2010).
[4] See Edith Ouzts Humphreys, *College Unions: A Handbook on Camus Community Centers* (Ithaca, NY: Association of College Unions, 1946) and *College Unions … Year Fifty*, Chester Berry, ed. (Association of College Unions, 1964), and numerous publications by Porter Butts, such as *The College Union Idea* (Association of College Unions, 1971).
[5] Houston Hall at the University of Pennsylvania was founded in 1896. For information about its financing and facilities, see the *Convention Proceedings of the Association of College Unions* (1925) National Student Affairs Archives, Bowling Green State University: 14-15).
[6] See descriptions of Purdue, Minnesota, Iowa, and Iowa State University Unions in the *Convention Proceedings of the Association of College Unions* (1925) National Student Affairs Archives, Bowling Green State University: 21-27.
[7] Also see Porter Butts, *State of the College Union Around the World* (Ithaca, NY: Association of College Unions International, 1967) for a description of the building and its influence (38-45).
[8] See *Architectural Forum* Vol XL No 1 (January 1924) p12; *American Architect* Vol 117 pt 2 No 3213, 506b (April 12, 1920); *Builders* Vol 119 (July 2, 1920): 4-5 and Vol 130 (February 5, 1926): 246.
[9] See *The Association of College Unions Convention Proceedings* (1925) National Student Affairs Archives, Bowling Green State University: 30.
[10] The complete list included alumni offices, art room, union administrative offices, banquet rooms, bowling alleys, barbershop and tailor shop, cafeteria, committee and conference rooms, cigar, candy and news counters, co-operative student store, chapel and meditation room, dining hall, dance hall, debating hall, faculty rooms, game room for cards, chess, checkers, hotel rooms, information and employment bureau, library, locker room and check room, general lounge room, men's lounge room, women's lounge room, magazine and newspaper room, music room, organization offices for activities headquarters, pool and billiards room, branch post office, reading room, reception rooms, restrooms, radio broadcasting room, soda fountain, shoe shining stand, smoking room, show and bath rooms, theater, toilets, writing room, YMCA rooms, and athletics not otherwise provided for.
[11] British Unions surveyed included the Cambridge Union Society, Glasgow Union, Belfast Union, The Dublin Historical Society, and the Oxford Union (*Convention Proceedings of the Association of College Unions* (1925) National Student Affairs Archives, Bowling Green State University.
[12] Humphreys came from a young group of student affairs professionals who were trained on the job to attend to the personal development of students, both in and outside the classroom. As a classroom teacher, student counselor, and personnel officer, Humphreys approached her project with educational concepts and techniques learned in the 1920s. Humphreys had worked as Student Union staff in Willard Straight Hall at Cornell University for ten years and believed that she, like her fellow workers, recognized the College Union as a unique social laboratory. Thus, she claimed, the impetus for her study was to understand the Union movement in its entirety and to lay ground for its future.
[13] *The Bulletin of the Association of College Unions* regularly reported billiard and bowling scores from competing schools. If tournaments were not held fact-to-face, they were held by telephone. In addition to these tournaments, regular instructors circulated among the Unions, teaching the game and social etiquette.

Genealogy of Collage and Architecture

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ABSTRACT: Collage has been a vital representational and procedural medium in the history of modern architecture and a bridge between artists and architects of the past century. One century ago, collage entered the lexicon of the contemporary art world when Pablo Picasso, in May of 1912, first appropriated a found material into a work of art. The founders of Cubism valued collage as a hybridization of painting and sculpture, existing at the threshold of two and three dimensions. For the first time in 450 years, the Renaissance approach to representation (privileging visual experience) was rejected. The Cubists instead represented aspects of daily life through abstraction, material juxtapositions, and fragmentation and synthesis of form, capturing spatial and material qualities of commonplace subjects. As a means of investigating the potentialities of three-dimensional space in a two-dimensional medium, collage facilitated a new conception of space. This paper reconstructs the genealogy of collage, tracing the legacy of this first act of collage-making in the Modernist canon. Collage, as an art form unique to the modern era, emphasizes process over product. Simultaneity of spatial, material, and intellectual content is inherent in collage through a synthesis of unrelated fragments, as the process of construction remains evident in the resulting work. Just as a work of architecture is only fully created and comprehended through bodily, sensory engagement, collage serves as a representational analogue, providing the medium to interrogate spatial and material possibilities. In its conceptual, material, and technical originality, collage has profoundly influenced numerous artists and architects throughout the twentieth century and into the twenty-first. This paper will focus on the transformation of collage as an analytical and generative tool over the past century through the work of Bernhard Hoesli, Richard Meier, and FELD studio.

KEYWORDS: art, collage, Modernism, materiality, representation

1.0 INTRODUCTION

One century ago, collage entered the lexicon of the contemporary art world. Pablo Picasso, in May of 1912, first appropriated a found material into a work of art in his *Still-life with Chair Caning*. The founders of Cubism - Pablo Picasso, Georges Braque, and Juan Gris - valued collage as a hybridization of painting and sculpture existing at the threshold of two and three dimensions. As a means of investigating the potentialities of three-dimensional space in a two-dimensional medium, collage facilitated a new conception of space. These first acts of collage-making in the Modernist canon, in their conceptual, material, and technical originality, have profoundly influenced numerous artists and architects throughout the twentieth century and into the twenty-first.

Collage, as an art form unique to the modern era, emphasizes process over product. A collage as a work of art consists of the assembly of various fragments of materials, combined in such a way that the composition has a new meaning, not inherent in any of the individual fragments. According to Diane Waldman in *Collage, Assemblage, and the Found Object*, a collage has several levels of meaning: "the original identity of the fragment or object and all of the history it brings with it; the new meaning it gains in association with other objects or elements; and the meaning it acquires as the result of its metamorphosis into a new entity." (Waldman 1992, 11) Simultaneity of spatial, material, and intellectual content is inherent in collage through a synthesis of unrelated fragments, as the process of construction remains evident in the resulting work. Like a collage, revealing evidence of time and its methods of construction, a work of architecture contains accumulated history as it is lived and engaged rather than observed. Just as a work of architecture is only fully created and comprehended through bodily, sensory engagement, collage can serve as a representational analogue, providing the medium to interrogate spatial and material possibilities. Collage can be practiced not only to capture spatial and material characteristics of the built environment, as an analytical and interpretive mechanism. Through this understanding, we can build with a conscious and intentional response to the multivalence extant in sites and cities.

Figure 1: Juan Gris, *The Bottle of Anis del Moro* (1914)

1.1 Collage genealogy

To provide a methodological framework for an understanding of collage, we begin a century ago with Cubism. For the first time in 450 years, the Renaissance approach to representation (privileging visual experience) was rejected. The Cubists instead represented aspects of daily life through abstraction, material juxtapositions, and fragmentation and synthesis of form, capturing spatial and material qualities of commonplace subjects. The genealogy of collage and the influences of Cubism on art and architecture are illustrated in the *Collage Genealogy*, demonstrating the conceptual or technical affiliations between various artists and architects throughout the past century.

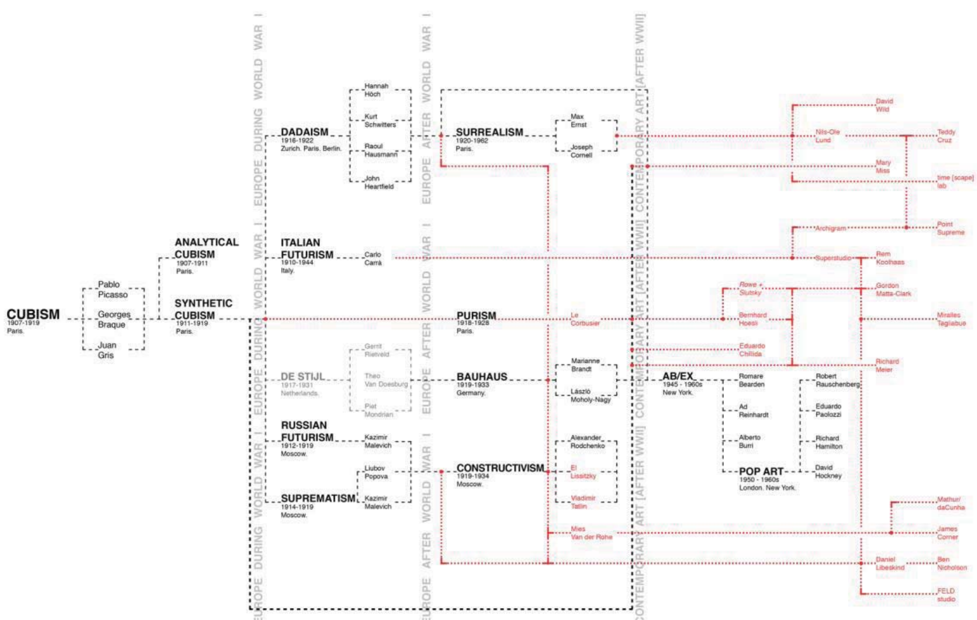

Figure 2: Jennifer A. E. Shields, *Collage Genealogy* (2012)

The legacy of Cubism as demonstrated in this genealogy has its foundation in Alfred H. Barr, Jr.'s chart for *Cubism and Abstract Art*, the Museum of Modern Art exhibition in 1936, in which he illustrated the movements that influenced Cubism and the movements that were subsequently informed by Cubism. The bold geometric forms of the Cubist collage were quickly adopted by artists outside France, while political unrest in Europe leading up to World War I saw the appropriation of collage for political and cultural purposes. The Italian and Russian Futurists were the first groups of artists to respond to the radical shift in representation initiated by the Cubists. Collage continued to be a dominant medium for artists in the Russian Avant Garde, Dadaism, and Surrealism, with the proliferation of photography in print media appropriated for use in photomontage. These methods are tied to the architectural practices of Mies van der Rohe, Archigram, and Miralles Tagliabue, among others. Though Le Corbusier and other early 20th century architects made use of collage in their design process to experiment with spatial and material juxtapositions, collage as a theoretical concept only became widely discussed after the publication of *Collage City* by Colin Rowe and Fred Koetter in 1987. In this publication, the authors were interested in collage for its metaphorical value, serving as a means of understanding the potentialities in the rich layering and complexity of the built environment. Architects continue exploited collage for both its conceptual possibilities as well as its material, formal, and representational potential.

1.2 Cubist legacy

To articulate the architectural relevance and legacy of Cubist collage in contemporary design, we must consider the Cubist collage as illustrative of both the labor of making and the process of fragmentation, aggregation, and synthesis. The Cubist collagists achieved a deconstruction of form through an additive process. The innovative materials and techniques of the Cubists are demonstrated in their pasted paper works called *papiers-collés* in which fragments of paper are used for their form, color, pattern, and/or meaning in conjunction with other media such as oils or charcoals. According to Robin Dripps, in Cubist collages, "Figures of all kinds were carefully taken apart just to the point at which the resulting fragments were the most open to external relationships but not so far that reference to the original whole was lost." (Dripps 2005, 79)

While the Cubists inserted conditions of order into their collaged analyses as a means of organizing, fragmenting, and layering figures and fields, these foreign conditions were manipulated by the physical characteristics subject to the analysis, much like the architects who have employed collage in their design work. The value of the relational qualities over those of individual objects was recognized and tested by the Cubists in their collage-making and shortly thereafter by Le Corbusier. His artistic and architectural work, like that of the Cubists, experimented with themes of phenomenal transparency, ambiguity of figure and field, distillation, and synthesis which subsequently impacted the collage-making, design, and pedagogy of Bernhard Hoesli and others.

A protégé of Corb, Bernhard Hoesli further abstracted and geometricized his collage compositions and contributed to the articulation of phenomenal transparency as a condition of overlap in his work with Colin Rowe and Robert Slutsky at the University of Texas at Austin in the 1950s. The Cubist abstraction of space is also powerfully evident in the collages and built work of Richard Meier. Translating and transforming these concepts into the digital realm is Berlin-based FELD studio. These designers acknowledge an underlying order that is manipulated or disrupted by conditions of site, program, or perceptual intent – often outside the architect's control - creating an ambiguity between figure and field.

2.0 BERNHARD HOESLI

> So a collage is not only meant as an object, something made, a result, but what is perhaps far more interesting: a process. Moreover, that behind this way of doing something which as a result then leads to a collage, the collage could be meant as an attitude of mind… (Pint 2001, 1)
>
> - B.H. Lecture, May 2, 1983, Bern

Bernhard Hoesli was a Swiss architect and educator best known for his pedagogical innovations at the University of Texas in Austin in the 1950s. His experiences leading up to this dynamic period in architectural education profoundly influenced his pedagogical intent. After receiving his degree in architecture from ETH Zurich in 1944, Bernhard Hoesli first studied painting in Fernand Léger's studio in Paris. Hoesli was soon accepted as an assistant at Le Corbusier's studio, eventually supervising the design and construction of Casa Curutchet in La Plata, Argentina, and Unité d'Habitation in Marseilles. In 1951, Hoesli moved to the United States where he joined faculty of the University of Texas in Austin. He and colleagues Colin Rowe, Robert Slutzky, and John Hejduk (among others) came to be known as the Texas Rangers. Hoesli aided in the development of Rowe and Slutzky's concept of phenomenal transparency in the essay *Transparency*

[1955]. This concept was incorporated into the architectural curriculum at UT Austin, where students completed exercises in which Cubist paintings were diagrammed in order to apply underlying formal properties to design problems. Rowe's equally influential book *Collage City* (with Fred Koetter) built upon this theoretical framework, proposing collage as a metaphor to critique a unified vision for city planning and instead advocating a multivalent approach.

According to Alexander Caragonne, a student of Hoesli: "…Hoesli's interest in the relationship between analytical cubism and modern architecture led him to propose that space – architectural space – was the basic, irreducible phenomenon that united the apparently disparate work of Wright, Mies, and Le Corbusier." (Caragonne 1995, 320) For Hoesli, transparency was a requisite characteristic of modern architecture – the ambiguity of figure and field initiated by the Cubists and further interrogated by subsequent art movements served, not as a means of fracturing, but a means of synthesizing. (Jarzombek 2001, 5) Hoesli was invested in the concept of phenomenal transparency and its place as a defining characteristic of modern architecture and wrote a substantial commentary in the 1964 edition of Rowe and Slutzky's *Transparency*. (Hoesli translated *Transparency* into German for publication in the 1960s.) In his commentary, Hoesli points out that the value in abstract painting and sculpture as scaleless (or 1:1 scale) objects is that it serves as an immediately tangible way to investigate architectural space. (Hoesli 1964) Hoesli saw phenomenal transparency as a tool for formal and spatial ordering and the graphic representation of this ordering – evident in his untitled collage from 1966. This collage reveals a constantly shifting figure and field in the black rectangles delimiting the circular central figure. Hoesli understood form as "an instrument for design," (Hoesli 1964, 87) rather than an end in and of itself or the mere outcome of a design process – as such, phenomenal transparency became the operative mechanism for this method. Collage became the medium by which to interrogate form as process. For Hoesli, collage served as a means by which to test these themes, informing both his professional practice and his pedagogical approach.

Figure 3: Bernhard Hoesli, *XXVI: Untitled* (1966)

The interest in process over product is evident from Hoesli's earliest collage-making in the 1960s, in which he utilized found materials with a focus on their haptic qualities. Precisely cut orthogonal fragments are often juxtaposed against torn, irregular fragments. As we will see, the collages of Richard Meier follow similar methods and result in a similar aesthetic. The use of highly tactile, weathered materials speaks to Hoesli's interest in the role of time and chance in the design process. (Pint 2001) A number of his collages reveal time in their creation – constructed and reworked over a period of years.

Hoesli's early collages, while abstract, begin to suggest landscapes imbedded with architectural form, implying a sense of scale. John Shaw, a member of the Texas Rangers, observed: "Many [compositions] read as perspectival landscapes with insistent horizons, yet a tendency to flatten challenges the perception of deep space.” (Shaw 2001, 14) In these compositions suggestive of site, there is an ambiguity and multivalence in the reading of both compressed frontality and three-dimensional space. The collapse of space within the compositions suggests a response to the spatial investigations of Cubist collages and the paintings, collages, and architecture of Le Corbusier.

Figure 4: Bernhard Hoesli, *Santa Eulalia, Ibiza* (1963)

Hoesli pursued investigations of spatial overlap and phenomenal transparency throughout his career, focusing on its relevance to design method. He articulated his interest in the dialogue between figure and ground, stating, “Solid and void are similarly constituted in the overall spatial continuum. Space within a building and space between buildings are parts of the same medium, the same totality. This dualistic spatial concept of a *figure-ground continuum* [emphasis added] in which building and space are complementary manifestations of an entirety, is – as practically every planned or built example shows – the modern space concept.” (Caragonne 1995, 383) On a conceptual level, the architectural implications of Hoesli’s collages speak to the ‘givens’ of geometries and materials juxtaposed against the idiosyncrasies of program and site, a theme we’ll see develop in the work of Richard Meier and FELD studio.

2.1 Richard Meier

> Architecture is a long process. The beginning through drawings, through construction, through when it is actually occupied and used. A project takes anywhere from three years to twelve years. Whereas this - [collage-making] - is immediate gratification. For the most part, but not totally, if I do this, I put it down and it’s done. But occasionally I’ll go back over it, change it and revisit it. And that’s a good reason not to frame something. It is more about the moment than about a span of time. (Meier 2012)
>
> - Richard Meier, in an interview with the author, March 2012

Richard Meier, Pritzker-prize winning architect, has been creating collages for over fifty years. An avid painter, Meier began making collages in 1959 after a transition to a small studio space precluded the continuation of his large-scale paintings. Collage became a method for pursuing his interest in two-dimensional compositions. His collage-making accelerated in the 1970s while he was working on the Getty Museum in Los Angeles. He spent significant amounts of time traveling, so he would bring a box of collage materials with him on cross-country flights and pass the time in collage-making. As a personal and meditative ritual, Meier constructed collages directly in books, never intending for them to be framed or even viewed by others. This daily practice is responsible for 160 books of collages and over 4000 loose collages. (Meier 2012) Having attended architecture school at Cornell in the early 1960s, Meier was clearly influenced by Colin Rowe and Robert Slutzky and their articulation of phenomenal transparency as a conceptual link between modern art and architecture. In his collage work, Meier acknowledges a debt to Cubists Picasso and Braque and Dadaists Kurt Schwitters and Hannah Höch. Methodologically, Meier draws from Schwitters’ appropriation of refuse from daily life, such as bus tickets and food packaging, for use in abstract compositions. Subtler links include De Stijl, Russian Constructivism, and the Bauhaus.

The material fragments used by Meier have been collected throughout his travels and include postcards, ticket stubs, photographs, and advertisements archived for future use. While incorporating fragments from his travels and experiences, the collages are not meant to document them. Meier attempts to select and compose the paper fragments in such a way as to shed their significance. The temporal displacement occurring as a result of archiving encourages the dissolution of meaning. Fragments may be archived for decades: when they are revisited and considered for use in a collage, their original geographic source and meaning has been lost to memory. Even the text in the paper fragments is divorced from its semantic value. Meier prefers text in other languages and alphabets (like Cyrillic) for this reason. In some cases, the text becomes a ground that Meier builds off of, establishing a grain for the composition. In other cases the text fragments become figural. Meier ultimately selects fragments based on color, texture, and form over meaning, valuing composition over connotation. Like Bernhard Hoesli, Meier's collages are often intuitive and gestural, rather than premeditated.

Meier's collage-making process is typically founded in the establishment of a few simple parameters. A common parameter in Meier's collages is the module of the substrate. When working on loose sheets, the collages are typically 10x10 inch or 16x16 inch squares. The replicated format, a small square defined and inset within the larger physical boundaries of the paper, was a boundary rarely permeated. A number of Meier's collages recall the dynamic diagonal compositions of the Russian Constructivists, but few (like *annano agent* from 1987) selectively puncture the frame.

Figure 5: Richard Meier, *annano agent* (1987)

In contrast with the white architecture for which Meier is famous, his collages are replete with vibrant colors. According to Lois Nesbitt in the foreword to *Richard Meier Collages*, "A student of postwar Abstract Expressionism,…Meier also deletes any explicit thematic strands from the collages, favouring instead juxtapositions of pure colour." (Nesbitt 1990, 13) Meier confirms this distinction, pointing out that the variable environment in which architecture is embedded offers color to the composition, as the white panels take on contextual hues. The static nature of collage with regard to its engagement with nature requires that the collage itself embody color.

Although Meier views his practices of collage-making and architecture as distinct, his formal strategies for composition permeate his works in both collage and architecture. Strong genealogical ties exist between Meier and Le Corbusier and Hoesli in their strategies for spatial and material configuration. The juxtaposition of a precise, rectilinear field against fluid figures is common to the compositions of both architects. In an interview with Lois Nesbitt, Meier said, "Always, within the collages, there is fragmentation and there is organisation. For the most part there is a rectilinear organization, which is then related perhaps to curvilinear elements, and there's a sense of structure. The structure in the collages is generally based on the material at hand, so although the structure of the buildings is based on perhaps a more clearly defined grid…within that there can be fragmentation and a shifting of grids, there are certain formal similarities." (Nesbitt 1990, 13) Meier's Smith House, constructed in 1965-67 on a bucolic site overlooking the Long Island Sound demonstrates clear formal similarities to his collage compositions. Looking specifically at *O4A* from 1987, we see a pure geometric figure suspended in the infinite depth of the canvas, disrupted by irregular fragments that begin to blur the boundaries of the figure.

Figure 6: Richard Meier, *O4A* (1987)

Compared to the augmented distinction between the work of architecture and the landscape in the Smith House, we read an artificial construct – a pure geometric figure - implanted into the existing natural context. Meier articulates a need for the artificiality of architecture to be evident, in order for the architecture to be authentic. It seems that working with the logic of a module like the square reinforces the idea of the artificial: rather than ignoring the richness of the natural context, the pure white geometries are acting in deference to it. Meier describes his approach in an essay for *Perspecta*, saying: “In my work, I have come to rely more and more on the juxtaposition of that which one makes against that which one does not. This has to do with the play of architecture's inherent artificiality against an unpredictable and dynamic context. I believe that this dynamic quality of natural and urban phenomena is very much a part of man's experience of architecture.” (Meier 1988, 104)

Meier explained to Nesbitt: “I've always tried - maybe it's a kind of baroque aspect of my nature – to create an order and then to give a counterpoint to the rectilinear order that is established. That's really what the curvilinear elements do. In a sense they're an expression of a hierarchy within the construct.” (Nesbitt 1990, 10) On one hand, Meier describes the disruption of order as a formal decision within the artifact of the collage or the object of the building. However, he also acknowledges that the site plays an important role in some of these manipulations of order. The Arp Museum in Rolandseck, Germany – exhibiting the work of Dada artist and collagist Jean Arp, completed in 2007 - demonstrates the significant influence that the geometry and other intangible factors of the site had on the resultant architecture. Rather than a self-contained object, Meier created a fragmented composition that interlocks the architectural elements with the escarpment overlooking the Rhine River. In response to this observation, Meier confirmed: “The site is very, very important. Both in terms of its physicality but also its history. So it’s not just the nature of the site as you find it, but what it is in terms of its relation to its context is very important. You are making your own context.” (Meier 2012) While there is a cohesiveness and a consistency to the body of work that Meier has created both in his collage and his architecture, his tactics for abstraction and composition have slowly evolved. The discreet practices of collage-making and architectural design have witnessed mutual transformation: it is apparent that Meier’s architectural design work stimulates his collage-making, while experiments in gestural collage-making inspire his architecture.

2.2 FELD studio of digital crafts

> FELD balances what computers and what people are good at: Leveraging the relentless, precise and high-speed computational processes or custom machines to unfold their works, but having the designers always at the helm result in thought provoking, aesthetic and elegant works. (FELD 2012)

Digital methods in collage exploit the capacity for digital media to both facilitate analogue techniques and devise new techniques for collage-making through direct and indirect manipulation. All tools for representation can be seen as extensions of the human body, guided by mental and physical processes. The interface, or shared boundary, between the body and the instrument is the first degree of separation between the artist and the work. While digital media can accelerate the direct manipulation and composition of images, as a correlate to analogue techniques, it more importantly offers the opportunity for indirect manipulation. Indirect manipulation refers to the use of commands, or a series of commands (a script) to execute an action on an image, increasing the depth of interface between the artist and the work. FELD studio's interest in this interface seems to be a response to Marshall McLuhan's theory that we are returning to acoustic space, which is multi-sensory and experiential, in contrast with visual space which is mono-sensory and rational. Acoustic space, like collage, is founded in the relationships between elements and the perceiver rather than the autonomous identities of objects.

The FELD studio of digital crafts was established in 2007, self-described as "a group of Berlin based designers who share a common language of digital thinking in their work process." (FELD 2012) Their portfolio includes work diverse in media and scale, including collage, handheld interactive devices, and urban sculptures. The intellectual background driving the design work coming out of FELD studio is "post-digital" in nature. Their design installations incorporate digital fabrication and processing tools in a way that demands human interaction in order to be understood.

Much of their work considers human cognition with regard to memory and perception. The invention of custom machines and computational processes serves to reinterpret, enhance and/or encapsulate memory and human perception. These projects, in the interface between human and machine, foreground the properties of acoustic space through synaesthetic engagement. The digital methodology employed by FELD is very much a humanization and reengagement of multiple senses in the digital interface. FELD's *Extracts of Local Distance* draws on these themes for collage generation through digital means. *Extracts of Local Distance* employs a series of customized photo-analysis scripts to deconstruct photographs and then reassemble the fragments in service of creating new 'common perspective' photomontages. FELD collaborated with architectural photographer Klaus Frahm, whose large format analogue photographs became the source material for this project. They were driven by the potential "to use computational possibilities in order to achieve a much more complex result but still not lose the personality and artistic control of a conventional collage." (Gmeiner 2010, 2) The developed software is customized to work with architectural photography.

> Using a vast archive of fragments of scanned architectural photographs, new architectural images are created as multilayered collages of these fragments. The images, created as complex reconstructions of fragments of real images, introduce a third, abstract point of view to the original views of architect and photographer. (FELD 2012)
> - FELD studio

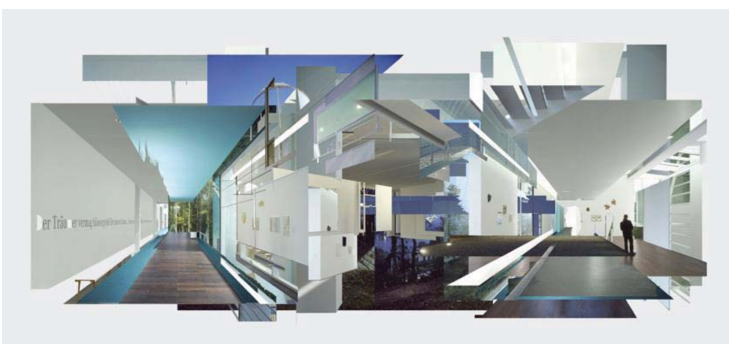

Figure 7: FELD studio, *Extracts of Local Distance: Arp Museum* (2010)

This abstract point of view dissects and reinterprets the relationship between figure and field, or architecture and its context, in projects such as Richard Meier's Arp Museum. This collage synthesizes two artificial one-point perspectives. In the academic paper that accompanied the presentation of *Extracts of Local Distance* at the University of the Arts Berlin, FELD describes their process. The generation of photomontages from the metadata involves two steps: first, the analysis and segmentation of the individual photographs, and second, the composition of new images from these segments. (Gmeiner 2010) The first step is the most labor-intensive. It entails conducting a vanishing point analysis of each photograph, defining the segmentation within each photograph, extracting image segments, and assigning the segments to corresponding vanishing points. In the second step, the composition of the new image is initiated by setting the new vanishing point for the collage image and constructing a coarse geometry for a perspective grid, to be associated with each applied image segment.

What makes *Extracts of Local Distance* of interest to our discussions regarding digital collage is the way in which they designed means to control the output of the generated collage, particularly in the composition of the image segments. The user can create the compositional framework that will guide the collage. In addition to setting the perspectival map, the algorithm can be adjusted by a series of input sliders that provide the user the ability to narrow the selection range in the collage making process. By allowing the user to control the number and type of source photographs, the composition of the perspective grid, as well as the composition of the white space upon the page, *Extracts of Local Distance* harnesses the computational processing power and precision of the computer to create highly synthesized perspectival photomontages.

In respect to the larger discourses relating to architectural thought, FELD studio points out that “many associations with the architectural movement of ‘Deconstructivism’ arose, due to the process of recombining architectural fragments.” (Gmeiner 2010, 5) FELD in fact deconstructs a Deconstructivist building, creating a photomontage out of image fragments of Daniel Libeskind’s Jewish Museum in Berlin. FELD anticipates additional uses for this procedure of image making, including animation, three-dimensional representations, large-scale projections, and the appropriation of image segments drawn from renderings and sketches, leading to “unpredictable visual mash-ups, going against the grain of the evermore photorealistic representation.” (Gmeiner 2010, 5) Their interactive projects prompt questions of the role of technology in indexing and foregrounding relevant data from our environment, while allowing the user or inhabitant a degree of control and manipulation.

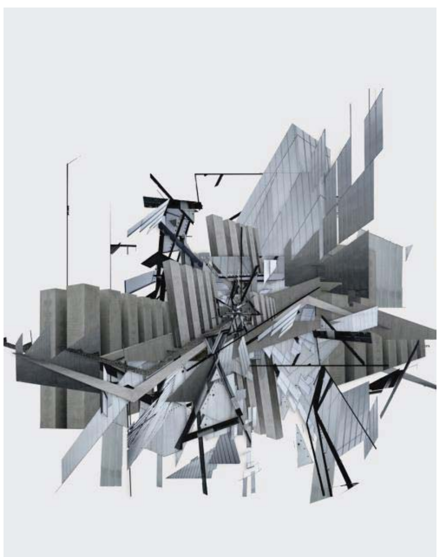

Figure 8: FELD Studio, *Extracts of Local Distance: Jewish Museum* (2010)

CONCLUSION

Envisioning potential architectural futures through collage offers opportunities for design that accounts for the variables over which the designer has control, while embracing the givens, the unknowns, and the elements in flux. Although this paper elaborates on only a small selection of the architects who have continued the legacy of the Cubists through their use of collage, the work of Hoesli, Meier and FELD studio embodies the balance and synthesis of the defined and the indeterminate.

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The A. D German Warehouse: Frank Lloyd Wright's Design Process

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ABSTRACT: This research discusses a long-overlooked building designed by Frank Lloyd Wright. The focus is on the project as a case study exemplifying Wright's design process. Although Wright's work is often described as appearing fully-conceived and then drawn in a single sitting onto the paper, the archival documents, correspondence and actual physical building of the A.D. German Warehouse tell a different story. The A.D. German Warehouse was designed ca. 1914 for Richland Center, Wisconsin, and was to be the only building Wright ever designed for the town of his birth. Built for businessman Albert Dell German of Richland Center, the warehouse is also Wright's only warehouse among his many projects.

The research presented involved the study of archival documents, the building, interviews with local residents, and a review of writings about the warehouse. Analyses of the drawings produced throughout the project were used to construct a view into Wright's interior design process.

When the warehouse was originally designed and constructed, Wright was also working on Taliesin (located approximately twenty-five miles from the warehouse project), Midway Gardens and the Imperial Hotel. The second design iteration occurred during the second phase of Wright's career when he was working on projects such as Fallingwater. The Warehouse project provides a snap shot of Wright's design approach during these two periods.

Wright's drawings for the Warehouse rehabilitation, located in the archives at Taliesin West in Arizona, have never been previously published. The complete holdings consist of approximately 90 drawings and sketches for the project including floor plans, sections, elevations and furniture design sketches. The significance of the A.D. German Warehouse to Wright is demonstrated by his decision to publish it in Wijdeveld's 1925 Wendingen collection of his projects which also included Midway Gardens, the Imperial Hotel and the Larkin Building. (Wright, 1965 reprint edition). This paper argues that the A.D. German Warehouse provides a view into the complex design process by Wright.

KEYWORDS: architecture, history, design process, Wright

INTRODUCTION

This research discusses a long-overlooked building designed by Frank Lloyd Wright. The focus is on the project as a case study exemplifying Wright's design process. The A.D. German Warehouse, located in Richland Center Wisconsin, is the only building designed by Wright in the town of his birth. Wright worked on the design of the warehouse while living at Taliesin in Spring Green—located within twenty-five miles of Richland Center--Wisconsin. Designed for businessman Albert Dell German of Richland Center, the warehouse is also Wright's only warehouse among his many projects. According to amateur local historian, Margaret Scott, Wright first met German while gathering supplies for the workmen and construction materials for Taliesin.[1] Local lore contends that Wright and German bartered Wright's need for supplies for the design services on the warehouse.[2] Although Wright claims the A.D. German Warehouse was first designed in 1912, [3] local papers mention its actual construction between 1917 through 1920.[4] Copies of the drawings located in the archives at Taliesin West do not contain a date.[5] This has led historians to surmise that the original drawings for the warehouse burned in the fire at Taliesin.

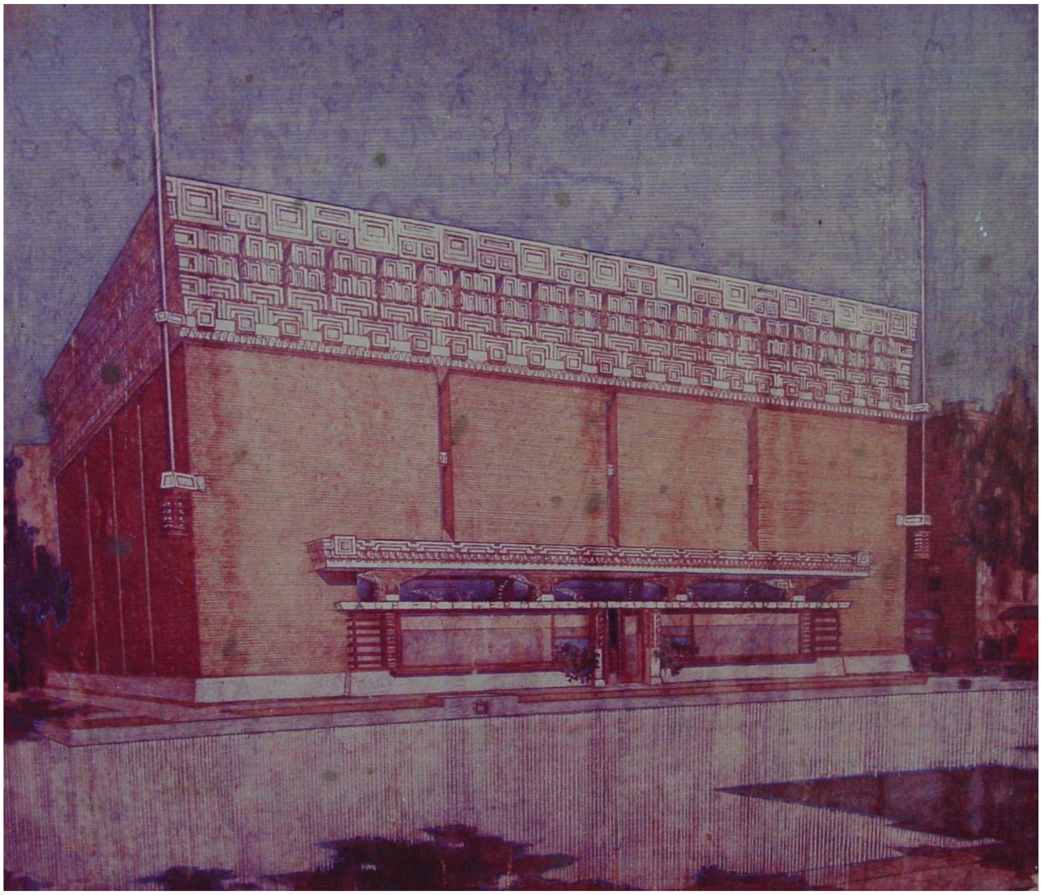
Figure 1: Original Watercolor rendering in possession of Harvey Glanzer. Source: (Author 2008)

This paper argues that the A.D. German Warehouse provides a case study demonstrating the complex design process of Frank Lloyd Wright. It is also important for several other reasons--It is the first building by Wright that was actually built reflecting the influence of Mayan architecture; Wright's invention of the Barton Spider web structural system was unique to this building; and that the building is located in Richland Center Wisconsin and is the only Wright-designed building in the town of his birth. The building's primary contribution to history is as a window into the design process of a master as revealed through the changing design of the building. The proximity to Taliesin increased the likelihood that Wright would visit the Warehouse throughout his lifetime. In addition, Wright had a long-lasting relationship with German and created designs for him over a period of 20+ years (1912-1934 spanning two well-known periods of practice--the Prairie House and Usonian House eras.

1.0 History of the Warehouse Ownership

By 1916, the warehouse project was under construction as announced in the local paper that also includes Wright's cost estimate of $30,000. According to the article, the building was a multipurpose warehouse including storage of wholesale goods, a small teahouse restaurant, retail space, gallery exhibition space for local artists and Wright's work, and a wholesale outlet store.[6] By 1919, with the actual construction price of the warehouse, $125,000, far exceeding Wright's original estimate, construction ceased. The first-floor windows and doors were boarded up. At the same time, the advent of World War I led to rationing of sugar, coal and other of German's commodities. This combination of unfortunate financial factors forced German into bankruptcy thus losing the building to a local competitor, H. H. Krousap. By 1935, German purchased the building back under his newly formed "Richland Warehouse Company, Ltd." and hired Wright once again—to finish the plans for the building. Unfortunately, a second round of bankruptcy proceedings against German were initiated again in 1936 and William Graff assumed ownership of the warehouse in 1937.[7]

The warehouse sat largely unused—except for miscellaneous storage--during the period between 1937 and 1960. Some local residents proposed demolition of the building while others considered it as a location for the local library. In 1970, Barbara and Robert Bust purchased the warehouse with the intention of revitalizing it. The Busts worked to have the Warehouse listed on the National Register of Historic Places (1974). Although the Busts raised funds for the building revitalization, work was never completed. In 1980, Harvey Glanzer and Beth Caulkins, the current owners of the warehouse, purchased the building. They hired Wright's longtime apprentice, John H. Howe to design renovations for the building that were successfully completed in the 1980s. A small theater and gift shop were added to the first floor. In the tradition of the Busts, Glanzer and Caulkins continued to conduct tours of the building for interested tourists.

1.1. The ca. 1912-1915 Design for the Warehouse

Although no precise date for the production of the first iteration of warehouse drawings has been established, a comparison of an earlier rendering to later drawings and the final building hint at the mid-1910s as a likely date for the start of the design. According to Wright's own listing of his work in *An Organic Architecture: The Architecture of Democracy* (1939), Wright includes the A.D. German Warehouse among his buildings between 1887 and 1939 entered in both 1912 and 1915.[8] An early rendering supports this view as the front of the Warehouse faces Haseltine Street. In the later drawings and in the final building Wright rotated the design ninety degrees to face Church Street, likely responding to the construction of a house in 1915 effectively blocking access to a train spur.

1.2. Architectural Description and Influences

The four-story warehouse building has a brick exterior on the first three floors and a poured in place concrete cornice on the fourth floor level. Although Wright used Mayan motifs in earlier buildings such as the Kehl Dance Academy (1912), the German Warehouse presented the first instance of actual built forms following the architecture of indigenous American people.

Scholarly discussions of the building indicate that Wright's inspiration for the Warehouse included many influences: Mayan prototypes, Japanese decorative motifs, and contemporary designers in Europe experimenting with similar motifs and influences. Tselos (1954) and Scully (1960) separately attributed the design of the cornice to Mayan influence, noting that Wright had seen photos and full plaster casts of Yucatan ruins at Chichen Itza at the World's Columbian Exposition at the Chicago World's Fair in 1893. Tselos (1969) later revisited his research of pre-Columbia architecture, indicating that Wright himself had written to the *Magazine of Art* to declare "his admiration of pre-Columbian architecture and the involvement of all living architecture, including his own, with the growth of man, society at large, and democracy, within whose fabric such involvements are best realized."[9]

By contrast, Hitchcock (1973) groups the A.D. German Warehouse with Wright's Japanese years works such as the Bogk House (Milwaukee, 1916), Midway Gardens (1913) and the Imperial Hotel (1916).[10] Alofsin (1993) provides perhaps the most thorough discussion of influences for the A.D. German Warehouse. Alofsin describes the origins of the square within a square motif of the cornice, attributing a connection of Mayan architecture to contemporary European design practice as found in Owen Jones' *Grammar of Ornament.* Alfosin points out that Wright's design differs from Mayan inspiration in the treatment of the outwardly canting cornice, noting a connection to J.L.M. Lauwerik's design system for a wall cabinet and works by Joseph Maria Olbrick.[11]

Regardless of the sources and influences that may have impacted Wright's design, the Warehouse represents a clear departure from Wright's earlier prairie work and links to other post-prairie commissions in organization and structural innovation. The building does not connect with the landscape, but rather, turns inward. Wright omits his customary views and outdoor connection in favor of a tomb-like experience recognizing that a cold storage warehouse would not require fenestration. The proposed use as a gallery also calls for lots of uninterrupted wall space. Wright located the functions that would benefit from the use of natural light—the retail space and teahouse—on the first floor, where a storefront was used at the entry. In the original drawings, the entry showed planters and a deep overhang that somewhat obscured the entry—Wright's only concession to nature.

It should be noted that many of Wright's public buildings are also inward focused. The Larkin Building directs all attention towards a central atrium. Unity Temple has small clerestory windows in the otherwise monolithic façade. In this way, Wright's use of this approach at the warehouse is not unusual.

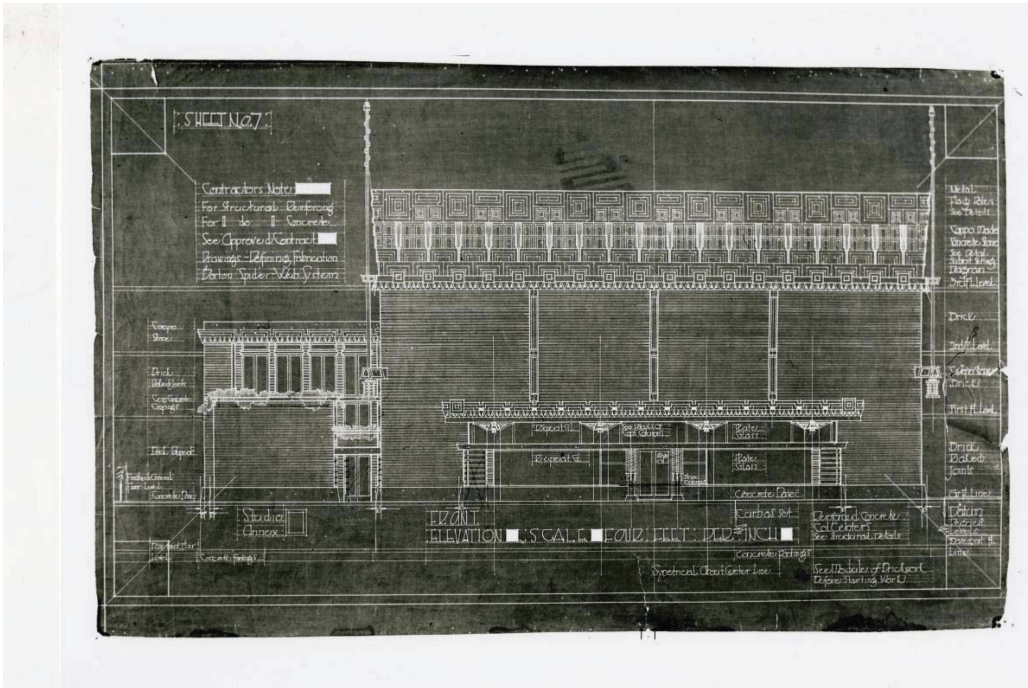

Figure 2: Blue Prints in possession of Harvey Glanzer. Source: (Author 2008)

1.3. The Structural System

As with a number of other commissions, Wright invented a structural system for the A.D. German Warehouse. Designed to carry the extra weight of bags of grain, sugar and other goods, Wright used a series of steel reinforcing rods (rebar) that were intertwined from the columns through their canted capitals and into the reinforced concrete floor system, not dissimilar from the system he used later in the Johnson Wax Building (1936-1939). Authors of the *Concrete Engineers' Handbook* describe the Barton Spider Web System as follows: "The Barton Spider Web system is similar to other flat-slab systems as to the arrangement of columns, column heads, and drop panels, but differs radically in the type of reinforcement used. As regards the slab, it is a four-way system and over the head of the column, it is a two-way system."[12] The innovative use of steel reinforcement for this structural system has earned Wright a place in engineering history.

1.4. The 1934 Rehabilitation Scheme

Despite the many contributions of the warehouse to Wright's oeuvre, drawings for the A.D. German Warehouse rehabilitation have never been published in their entirety and can only be found in the archives located at Taliesin West in Arizona. The complete holdings consist of ninety drawings and sketches for the project including floor plans, sections, elevations and furniture design sketches. Wright published a few of the early drawings of the warehouse in Wijdeveld's 1925 Wendingen collection of his projects that also included Midway Gardens, the Imperial Hotel and the Larkin Building. (Wright, 1965 reprint edition)[13].

Only a limited number of extant drawings remain of the 1915 initial scheme. These include floor plans and exterior elevations. In addition, two color renderings of the initial proposal are in the possession of the archives at Taliesin West and with the owner of the warehouse. Whether burned in the fire at Taliesin or never completed, the only drawings showing Wright's interior designs for the Warehouse are in the 1934 rehabilitation scheme drawings and sketches.

Wright's return to the work on this building after twenty years suggests an affinity with the project and client. German and Wright were both of Welsh descent, near to each other in age and both grew up in Richland County Wisconsin. Like Wright, German was one of several siblings (the youngest of seven). Since part of German's original program was to include an exhibit space for Wright's work and because German chose to barter with Wright when others in Richland Center would not, it appears the two men had a mutually respectful relationship over several years.[14] Aside from his own residences at Taliesin and Taliesin West, the warehouse is also one of the few projects to which Wright returned during his long career.

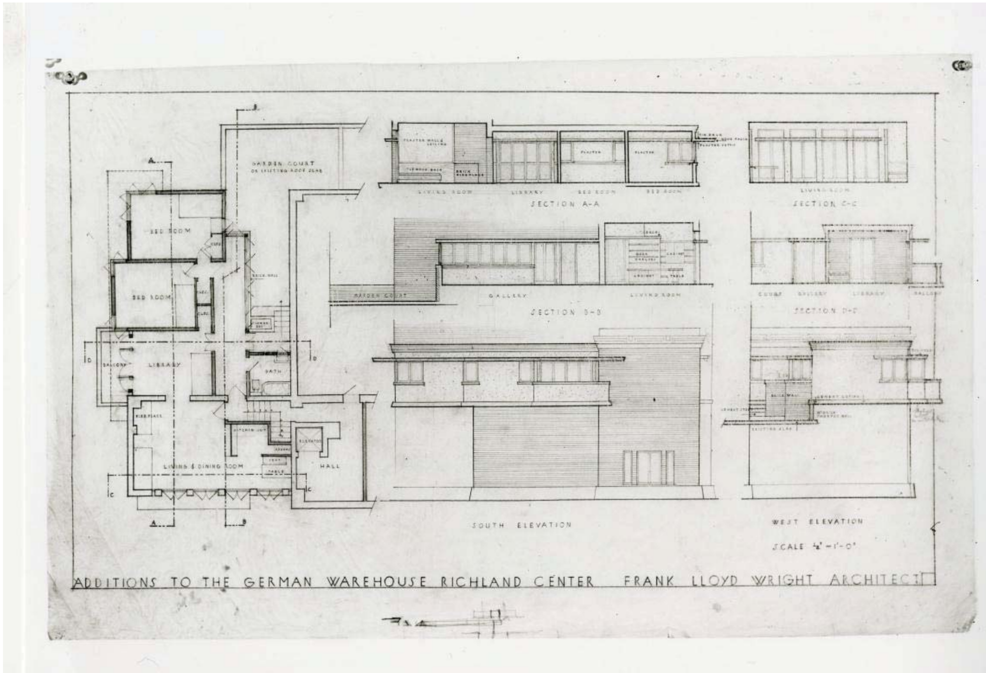

Figure 3: Sketch for German Apartment Source: (Taliesin Archives—will need to obtain written permission prior to publication)

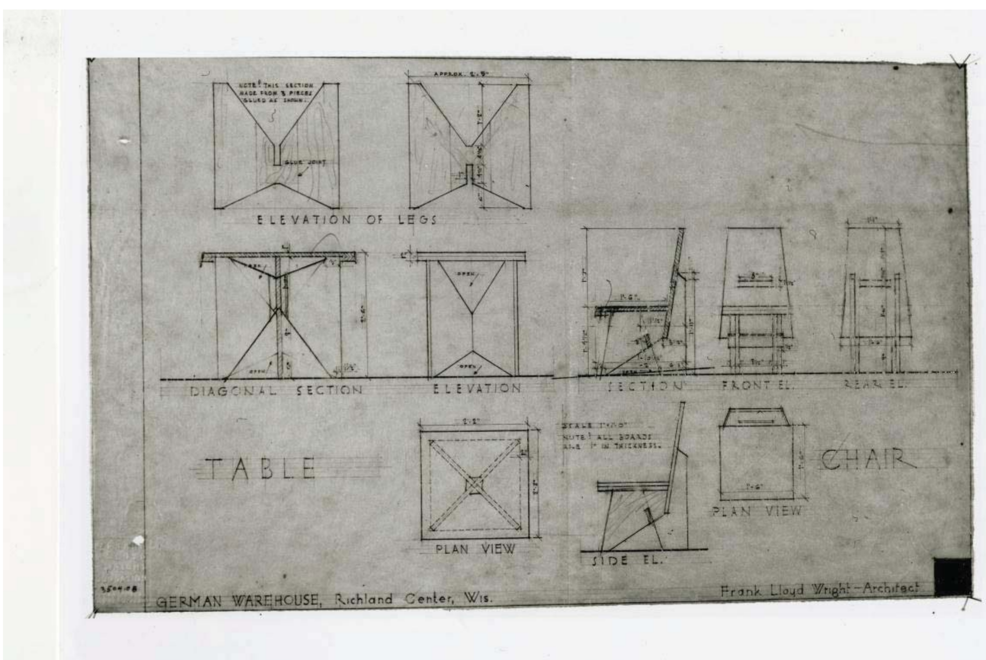

Figure 4: Sketch for Proposed Restaurant Furniture Design Source: (Taliesin Archives—will need to obtain written permission prior to publication)

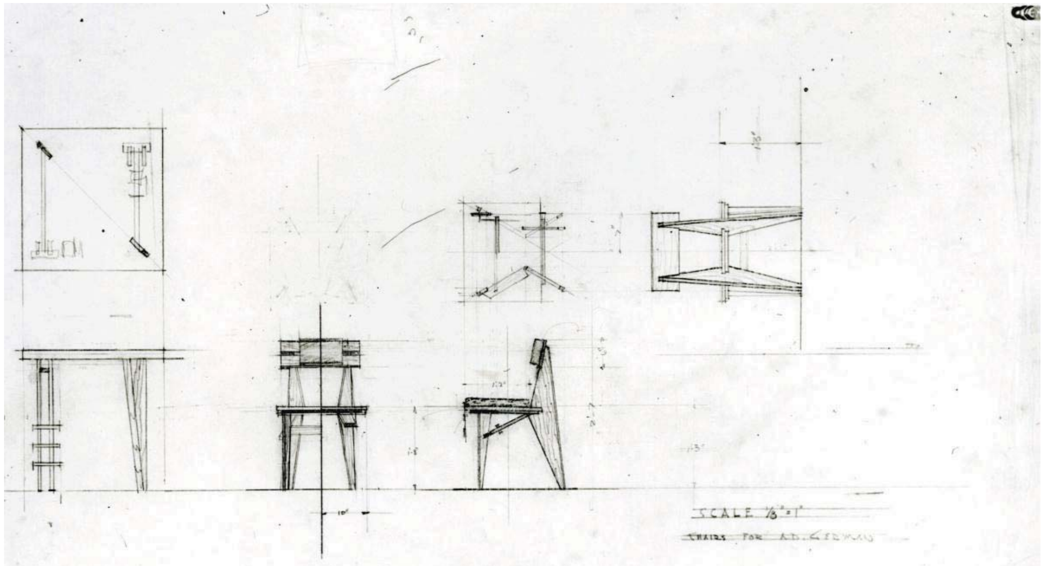

Figure 5: Sketch for Proposed Restaurant Furniture Design Source: (Taliesin Archives—will need to obtain written permission prior to publication)

1.5. Frank Lloyd Wright and Process

One of the most revealing aspects of the A.D. German Warehouse building and project is that there was a process to Wright's interior design work that is rarely written about. In this single project, we see no fewer than four phases of revision including sketch plans, elevations and furniture designs. The first rendering as compared to the first final set of drawings, shows that the orientation of the building's main façade changed and that an apartment was added for Anna German. For a second intervention, Wright created a series of floor plans for the ca. 1915 design. Then in 1934, several new variations were presented—although none were built.

According to authors Tice and Laseau (1992), "Within the extraordinary volume of literature on Wright is an amazing poverty of discourse on his design processes. Even colleagues who worked by his side for thirty years appear incapable of or reluctant to discuss his methods."[15] They go on to outline their proposal of Wright's methods. "Wright's achievements in design owe much to his mastery of a design process strongly driven by geometric order. His design approach proceeds from form as well as principle. He gave his design principles a formal expression through the use of the grids that integrated compositional structure and thematic unity."[16] They further claim that Wright's process is a "critique of the limits of pure inductive reasoning" and "an affirmation of the value of deductive reasoning."[17]

What Laseau and Tice do not include in their description of Wright's process is the notion of multiple iterations in response to the site and a client—both which appear in the A.D. German scheme and its multiple revisions. For example, the A.D. German Warehouse reveals an interesting difference between Wright's approaches to the design of the interior versus that of the exterior. The exterior form, mass, and details are basically the same from the first conceptual rendering through the final construction documents and through the 1934 ideations. Even when the orientation of the building shifts 90 degrees on the site to respond to site changes, the exterior design does not vary. Wright's approach to the interior, on the other hand, depicts a much more iterative and exploratory process involving test fits responding to programmatic variations and embodies the notion of designing spatially in plan, elevation and detail simultaneously.

1.6. Iterations

The design process drawings can be divided into three types: Floor Plans, Elevations, and Details including Furniture and into two periods of design (1914-17 and 1934). The floor plans included revisions for the first floor, the fourth floor and the adjoining apartment. Corresponding elevations, sections and details were also produced. The drawings included three different versions of tables and chairs for the restaurant as well as several drawings for built in shelving, tables and other furniture for the restaurant and upper floor apartments as well as door openings for the stair landings.

Wright produced several versions of floor plans for the first level of the main warehouse building. The first of these plans shows a side entry into a restaurant on the left and a store on the right. Booths are located on the lower level with steps up to an area containing freestanding tables and chairs. The drawing is quite sketchy in nature although the walls are drafted in this development of the scheme. A drafted version of this same plan provides additional detail and all furniture is drafted. Another version illustrates a larger store and storage area on the right. A complete departure from this is shown in the next version of the floor plan that places an office at the front of the first floor entered through a centrally placed door. The rear of the first floor is not show. A small office for AD German is located to the left of the main entrance. A variation on the restaurant theme illustrates a much smaller restaurant, maintains the office for German and adds a large storage area at the rear of the first floor. The bathrooms are relocated as is the kitchen and bar. Two additional sketchy plans are provided in this grouping showing different table configurations. Only one blue print resulted from this series—that of the larger restaurant with small store. The multiple floor plans clearly show Wright working through the space allocations for the first floor and exploring a variety of configurations, options and finally arriving at an agreed upon solution.

A similar series of explorations exists for the annexed apartment. Like the first floor iterations, some of these are drafted and others are much sketchier exploring room variations, bathroom locations and even the addition of a bay window in one. Like the restaurant series, things are crossed out, drawn over and finally result in a single drawing. Again, the series of six different schemes illustrates an interactive and iterative design process.

A series of floor plans were also produced for the fourth floor apartments. The first version shows eight apartments. Although they vary in size, all include an efficiency-style apartment with a bed area, a kitchen area and a bathroom. Following the methodology of the first floor plans, a more complete drafted version follows the first plan. The next drawing shows a single unit at an enlarged scale for the kitchen and bath area showing specific fixture locations and an additional level of detail. Elevation drawings and partial sections accompany the enlarged plan. Another iteration also includes eight units, but each unit has been altered. The drawing itself is partially drafted and partially sketched in. This last set of alterations then became the basis for the blue print of the fourth floor.

A clear process is revealed in these floor plans. First a sketch plan is drawn. This is then developed into a more drafted and precise version followed by additional detail. Finally another round (or more) of revisions is explored in sketch form and then developed into a final drawing with a title block for distribution. The presumed reasons for the revisions are evident in the change in use with each version. In response to changes in Richland Center and in German's business—availability of product, changes to the location of the railroad spur which was to originally serve the building—required changes in Wright's design during the initial design time between 1914 and 1917 when construction commenced.

Although interior elevations were not produced to accompany every floor plan, they reveal the same sort of process. Nearly every floor plan has drafted elevation drawings below the floor plan on the same page. Often these also include materials notations such as "plaster" and "plywood counter." The corresponding elevations show furniture, ceiling heights, partial walls, the splayed topped columns and steps. Built-in planters are also illustrated. In the case of the apartment annex, most of the elevations are actually exterior views to show the multiple window locations for each version of the floor plan.

The only freestanding furniture variations designed by Wright were for the restaurant. These too illustrate his process. The first set of chairs and accompanying table include minimal dimensions and materials notes (1/2" plywood). The axonometric view of the proposed table is crossed out. A second iteration includes a completely different table and chair. Some freehand sketching is done over the drafted drawings. The third version of the tables and chairs is sketchy with only some drafting. Several connections details are added as well as some additional materials such as "white oak top (no finish)." As with all the other drawings produced, this version was then drafted more formally with drawings notations, dimensions, and a title block. The furniture drawings alone show Wright trying different options for single design.

The drawings for the A.D. German Warehouse show that Wright worked out his ideas on paper. Using a combination of sketching and drafting, he thought through the design problems with which he was grappling while responding to client needs and his own changes. Input, either from the client or another source, led to revisions and new ideas, until a final solution was drafted for dissemination.

1.7. Frank Lloyd Wright's Design Process

The A.D. German Warehouse, like much of Wright's work, emphasizes geometric forms and the adherence to a single conceptual approach throughout the project. As the most prominent feature of the exterior, the cornice consists of a series of squares, squares within squares and rectangles. A 16' x 16' column grid reinforces the geometry of the square. Even the floor of the restaurant was to be "cement floor lined in squares."[18] The tables were square as were the seats of the chairs. The geometry of the square impacts all aspects of the project, including the title block and page layout of the final drawings. This adherence to a single geometry is common in Wright's work.

Through the many variations and explorations, Wright adhered to his singular vision for the development of the interiors. The basic geometry of the rooms and furnishings as well as materials selections remained constant. The only interior materials mentioned by Wright throughout the project drawings were plywood, plaster, concrete/cement and brick. All counters, shelving and furniture were fabricated from oak plywood. Concrete formed all floors, ceilings and columns as well as the walls on the fourth floor. Wright indicated a painted finish to the fourth floor columns. Plaster clad the brick exterior walls exposed to the interior spaces. Any added interior walls also featured a plaster finish. All windows had wood frames and plate glass with the exception of the metal storefront on the first floor.

In keeping with his other work, Wright used shelving and a relatively low ceiling to emphasize the horizontality of the rooms. The shelving device as a horizontal constant is used in the restaurant and shop, in the apartment annex and the fourth floor apartments. In all instances, the horizontal shelves stop two-thirds of the way up the columns leaving the column capital splays a visible and prominent feature in the space. The use of built in furniture also echoes Wright's residential work. The apartment annex and fourth floor apartments all include built in shelves, tables, counters, closets, and desks.

CONCLUSIONS

The interior designs for the A.D. German Warehouse provide a rare look into a building by Wright which has never been completed and for which a series of proposals over twenty years were made. This insight into Wright's design process and thinking for the interior goes against traditional wisdom that Wright produced his designs in a single and final iteration—as is often told regarding how Wright designed Fallingwater and other projects. The building stands vacant (in Richland Center Wisconsin) as it has been for most of its life. For a brief period in the 1980s and 1990s, the building was open to tours at the convenience of the owners who also ran the first floor gift store. Over the years, the building has fallen into further disrepair and the tours have recently been discontinued.[19] Despite this, the A.D. German Warehouse is a significant building and has much to tell us about Wright, the designer and an aspect of his design process.

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[13] The Wendigen Publication originated in Holland. The preface was written by T. Wijdeveld, a Dutch Architect. Published in 1923, this was one of the first published volumes of Wright's work in Europe. Thirty one projects were included in the publication dating between 1902 and 1923. Henrikus Theodorus Wijdeveld was a Dutch architect and the founder of the *Wendigen* magazine. The 1925 Wendigen Series was originally published as seven issues of Wendigen focused on Wright's work and later one book (*Frank Lloyd Wright: The Life-Work of the American Architecture Frank Lloyd Wright*) in Holland.
[14] According to local residents, Frank Lloyd Wright incurred several debts in Richland Center that he never repaid. Thus local vendors would no longer allow him to buy things on credit.
[15] Laseau, Paul and Tice, James. *Frank Lloyd Wright: Between Principles and Form*. New York: Van Nostrand Reinhold, 1992, 180.
[16] Laseau, 180.
[17] Laseau, 180.
[18] Taliesin Drawing 3504.062, floor plan notation.
[19] In 2010, the building's longtime owner and advocate, Harvey Glanzer, died.

PEDAGOGY

New Visions in Architectural Education

Methods for Developing Flexible Technical Knowledge in Architectural Education

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ABSTRACT: Building technology is often the focus of required courses in architecture programs where there is an expectation that technical knowledge will help inform a student's design process. The authors' surveys of architecture faculty suggest programs desire students to integrate skills from technology courses into the studio setting, yet research reveals poor to mixed results. Research in other technical academic fields suggests traditional lecture course formats result in lower student retention of course content. Evidence shows content learned via lecture methods alone tends to be highly compartmentalized and inflexible, thus reducing the successful application of technical knowledge to other contexts, such as the technical courses and design studios found in architecture education.

This paper examines active learning methodologies used in other technical academic curricula and considers how they may be applied to technical curricula in architecture. The paper proposes student's difficulty in applying technical knowledge to design can be attributed to passive teaching methodologies used in lecture-based technology courses. To explore this proposition the authors reviewed pertinent literature from other disciplines and surveyed instructors experienced in employing laboratory type activities in their curriculum. The results of this research suggest hybridized problem-based learning (PBL) methodologies can be integrated into high content technical curricula to increase students' problem solving skills with the aim of developing long-term flexible knowledge.

The research also examines the architecture curriculum at the researchers' institution. There, building technology courses were traditionally passive and lecture-based but the curriculum is currently under revision. The research considers class size, student-faculty ratios, course content, accreditation requirements and assessment methods to propose incorporation of PBL-type activities into existing lecture-based courses. The paper concludes by proposing a methodology for pre- and post- class learning assessment to evaluate the success of curriculum changes.

KEYWORDS: problem-based learning, architectural education, building technology lectures, pedagogy, self-directed learning

1.0 INTRODUCTION

Many professional architecture programs organize their curriculum around a sequence of core design studios and lecture-based support courses focusing on specific architectural topics such as history, theory, digital modeling, building technology and structural performance. It is the goal of many architecture programs for students to integrate the knowledge from support courses into the design studios setting, becoming more sophisticated designers as they incorporate more content from their support courses into their design process (Banerjee, 1996).

While specific methodologies vary, academics generally agree (as found in the authors' instructors survey) that design studios, given their activity type, student generated research, individualized projects, and low student-faculty ratios, are active, student centered learning experiences. In contrast, the building technology courses being researched are often considered a passive learning methodology, employing a lecture-based format that is less interactive. The lecture format is often criticized for not requiring students to be actively engaged in their learning process. Often only a small portion of class time is available for interaction with students, clarification of questions, or advanced topical discussions. As a result, research suggests the percentage of information retained by students is low. Furthermore, the information retained is highly compartmentalized and not successfully transferable to new situations such as design studio (Michel 2009).

Despite concerns benefits to traditional lecture settings for building technology courses are significant. They provide a medium for the distribution of large amounts of content (typically required to fulfill professional accreditation requirements), over a short period of time. Faculty to student ratios can be larger in such a class setting. Survey results showed that assessment typically done through multiple-choice or fill-in-the-blank examinations are considered time efficient and easily documented for accrediting bodies.

In contrast to lecture-based learning, active learning methods attempt to create a more engaging learning environment that requires students to develop critical thinking and problem solving skills. Research suggests knowledge acquired via active learning methods is more transferrable, meaning that content is not only recalled but can be applied to new and varied contexts (Michel 2009).

These methods though often positively regarded in pedagogical research also come with challenges to consider. A reduction in the quantity of delivered content is one key problem associated with active learning methods, where activities and in-class problems consume more class time than versus the same content delivered in a lecture format. Building technology courses with accreditation criteria require a large and specific set of content to be completed in each course. Additionally instructors surveyed believe that assessing problem-based learning activities, such as providing critical feedback and evaluation of unique projects and presentations, requires more time than assessment of traditional quizzes and exams.

2.0 ACTIVE LEARNING METHODS FOR TECHNICAL CURRICULA

2.1 Technical lectures as passive learning/nontransferable knowledge

Building technology courses in a design curriculum are intended to help students gain a deeper understanding of performance parameters related to design so that they can develop technically-performative, informed design decisions. Traditionally, content delivery in such courses is lecture-based, employing an instructional paradigm where the faculty delivers new information while assuming little to no previous knowledge of the subject matter by the students (Barr 1995). A lecturer may provide fifty-minute presentations including visual slides along with key terminology on a specific topic. The accompanying assessment is often exam-based, requiring identification of slides or terminology covered in the lectures. This system allows for a large amount of curriculum content to be covered efficiently and focuses assessment methods on students' ability to recall lectured material (Schwartz 1998).

Research suggests that employing this type of lecture-based methodology results in inflexible knowledge that students struggle to transfer to different contexts. Students develop only a shallow understanding of the lectured material and often rely on rote memorization of new material. (Van Dijk 1999). New knowledge is not integrated with student's' existing knowledge base and becomes isolated, inflexible and not transferrable to other settings. (Schneps 1988). Furthermore, students are often unable to develop a personal context to the new information presented in lecture and may have competing existing experiences or information that reduces their ability to comprehend the new information. Research suggests the inflexibility of new knowledge is partially due to a lack of self-reflective critical thinking moments for students when integrating the new information. Assessment also tends to lack evaluation of reflection and analysis, which research shows is critical to the integration of long-term flexible knowledge (Schneps 1988 & Schwartz 1998).

2.2 Active learning methodologies

Pedagogical research in the sciences, medicine and engineering have fostered methodologies for increasing in-class active problem solving skills and self-directed learning to encourage students to have a stronger investment in their learning process with the aim of developing long term flexible knowledge (Hmelo-Silver 2004). Active learning techniques that involve developing problem-solving skills can provide students with greater context to assimilate new information through meaningful practical experience and increase long term learning outcomes (Hmelo-Silver 2004). As a facilitator, the faculty guides students through a process which includes problem identification, outlining of goals and strategies, problem solving, and concluding moments of reflection and self-evaluation in solving problems that require critical thinking skills (Hemlo-Silver 2004). The key in these student-centered paradigms is the focus on creating meaningful mental engagements during class for students to incorporate and appropriately utilize new information. This is an aspect that is critically absent in most technical lecture presentations which often quickly summarize and condense contextual information in order to cover more content and do not require students to synthesize the material or provide them reflective opportunities necessary for long-term learning.

2.3 Problem-based learning methods

Problem-based Learning (PBL) is one active learning methodology employed in many science and engineering curricula as a method of increasing critical thinking and problem solving skills in a similar manner as they would in practice (Ditzler 1995). In PBL, students identify their own pre-existing knowledge related to the subject matter, frame the problem, determine their gaps in knowledge, self-direct their learning to solve the problem, and reflectively evaluate their success (Schwartz 1998 & Hemlo-Silver 2004). Reflection on new knowledge and existing knowledge allows for correction or modification of pre-existing information and enhances student's ability to apply new knowledge in future scenarios. In course sequences such as those found in architectural building technology courses, this process of identification of gaps, seeking of new knowledge, and self-reflection, may greatly enhance the transfer of knowledge from course to course, course to design studio, and semester to semester.

2.4 Integrating PBL with high content technical material

An integrated PBL/Lecture-based course methodology, as proposed by Schwartz and Bransford, attempts to create an enhanced environment in traditional class lectures through student activities before and after class, seeking to optimize content delivery and transferrable knowledge. In this hybrid method, class assignments are structured to maximize analysis and reflection of information before and after class by taking portions of the lecture material and coupling them with student activities outside of the classroom.

These integrated assignments do not merely practice new knowledge but are designed to help students prepare for forthcoming knowledge, and analyze and reflect upon new material presented in class. Rather than a reading assignment that parallels class lecture, the reading is part of an analytical problem that requires the students to utilize existing knowledge, readings, and forthcoming lectures to solve the problem, thus integrating content from multiple sources. Students identify what information is needed to solve the problem, find partial content in reading material, then come to class prepared to learn additional content via lecture. After the lecture students return to the assigned problem equipped with knowledge from various sources to solve the problem (Schwarz 1998). This methodology attempts to create moments for critical thinking before, during and after class with a goal of students actively searching for the knowledge that they have identified as a gap in their existing knowledge base.

2.5 PBL outcomes / survey research

In 2012, the authors interviewed and surveyed multiple instructors experienced in implementing student-centered activities such as PBL and others to determine what benefits and difficulties they found in implementing these methods into a traditional lecture course curriculum.

Positively, instructors confirmed that these student-based activities facilitate a structured method for integration of new knowledge and self-reflection that has a lasting and meaningful effect on student learning. Concerns include the time required for these student-centered activities given the large amount of content in their technical courses. There is added concern when the course is a part of a multi-course sequence that teaches sequential content. While instructors value engaging student activities in class, they realize that these activities cannot cover as much content as a lecture in the same amount of time. Instructors stated that assessment of student learning can also be more difficult in PBL. Exams and quizzes used in traditional lecture courses are more readily standardized and assessed than laboratory activities involving in-class student engagement. Instructors further stated that moving towards PBL increased the course preparation time for activity-based sessions. Student to faculty ratio is of equally significant concern among those surveyed. In general faculty agreed that a ratio of 8:1 is ideal, 12:1 is acceptable, 15:1 is functional, and any higher ratio becomes very difficult to administer.

3.0 PROPOSED APPLICATION OF RESEARCH

3.1 Architectural building technology curriculum at Philadelphia University

In the fall of 2010, the authors and collaborating faculty in the architecture program at Philadelphia University began redesign of the five-course building technology sequence, updating the courses in response to emerging and shifting trends in sustainable technologies, digital media and building performance criteria. The Bachelor of Architecture program is a 5-year professionally-accredited (NAAB) undergraduate degree, with a total of approximately 350 students enrolled in the program. The academic timetable is two semesters of 15 weeks each, per year. Building Technology (BT) courses are taught sequentially each semester, beginning with BT1 in the fall semester of a student's second year. The BT course sequence, which is required for program accreditation, is primarily directed to architecture majors but also offered to students majoring in related programs. A primary goal of the course sequence is student development of technological knowledge enabling informed architectural design decisions.

The five courses in the BT sequence vary with regard to content; yet share similarities including the lecture/lab credit structure (2-2-3), technical accreditation requirements, fulltime to adjunct faculty ratio (1:2-3), faculty to student ratio (1:25), and zero laboratory or grading assistance. The courses are scheduled as two, one-hour and fifty-minute meetings per week; resulting in approximately 60 hours of class time per semester. Assessment is based primarily on exams and quizzes (on average 60% of the grading) with class participation and projects constituting the remainder (40% of the grading).

3.2 Building technology curriculum considerations regarding implementation

On examination of the Building Technology course sequence, the following significant issues come to light related to integrating active learning methods into the traditionally lecture focused courses:

- Despite their lecture/lab credit structure, the courses were primarily lecture based. Laboratory, "hands-on" learning moments ranged from 10-20% of class time and were not integrated into the lecture material.
- Faculty to student ratios are larger than are recommended for effective PBL methodologies.

- The ratio of adjunct faculty to full-time faculty is very high, leading to significant challenges regarding the training of faculty in PBL methods.
- The student-faculty ratio is prohibitively high for in-class instructor guidance of complex student projects.
- Quantitative assessment techniques do not foster establishment of goals, process, and post-problem reflection and self-assessment critical to PBL methods.

3.3 Proposed methods and examples for enhancing technical lectures

Given the benefits and draw backs of both passive and active learning methods the authors propose a framework for the Building Technology (BT) curriculum wherein lectures embedded with in-class laboratory activities enhance learning opportunities while delivering high levels of technical content.

1. Student-centered activity will increase in all courses, and increase sequentially from course to course.

The implementation of student-centered learning in high content, sequential courses requires staged integration to insure that required content is delivered in each course before advancing to the next (Banjaree 1996). Using that framework, the distribution of lecture and student-centered activity is shown in Table 1.

Table 1: Teaching method distribution in hybridized building technology courses.

Course	Lecture	Student-centered activity
Building Technology 1	70%	30%
Building Technology 2	60%	40%
Building Technology 3	50%	50%
Building Technology 4	40%	60%
Building Technology 5	30%	70%

2. Student-centered activities such as laboratory sessions and problem assignments will be required to assimilate new knowledge from reading and lectures with existing student knowledge to enhance the development of flexible knowledge and critical thinking related to the course content.

Problem-solving assignments will be used to prepare the students for forthcoming lecture or laboratory content, not only for review of previously delivered content. The goal is students will then create a mental context for the assimilation of new information and be more prepared to reflect on their learning during class discussion. This is similar to the method described by D.L. Schwartz in the article "A time for telling. Cognitive Instruction, vol. 16, 1998" where students prepare for lectures by performing a comparative analysis of multiple readings and similar to the PBL method (Hemlo-Silver 2004) where student identify gaps in their own knowledge related to solving a problem and then use lecture content to fill those gaps.

3. Shift high level course content from in-class lecture to readings or online lectures.

To meet content, accreditation and sequential curricular outcomes, some content traditionally covered in lecture must be shifted outside of class to enable increased class-time for active learning opportunities and integration of knowledge from multiple sources.

4. Reduce instructor to student ratio for active learning settings to 1:8-15 using teaching assistants

Research highly suggests meaningful faculty interaction and guidance in active learning settings require student to faculty ratios of 8 to 15 per instructor, thus modification of the course structure or utilization of teaching assistants during the lab sessions is essential. Interviewed instructors note that upper-class student teaching assistants made excellent activity assistants because students felt more comfortable asking questions to fellow students than to instructors.

5. Utilize traditional quantitative testing methods as primary means of assessment

While it is critical for students to actively participate in student-centered activities, our research recognizes significantly increased assessment as a challenge. Additionally, given the quantitative nature of existing accreditation criteria, testing remains an efficient means of technical content assessment .

6. Utilize alternative forms of assessment to gauge progress of student-centered activities

Self-reflective, peer, and verbal instructor assessment, combined with online submissions such as blogs, Blackboard, and other web-based centers, is the proposed method for gauging student work while addressing the time intensive concerns of assessing student-centered activities. Students will post weekly progress of activities, time-stamped to insure participation; this work will be formally assessed at only a few significant moments in the semester, such as midterm and final grading. Peer assessment and group assessment will also be employed and recognized as significant opportunities for student development.

7. Train faculty in active learning methodologies

While architecture faculty often use hands-on or active teaching methods in their studio courses, training on the critical steps in active learning methods (intent, process, expected outcomes and student reflection), is critical to ensure student development of long term flexible knowledge. Training on assessment and methods of effective in-class activities will ensure administrative success.

3.4 Proposal example

An example of these guidelines in use is a learning module examining exterior wall systems. A pre-class assignment will be written to ask students to provide graphic comparative analysis of two different exterior wall systems. With students first reading about and then comparing and contrasting each building system in the form of a drawing assignment, the readings are utilized to develop broader context and encourage critical thinking related to the material. The pre-class assignment also requires additional lecture content to solve the problem. This prepares students to receive new information in class by creating a context for the lecture information. Although a few students are able to complete the exercise without the lecture or reading content these steps in the learning process will provide enhanced techniques on the use and assembly of external wall systems. These embedded in-class activities will target not only technical demonstration but highlight design relevance beyond performative issues.

3.5 Implementing surveys and assessing learning gains

To help instructors design their courses to effectively utilize active learning methods some instructors utilize pre-class and post-class surveys to assess their students' progress and gauge desired learning outcomes. Pre- and post-class online surveys assess the effectiveness of implementing new pedagogical techniques and providing rapid feedback for the instructor’s use during the semester.

Measuring student confidence in the integration of course materials is a key metric in studying the impact of learning methods and the creation of long term flexible knowledge and skills. The format of survey questions should target specific content knowledge and measure whether students believe the material has become integrated into their knowledge base well enough to be transferred to different contexts. For instance Bower and Ashley (2007) asked students to rate how likely they would be to read an article on a topic related to the material covered in class and how likely they would be to engage in conversations regarding the class topics outside of class with their families or friends. Higher confidence levels often inferred a more fundamental integration into the student’s knowledge base. One resource that is readily available to implement these surveys is the “Student Assessment of Their Learning Gains” website (www.salgsite.org). The tools available enable academics to survey student assessment of learning gains.

4.0 CONCLUSION

While assessing student learning relative to accreditation criteria is a requirement of professional programs, a critical goal of architecture programs is to assess students’ ability to transfer and apply technical knowledge to their own design work, both in the academy and profession. Enhanced active learning methodologies in building technology courses is the first step to integration of technical content and design. Through the establishment of guidelines for student-centered learning implementation, the authors predict an improved learning environment and increased flexible, transferable knowledge in students.

5.0 DISCUSSION

Active student centered learning such as PBL is an important existing aspect of architectural education commonly found in design studios. Adapting and developing these methods for use in high-content technical courses can greatly enhance desired long-term learning outcomes and students ability to transfer technical knowledge into the design studio setting. Our research and proposal for methods of enhancing technical lectures through short duration student-centered activities are being implemented in our building technology courses.

Some have suggested reversing the distribution of lecture-based versus active-learning activities through the curriculum; proposing a higher concentration of learner centered activities in earlier stages of the curriculum. While this proposal has merits, our proposal is based on two rationale, one pragmatic, and one research-based. Pragmatically, BT1 has traditionally been 90% lecture-based, 10% active-learning based. Given the five sections of the course, taught by one full time faculty and four adjunct faculty, a gradual implementation of active-learning methods is more likely to succeed. Furthermore, research suggests students need some level of existing knowledge from which to solve the problems we propose. (Banjaree, 1996). While this knowledge can be gain in multiple manners, a lecture-based approach for BT1 allows us to cover a large amount of information and helps create a common knowledge base for all first year students for future active learning methods in their subsequent BT classes.

The most difficult aspects related to successful implementation appear to be student faculty ratios and assessment challenges, yet essential to our research is determining the transference of technical knowledge from building technology courses to design studio settings, and that process is underway. It is an added challenge to this research, where evaluation of flexible learning requires coordination between the BT course and concurrent design studios, which are generally outside of the control of technology course instructors. Efforts in assessment will required coordination with studio faculty to target transference of technical knowledge into studios.

As we implement these changes in the BT curricula pre- and post-class surveys are planned for the technology courses and related upper level design studios to measure student gains and learning outcomes over the course of each semester. It will be interesting to see if these methods and outcomes can be successfully mapped across multiple semesters, not only targeting concurrent studios but future studios as well.

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Re-visioning Design Education: A Third Culture Epistemology

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ABSTRACT: Traditionally, education has been theorized as existing within a binary system—education in the sciences and education in the humanities. If education in design can be viewed as a third culture within this realm then it will have teachers that teach design, students that learn design, and mechanisms in place to insure that the teaching and learning of design occur. Resultantly, one must ask: What does it mean to know as a designer? This question is one of epistemic significance, and, as such, begins to create the basis of a framework for design knowledge and design education. What, in a newly categorized third culture, can establish such an epistemic foundation; are the epistemic models available in the sciences and humanities appropriate for design education? How can education in design both situate itself in relation to the sciences and the humanities while providing for an epistemic foundation that allows for design knowing, design teaching, and design learning?

It is the intention of this paper to explore a qualitative and philosophical inquiry that positions design education; a position that interrogates a two-culture epistemology of education and begins to allow for a third culture whose knowledge is founded upon its own epistemic authority. This positionality will be addressed by exploring design education in relation to traditional education, outlining and engaging the problematic assumptions of the historical emergence of design education, and then proposing a return to the virtues of durability, utility, and beauty as proposed by Vitruvius in his foundational text *De Architectura* (1st Century BC). This return to Vitruvian virtue re-theorizes a design epistemology—and; therefore, a design education—that is once again grounded in the material, the contextual, and the experiential. By way of this Vitruvian re-visioning—a re-visioning that positions design education firmly within a pragmatic and material world—the content of that education is expunged from the store of tradition and made available to all learners through the uniqueness and complexity of individually lived experience.

KEYWORDS: design, education, epistemology, Vitruvius, pragmatism

INTRODUCTION

Traditionally, education has been theorized as consisting of two distinct areas, two educational cultures with fundamentally different interests. These areas, broadly defined, are education in the sciences and education in the humanities. Nigel Cross argues that this ‘two culture’ binary has had significant influence upon “our social, cultural, and educational systems” (Cross 2006, 01). Further, he theorizes a third culture, education in design, that might act to validate what Bruce Archer noted as “the collected experience of the material culture, and the collected body of experience, skill, and understanding embodied in the arts of planning, inventing, making and doing” (Cross 2006, 01). This material culture is grounded in technology; the “synthesis of knowledge and skills from both the sciences and the humanities, in pursuit of practical tasks” (Cross 2006, 02). It is an education grounded in materiality, locatedness, and specificity that is arrived at through ambiguity and idiosyncrasy, as well as practicality and appropriateness.

It is the intention of this paper to explore a qualitative and philosophical inquiry that positions design education; a position that interrogates a two-culture epistemology of education and begins to allow for a third culture whose knowledge is founded upon its own epistemic authority. In theorizing this third culture, design education becomes a category of education that stands in contrast to the binary categories of science education and humanities education. Perhaps this position might best be viewed as a middle ground; an educational discipline that draws from both the humanities and the sciences without being fully subsumed by either.

If design can be viewed as a third culture within the realm of education, then it must have educational goals. As a category of education, it is implied that design education will have teachers that teach design, students that learn design, and mechanisms in place to insure that the teaching and learning of design occur. Viewed from this standpoint, education in design becomes a question of knowing; a question of epistemic significance, and, as such, begins to create the basis of a framework for design knowledge and design education. In a newly categorized third culture, a new epistemic foundation must be established; the epistemic models available in the sciences and humanities do not appear appropriate for design education. Education in design must situate itself in relation to the sciences and the humanities while providing for an epistemic foundation that allows for design knowing, design teaching, and design learning. Theorizing such an epistemic foundation requires situating design education within the traditional binary system, exploring historical documents that indicate the knowledge base necessary for designers, understanding contemporary theories of 'design science,' and then turning to a philosophical relativism that might provide a disciplinary veracity to design epistemology.

1.0 EDUCATION AND KNOWLEDGE

1.1 Traditional educational practice

One means of understanding education in design as different from education in both the humanities and the sciences is to view them in relation to the aim of education in a more general sense. According to John Dewey, the aim of education in traditional systems consists in transferring "bodies of information and of skills that have been worked out in the past; therefore, the chief business of the school is to transmit them to the new generation" and to form habits in students that conform to past "developed standards and rules of conduct" (Dewey 1997, 17). Dewey's delineation of the aims of traditional education might be simplified to consist of transmitting knowledge about particular phenomenon, acquiring skills in appropriate methods of enquiry, and inculcation in particular values. Cross employs these three criteria to begin the process of situating design education in relation to the existing cultures of science and humanities educational practice (Cross 2006).

1.2 Knowledge assumptions

According to Cross, the knowledge basis of each of the three cultures—science, humanities, and design—are, respectively, the natural world, human experience, and the artificial world. Methods of enquiry for these cultures consist of: in the sciences: experimentation, classification, and analysis; in the humanities: analogy, metaphor, and evaluation; in design: modeling, pattern-formation, and synthesis. The values expressed by each culture include objectivity, rationality, neutrality, and a quest for 'truth' in the sciences; subjectivity, imagination, commitment, and a concern for 'justice' in the humanities; and practicality, ingenuity, empathy, and a concern for 'appropriateness' in design education (Cross 2006).

Given the binary nature established by the traditional two-culture conception of education—and the dualism established in their explication—it appears that these systems are grounded in what Carolyn Korsmeyer would term patriarchal assumptions; assumptions bounded within established gender binaries (Korsmeyer 2004). The dualism present within these gendered and binary assumptions can readily be critiqued through Korsmeyer's concept of deep gender, a concept that critiques mainstream viewpoints based upon a deeply embedded juxtaposition of the gender concepts of masculinity and femininity. Further, the third culture of education in design might be viewed as having a relation to Lorraine Code's establishment of an epistemic middle ground that does not privilege mainstream models of epistemic knowing. Code's work in feminist theories of knowledge construction, her call for a mitigated relativism, might perhaps provide the epistemic foundation for design knowing and design education.

2.0 DESIGN KNOWING

2.1 On Architecture

Prior to theorizing an epistemic foundation for education in design, it is beneficial to explore the question: What should designers know? This question might appear extremely far-reaching; however, the foundations of this question can be traced to one historical document. In the first century before Christ, Marcus Vitruvius Pollio composed *De architectura*—On Architecture—a text that has influenced over two millennia of design education and practice (Tavernor 2009). Vitruvius was a military architect and engineer serving in the Roman Legion under Julius Caesar and this volume was devoted to Augustus and conceived of to provide "recommendations so that by examining them, you yourself may become familiar with the characteristics of buildings already constructed and of those which will be built; in these books I have laid out all the principles of the discipline" (On Architecture, Book I, Introduction, 3). As this treatise also contains detailed accounts of technologies and other machines, it can be assumed that the term architecture for Vitruvius included all design fields—those dealing with the practical and appropriate creation of the artificial world. Vitruvius noted that "Architecture has three divisions; the construction of buildings, of sundials, and of machines" (On

Architecture, Book I, Chapter III, 1). As such, *De architectura* can be positioned as the first text concerning the discipline of design; the first document that designates what designers should know.

As a disciplinary study, there are many fields that Vitruvius holds central to a designer's understanding. "He should have a literary education, be skillful in drawing, knowledgeable about geometry and familiar with a great number of historical works, and should have followed lectures in philosophy attentively; he should have a knowledge of music, should not be ignorant of medicine, should know the judgments of jurists and have a command of astronomy and of the celestial system" (On Architecture, Book I, Chapter I, 3). Vitruvius spends the rest of the chapter in explaining the reasons that an architect must have an education in these particular areas of knowledge; without this "wide literary and technical knowledge" they could not have "reached the highest sanctuary of architecture" (On Architecture, Book I, Chapter I, 11). Vitruvius' 'wide literary and technical knowledge' appears to cohere to the knowledge associated with both education in the humanities and education in the sciences. "The architect's professional knowledge is enriched by contributions from many disciplines and fields of knowledge… this expertise derives from theory and practice" (On Architecture, Book I, Chapter I, 1).

There is, of course, no direct correlation to the contemporary conception of education in design other than the assertion that the designer must have a wide knowledge of both the sciences and the humanities. One might; however, interpret Vitruvius' assertion that all buildings—including all constructed technologies—"must be executed in such a way as to take account of durability, utility, and beauty" (On Architecture, Book I, Chapter III, 2) as the foundational conditions of design. The Vitruvian virtues of durability, utility, and beauty begin to differentiate design knowing from knowing in the sciences and humanities; these conditions of design position the discipline within a material world where the pragmatic awareness of the appropriateness of particular materials define the durability of things made, the function of those things—how they are used by humans—are conditions of their utility, and the particular aesthetic value we place on those items define their beauty. In Vitruvius' triad of design conditions—a material, practical, aesthetic, and located relativism—can be found the foundation for a contemporary design epistemology. It is now critical to explore why the epistemic value of Vitruvius' assertions has not remained the primary concern of knowing in design education.

2.2 The rise of Positivism

Vitruvius' treatise, considered as a nascent design epistemology—one which we might define as establishing both design education and practice—has not maintained its epistemic authority. The influence of his work can be traced through the Renaissance works and writings of Leon Battista Alberti and Andrea Palladio, the works of Sebastiano Serlio for the French monarchy, the seventeenth century works of Inigo Jones in England, and Thomas Jefferson's University of Virginia. It wasn't until 1792, that architectural education began to question the authority of Vitruvius. At this time, under the auspices of Jean-Nicolas-Louis Durand, architectural education at the *École Polytechnique* was "organized to create scientists and technicians with specialized skills" (Tavernor 2009, xxxiii).

This shift away from a practically and materially located understanding of design cohered to the shift toward rational understanding typical of late Enlightenment thought. The logic of mathematics, the technologies of building, and a belief in humankind's authority over the natural world began to assert more influence on design education than the Vitruvian call for durability, utility, and beauty. As a result of this shift, architectural expression, architectural practice, and architectural education became "the servant of a new kind of rationality and science" (Tavernor 2009, xxxiv). The practical, material, appropriate, human world of design became subservient to the objectivist rationality of scientific epistemology. The project of Modernity abandoned the Vitruvian ideal in favor of a positivist universalism coherent with the belief systems established in scientific ways of knowing.

This positivist understanding of design knowing continued into the early twentieth century. Theo van Doesburg noted that "Our epoch is hostile to every subjective speculation in art, science, technology, etc. The new spirit, which already governs almost all modern life, is opposed to animal spontaneity, to nature's domination, to artistic flummery. In order to construct a new object we need a method, that is to say, an objective system" (Cross 2006, 95). Six years later, Le Corbusier fully objectified the house as a "machine for living"; "The use of the house consists of a regular sequence of definite functions. The regular sequence of these functions is a traffic phenomenon. To render that traffic exact, economical and rapid is the key effort of modern architectural science" (Cross 2006, 95).

The sensual world of embodied humanity was replaced with the efficiency of the rationality of architecture in the machine age. These early attempts to transform design into a scientific project were continued in the design methods movements of the 1960's. According to Cross, "the desire of the new movement was even more strongly than before to base design process (as well as the products of design) on objectivity and rationality" (Cross 2006, 95). The design methods movement reached its peak when Herbert Simon called for the development of "a science of design… a body of intellectually tough, analytic, partly formalizable, partly empirical, teachable doctrine about the design process" (Cross 2006, 96).

2.3 Critique of Positivist design

Simultaneous to the peak of the design methods movement, there was a critical interrogation of its scientific bias. Christopher Alexander rejected his earlier works on rational methods of design noting that the fields differed in that "scientists try to identify the components of existing structures, designers try to shape the components of new structures" (Cross 2006, 97). There was also a rising awareness that comparisons between science and design had been simplified and that there was, perhaps, more complexity in the distinctions between these two methodological endeavors than first assumed. Many thought that "perhaps there was not so much for design to learn from science after all, and rather that perhaps science had something to learn from design" (Cross 2006, 97). Cross further explicates this position when he notes that designers have "been seduced by the lure of *Wissenschaft*, and turned away from the lore of *Technik*; they have defected to the cultures of scientific and scholarly enquiry, instead of developing the culture of designerly enquiry" (Cross 2006, 06). A culture of designerly enquiry might be thought of as a middle ground culture based upon the disciplinary conditions articulated by Vitruvius—durability, utility, and beauty.

Contemporary interrogations of a design methodology founded upon scientific principles—on scientific ways of knowing and the romanticization of science as a paradigm for human life—have led to a destabilization of design knowing, and consequently, to design education. In light of this critique, I argue that it is not, perhaps, a science of design but, rather, an epistemological foundation of design that is necessary. In asking what we know and how we know as designers, we may be able to understand and justify approaches to how we teach design. An epistemology of design should lead to a more robust understanding of what it means to know as a designer and thus offer up theories and practices that insure the disciplinary veracity of design education; that insure that design education is substantially differentiated from educational practices in both the sciences and the humanities.

3.0 BINARY KNOWLEDGE SYSTEMS

3.1 Binary systems and design epistemology

One possible means to explicate an epistemology of design—of answering the question of what designers should know—is to turn to the feminist theories of Carolyn Korsmeyer and Lorraine Code. As noted above, the two-culture paradigm of education—the idea that education has two distinct areas of focus; education in the sciences and education in the humanities—allows a critique based upon the gender asymmetries illuminated in Korsmeyer's concept of deep gender. In the sense that Korsmeyer uses the term, deep gender is a predominantly hidden system of value judgments that hinge upon "oppositional concepts and schemes of value whose meanings fluctuate in different historical and cultural contexts" (Korsmeyer 2004, 03). The sciences and the humanities might be seen as such oppositional concepts. These oppositions can be associated with the binary opposition of the culturally determined deeply gendered terms *masculine* and *feminine*. This cultured gender binary of masculine/feminine is associated with the intellectual binary of mind/body dualism that is at the heart of contemporary scientific epistemology.

3.2 Gender heirarchy and epistemic value

Within Korsmeyer's deep gender analysis, the privileged and dominant binary *masculine* is associated with the Cartesian mind, and further, with rationality, knowledge, idealism, abstraction, and countless other seemingly neutral identifiers. For purposes of this analysis, education in the sciences seemingly coheres to—and should be considered congruent with—the *masculine* binary. In opposition to this privilege, the subordinate *feminine* binary is associated with the Cartesian body, with emotion, experience, pragmatism, materiality, and additional identifiers opposite those in the dominant category. Here, the subordinate binary to the sciences, the humanities, should be considered congruent to the subordinate *feminine*. In utilizing the gender categorization of these binary pairs, Korsmeyer holds that deep gender analysis exposes what might otherwise be perceived of as neutral ideas, statements, beliefs, systems, and cultures. In recognition of these gendered binaries, there is potential to move beyond the non-neutral exclusivity of these categoricals and pursue ideas, beliefs, and systems that celebrate difference, specificity, and locatedness.

It is within the oppositional values of these deep gender claims—claims identified within a hierarchy of dominant and subordinate—that Korsmeyer finds epistemic claims that support the continued oppression of women, other marginalized people, and ideas, beliefs, and epistemic systems that do not fall within the dominant patriarchal category encapsulated under the conceptual binary *masculine*. Additionally, this patriarchally established hierarchy oppresses any additional viewpoints other than the two encapsulated under the binary *masculine/feminine*. The extreme dualism that defines the binary masculine/feminine, mind/body, and knowledge/experience—a binary system that excludes all that is 'other'—appears, also, to encapsulate education in the sciences and education in the humanities and, as such, to exclude education in design as some thing 'other' to this binary pairing. The established binary viewpoint precludes all other viewpoints as meaningful to education; it precludes additional viewpoints from having epistemic worth. It is perhaps Korsmeyer's critique of the patriarchal assumptions deeply embedded within the two-culture binary of education that will provide room for a third culture—for education in design—and thus for an epistemology of design. Such an epistemology cannot be grounded within the dualism sciences/humanities, but must create its own ground for epistemic authority.

4.0 THIRD CULTURE EPISTEMOLOGY

4.1 Education's third culture

Employing Korsmeyer's conception of deep gender to critique the exclusive position of a two culture educational system allows the possibility for a third culture in education—education in design. As this third culture is 'other' than the established sciences/humanities binary, it, necessarily, must establish its epistemic authority; it must answer the question regarding what designers know. It must claim a knowing that is not based upon an epistemology of science or an epistemology of humanities. This third culture might be viewed as having a relation to Lorraine Code's establishment of an epistemic middle ground that does not privilege mainstream models of epistemic knowing. Code's work in feminist theories of knowledge construction, her call for a mitigated relativism, might perhaps provide the epistemic foundation for design knowing and design education.

4.2 Epistemological relativism

Code describes epistemological relativism as a system that holds that "knowledge, truth, or even 'reality' can be understood only in relation to particular sets of cultural or social circumstances, to a theoretical framework, a specifiable range of perspectives, a conceptual scheme, or a form of life. Conditions of justification, criteria of truth and falsity, and standards of rationality are likewise relative: there is no universal unchanging framework or scheme for rational adjudication among competing knowledge claims" (Code 1991, 02). In accepting this definition of epistemological relativism, it becomes obvious that the individual knower is of ultimate importance relative to what is known. To know, in this sense, is to have knowledge of; to experience in a particular way—particular to the individual knower. This particularity is essential to a third culture epistemology of design.

From this position, Code begins to dismantle the priority given a masculine identity posing as scientific and epistemic neutrality. In forming this argument, Code also critiques the essentialism of positions that affirm distinct and stereotypical masculinities and femininities. These mainstream, deep gender binaries have a significant impact upon the epistemological warrantability of education in the sciences and education in the humanities. In Code's critique of mainstream epistemology—one where the masculine/dominant objective epistemology of science subordinates the subjective epistemology of the humanities and completely excludes any other epistemic systems as unwarrantable—there is no expectation of a reversal of that epistemology, but rather, an expansion that recognizes subjective and other forms of knowledge for the individual and her beliefs, lived experiences, educational encounters, and practical knowledge about the world. This middle ground, pragmatist epistemology is, perhaps, the foundation of a design epistemology supporting, and supported by, Vitruvius' conditions of durability, utility, and beauty.

Code further clarifies her position when she differentiates between relativism and what might be perceived of as a radical subjectivism that could reasonably lead only to skepticism or solipsism. She accomplishes this task by showing that the relationship of the terms objective and subjective need not be polarized to the extent that they are irrevocably oppositional. To make this claim she employs both a critique of Aristotelian contradictories and culturally embedded dichotomies that "have structured mainstream Anglo-American epistemology" (Code 1991, 28). Contradictories—as exclusive and binary oppositions—exclude any room for a middle ground; there can be no knowledge that does not cohere to a stringent logic based upon principles of either/or. There are only two possibilities in an Aristotelian contradictory—possibility A or possibility not-A. These possibilities cohere to the two culture system extant in education in the sciences and education in the humanities. Such systems exclude all subtleties and insure that variety and reciprocity have no epistemic authority. This formal logic does have value in knowledge construction; however, it remains firmly grounded in intellectual isolationism and does not express the reality of lived experience. In the majority of relations that we have with the existential world there are subtleties of understanding, of judgment, and of knowledge that are predicated on the varieties of experiences, experiencers, and things experienced. In practical usage, contradictories "become instruments of oppression and social control" (Code 1991, 29).

4.3 Individual epistemic authority

Like Korsmeyer, Code is unwilling to accept a polarized subjectivism/objectivism and; therefore, advocates a form of relativism to justify the epistemic authority of the individual knower; a form of relativism that interrogates the masculine dominant and its claim of objectivity. Similarly, she must dismantle a polarized relativism if knowledge is to have any practical value. Relativism is one half of the binary pair that includes universalism. In exploring the universalism/relativism binary, Code again finds a middle ground by advocating a tempered moral relativism based upon specific and particular relationships tempered by critical evaluation. She holds that any "values and regulative principles invoked are appropriately responsive to the context" (Code 1991, 108). Restated, any universal moral principle must be tempered by evaluation of the reality of the people, events, and circumstances being held in judgment. In this way, knowledge claims find space within the subtleties of experienced life—they are not relegated to the exclusion required of an oppressive binary system. In making these moves that exist between polarizing binaries, Code avoids claims of dehumanizing objectivism, disabling subjectivism and a slippage into unmitigated relativism.

Code's proposal to resituate epistemological inquiry by recognizing the value of context in knowing provides a possible means to overcome the polarized binaries and the positivist biases of mainstream epistemology. Mainstream positivism is best characterized as an inquiry dependent on the rationalization, simplification, categorization, and the necessity of universalizing all knowledge claims. It is the basis of western conceptions of natural science and, for the most part, constitutes the contemporary western worldview. This worldview presupposes a disconnect of humankind from the natural world—we are observers, manipulators, controllers of a system that we can only understand in categorical simples and non-complex relations. This viewpoint allows no tangible relation to the natural world; we have no tangible expression of being in the world.

A Heideggerian approach to epistemic knowledge of the world may be one possible means of overturning the hegemony of reason for more sustainable relations with others, with nature, and with a future free of self-imposed disaster. Code notes that a feminist convergence with phenomenological thought might "offer an account of being in the world which resonates with the activities of moral and epistemic subjects who know and understand by positioning and repositioning themselves within a situation in order to understand its implications and see in those implications contextualized, situated reasons for action" (Code 1991, 148). This move from the purity and universality of rationalism to a contextualized reasonableness allows for us to know in specific and particular ways, to make informed decisions based on our knowing, and to take practical actions to insure the furtherance of our being in the world.

4.4 Epistemology of experience

Code suggests that institutionalized, 'public' knowledge is a product of the positivist unity-of-science project and that this knowledge legitimates "the networks of authority and expertise that sustain asymmetrical, oppressive social and institutional power structures" (Code 1991, 175). Postmodernist/post-structuralist/feminist thought has sought to combat the structures of 'public' knowledge by providing space for alternative authorities, alternative expertise. Seemingly, feminist thought has moved beyond awareness of the knowledge/power matrix of domination and toward dialogical systems that can allow for such alternatives. By employing Wittgenstein's knowledge/acknowledge observation, Code hopes to create space where women can acknowledge their own expertise and, as such, alleviate dependence on experts who currently support the oppressive systems that leave women with no space of their own. This same methodology might empower an epistemology of design; dialogical systems that allow for alternative views, alternative solutions, and alternative ways of knowing. This epistemic system gains its authority from a practicality and groundedness in the messy complexity of lived experience. In this way, the knowledge/experience binary—a deeply gendered and oppressive/exclusionary construct—can be dismantled or, at least, re-boundaried in order to make room for a more flexible form of knowing; for a mitigated relativism that allows additional ways of knowing.

Code's call for a mitigated relativism seems appropriate to rescue the epistemic authority of women, designers, and other groups marginalized by mainstream epistemic practices that favor rationality and ideal objectivism. With a commitment to realism represented by an engagement with the material, particular, spatial, and temporal qualities of lived experience, coupled with a practicality grounded in personal responsibility and accountability, these groups can re-value knowledge through practice and place it in a preferential position in regard to all epistemic claims. This positionality in the real, in the appropriate, and in the material acts to refute the authority and credibility of universalism, of oppositional binary systems, of ideal objectivity, and of subject-neutrality.

Mainstream epistemological theory, with its universalizing character, must be re-conceptualized to a model that recognizes the necessity of addressing the knowledge claims of the practical, the particular, and the material as issues that make up our experiential lives. In opposition to the mainstream and a possible replacement feminist philosophy, Code advocates a middle ground that challenges any unified theory by being located within "experiences, histories, social structures, material circumstances" (Code 1991, 322). It is this locatedness that expresses the potential for re-conceptualization. In being located, in having positionality as a defining characteristic, this middle ground requires both mitigated relativism and accountability. Mitigated relativism allows a re-conceptualized epistemology to avoid the problems of a unified theory that precludes difference; accountability insures that the included difference of "Other-ness" becomes central to methodological control.

Code's middle ground allows for a pluralist epistemology. She notes that the "diversity of situations and circumstances in which people need to be in a position to know makes it difficult to see how *a* theory of knowledge, *an* epistemology, could respond to their questions" (Code 1991, 315). In allowing a middle ground—a pluralism—to general knowledge construction, specialized epistemologies can likewise be understood through a pluralist theory. Particularly, design knowing benefits from an awareness that unified theories of knowing are absolutist, authoritarian, and do not account for difference—ambiguities that are personal, spatial, material, and environmental. Stenstad's anarchy celebrates the power of pluralist methodologies in noting that such methods insist upon "questioning, working and playing with ambiguities, being alert for the presence of the strange within the familiar, and allowing for concealment or unclarity in the midst of disclosure" (Code 1991, 319).

CONCLUSION

A mitigated relativism that seeks the middle ground of pluralism, allows for knowledge questions that are grounded in particularity, that take "place from *somewhere*" and are "committed to finding answers that make action possible" (Code 1991, 319) is analogous to a pragmatist philosophy, one where things that "work"—that have particular grounding—are true. This mitigated relativism/pragmatism—readily associated with the Vitruvian virtues of durability, utility, and beauty—appears to be a necessary condition for any design epistemology. It allows for a multiplicity of solutions to 'softly' defined problems; it does not require universal stances or responses, but rather, for critical, particular, and evolving responses to continually changing needs and circumstances.

Code's mitigated relativism coupled with the Vitruvian virtues appear to be necessary conditions for design epistemology—a knowing that is informed by "experiences, histories, social structures, material circumstances" (Code 1991, 322). This re-visioned design epistemology mediates a positionality between lived experience and propositional knowledge. This positionality allows for design solutions that are particularly located—particular to clients, to site conditions, to economic constraints, and to material circumstances. It is this locatedness that limits universal theories and produces design solutions that respond to particular needs, places, and understandings. It, perhaps, allows for the idiosyncrasies of designers, of clients, and of circumstances. Additionally, the pluralism implied in questioning "*a* theory of knowledge, *an* epistemology" (Code 1991, 315) structures well within a framework of design knowing. Design processes cannot be defined by singular methodologies, by singular ways of knowing. A re-visioned middle ground may indeed provide a framework for articulating design knowing that avoids general evasiveness but still allows for an ambiguity necessary for approaching solution-based problems. Perhaps this middle ground thinking will, additionally, allow for the formation of a pedagogical model that celebrates the pragmatic, the subversive, the idiosyncratic, and the ambiguous without losing its way and slipping toward the extremes of either a dehumanizing scientific rationalism or what might be termed the pure relativism of form-making.

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Researching Architectural Salvage through Experiential Education

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ABSTRACT: In the streets of post-Katrina New Orleans, it was trash heaps, rather than signage, that offered the promise of a homeowner's return. Street-side mountains of soggy sheetrock, worn-out flooring and old windows provided a visual testament of rebuilding efforts inside; these piles of architectural debris framing gutted houses on almost every block. Such material waste regularly accompanies standard construction practices, where the yardstick of progress measures the number of dumpsters filled, and transformation implies resource depletion.

This perverse line of thinking was called into question by one team of architecture students at Tulane University, who in the midst of the post-Katrina rebuilding of New Orleans, sought to illuminate demolition excesses and the untapped potential inherent to such processes. Their efforts to identify the type and scope of this material waste led to extensive field-based data collection, material cataloging and resource mapping. Once they had completed this exhaustive product index, the design team produced an alternative concept of one such trash heap, demonstrating the productive capacity of design thinking and the value of direct action in the face of wasteful rebuilding practices.

KEYWORDS: Pedagogy, Design/Build, New Orleans, Rebuilding, Advocacy

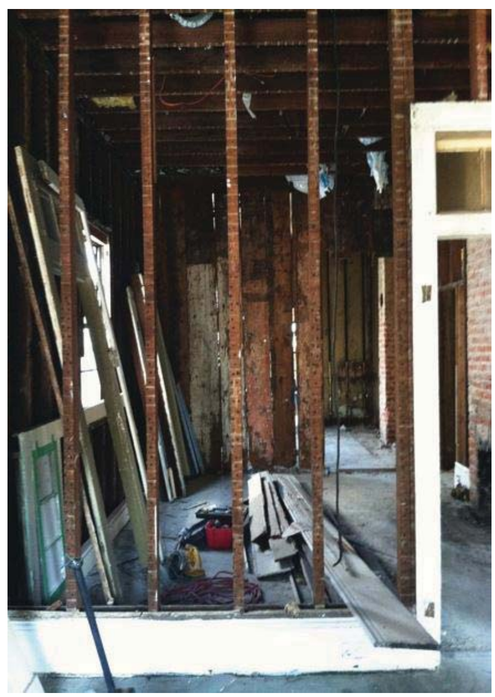

Figure 1: Outside a building in New Orleans, material slated for the landfill. Source: (Clouse 2011)
Figure 2: A gutted house in New Orleans, ready for reconstruction. Source: (Clouse 2011)

1.0 Experiential Education and Design Service

Post-Katrina New Orleans' waste-stream-made-visible provided a call to action; street-side debris became a ripe resource for both student-led research and their own subsequent creative design intervention. By framing this waste problem as a design opportunity, the pedagogical techniques of community service *and* rigorous data collection became a vehicle for student learning. In doing so, this two-pronged experiential approach also helped students to make the connection between design service and environmental awareness.

This architectural salvage research highlights the advantages of bridging conventional design teaching from established educational paradigms and the wooly, irregular and unexpected lessons presented in the real world. This pedagogical approach narrows the gap between thinking and doing, reinforcing accepted design principles through hands-on innovation and experimentation.

This model of experiential education has been articulated by deep-rooted educators such as Aristotle,[1] and canonized more recently into Western pedagogy with the work of John Dewey, Kurt Lewin, Jean Piaget, and Paolo Freire. The assertion that learning happens more effectively through instructive experiences (reflection by doing) fits neatly into architectural praxis. This disciplinary suitability was demonstrated in New Orleans, where design students developed their learning about environmental stewardship, material constraints, fabrication, product flows, community engagement and a host of other issues by responding to a real-world design challenge.

While experiential education takes many forms, this project was contained within the husk of research and inquiry; namely as an examination of existing conditions. Only once this survey and mapping was completed did the students probe deeper into their role as design-activists. Design-by-doing pairs well with critical interrogation and reflection, and in the case of this architectural salvage analysis, students balanced hands-on fieldwork with classroom research, material exploration with readings and references. The focus of this study was a real-world problem, and in digging into this issue, students honed extant skills while becoming exposed to new information.

2.0 Background

In an effort to understand the impact of the enormous construction debris caches that materialized in the wake of Hurricane Katrina, a small team of students from Tulane's School of Architecture took to the streets to collect data. Together they worked to inventory products, categorize material properties, and map subsequent flows. They began by questioning the characteristics of abandoned building materials, targeting one trash pile along a street in a flooded mid-city neighborhood. Initially, they picked apart the heap of debris to determine the amount, weight, volume and type of refuse generated by a typical freshly-gutted house.

Figure 3: The trash heap, typical in post-Katrina New Orleans, studied by students. Source: (Clouse 2010)

Although the home's unbuilders (or rebuilders) had intentionally rejected this pile of materials, the majority of this deconstruction waste was in fact reusable. Fine architectural fixtures of the last century---decadent moldings and solid true wood, windows, doors, cabinetry, and tongue and groove flooring---have value born out of the fact that they simply are not available today. While perhaps not suitable for their original house host, these items can be directly reused in another location or even upcycled to a different, improved use.

Once these architectural gems have been salvaged, the rest of the waste pile qualifies for a more traditional recycling route. Scrap wood, metals and glass could be separated and re-constructed. Organic matter would make rich compost. Toxic materials, such as asbestos, paints or poisons, might get quarantined in safe containers.

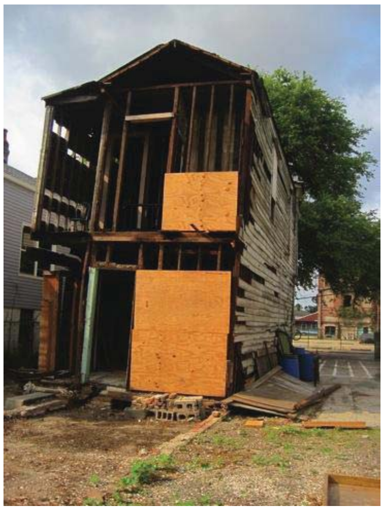

Figure 4: One typical house in New Orleans, awaiting renovation. Source: (Clouse 2011)

Yet despite the more than 22 million tons of construction and demolition debris generated by Hurricane Katrina in 2005, (Ardani 2007) material salvage operations served only a small fraction of the rebuilding community.[2] In New Orleans, salvaged building materials find new life only through a small number of enterprising organizations that rely entirely upon independent coordination with contractors and homeowners.[3] For every house that benefits from the selective deconstruction offered by these salvage operations, hundreds of other houses end up in the landfill.

Figure 5: New Orleans' primary landfill, which abuts the Mississippi River watershed. Source: (Clouse 2011)

These houses add up. The Greater New Orleans Community Data Center has estimated that 134,000 houses, occupied at the time of Katrina, were significantly damaged due to the storm and are undergoing renovation.(Plyer 2012, 1) The contents of these buildings have become a heavy burden for landfills to shoulder, which are, not surprisingly, bursting at the seams. In the months after Katrina made landfall, the City of New Orleans was pressed to reopen geriatric garbage pits to accommodate this influx of trash, to the detriment of surrounding communities and ecosystems.

While this massive resource-dumping may finally have been staunched by the gift of time in New Orleans, the dearth of salvaged building materials undoubtedly caused longer gestation periods for rebuilders. Students from the architectural salvage research team wanted to highlight this unfortunate loss. Believing that any city in today's resource-scarce environment, rebuilding or not, would benefit from more progressive material salvage practices, they saw this research as a form of public outreach, improving communication about architectural salvage.

Figure 6: A process board developed by students. Source: (Keller 2009)

3.0 Methodology

I. Representation as Research

The first phase of the architectural salvage research project employed field identification and subsequently, representational modes of architectural inquiry. The mapping and diagramming that was used to both index this trash and identify material salvage operations constituted new and useful visual references for others to resource. Coupled with Alan Weisman's projections for waste,(Weisman 2008) students began to parse both the type and effect of each product. In deciphering the pile of debris, students learned about the qualities of those materials, including where they came from and would be going next.

As one might expect in peeling back the layers of an entire house, the quality, weight, volume and properties of each of these materials varied considerably. Contents ranged from the predictable to the bizarre: one set of drawers, two crutches, two sets of suspenders, one ball of twine, one bag of rusted nails and screws, one ball of fishing line, 500 linear feet of tongue and groove pine flooring, one box of glassware, two mirrors, several lamps, one fluorescent light, one singing big mouth bass trophy, eight strands of Mardi Gras beads, thirty-six hangers, one pair of lace curtains, one ceramic paperweight, three chairs, one bicycle, one bag, 150 linear feet of miscellaneous wood scraps, two solid wood doors, and two brooms. The students approached this mountain of material as a modern-day midden, dissecting the bits and cataloguing each piece accordingly.

During this representational phase, these material findings were then translated into a material resource map, material quality lists, and a photographic essay that helped to tell the story of the pile's contents. In doing so, the students capably illustrated their findings, rendering the information accessible to the public. At this stage one of the most useful drawings emerged: a map depicting the recycling stations for architectural salvage in New Orleans for citizens to reference.

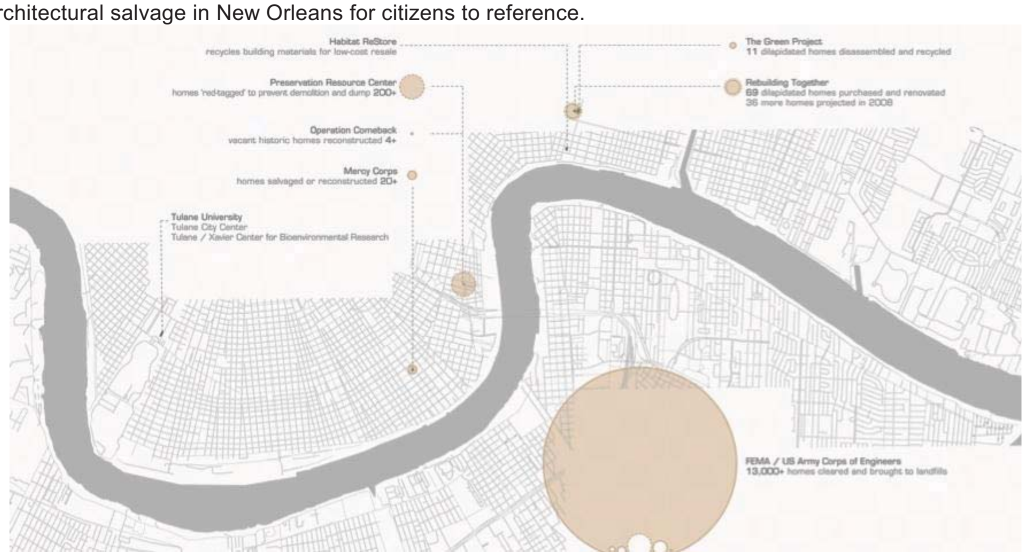

Figure 7: A resource map made by students for community use. Source: (Keller 2009)

II. Material Explorations

While the goal of this research was primarily to highlight the amount of trash generated by post-Katrina house gutting, a secondary intention was born out of the process itself. In parsing the data for the first phase, students stumbled upon appealing opportunities for formal design exploration. The project foregrounds creative re-use strategies for construction debris, which ultimately re-framed this research through the lens of material explorations (methods) and design|build.(Bonnemaison and Eisenbach 2009)

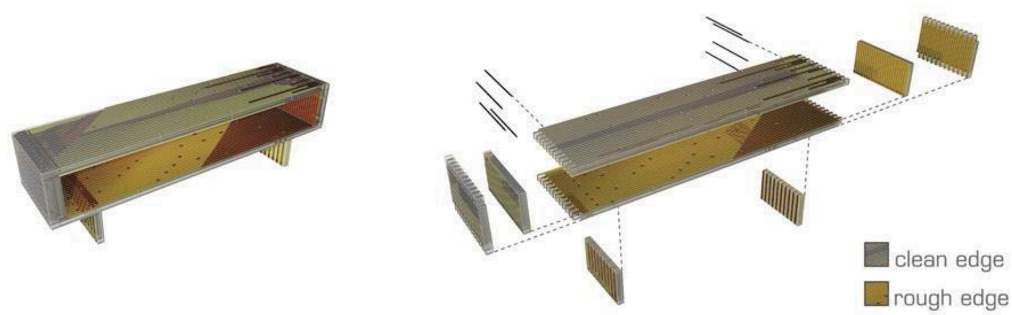

Figure 8: Design drawings for the student-fabricated furniture piece. Source: (Keller 2009)

After considering the possibilities revealed by each of the materials they uncovered, the students developed a design for a productive, upcycled physical object. In this case, it was a table that would illustrate the new potential embedded within old woodwork. This design was built entirely out of the materials found in the catalogued trash pile.

Figure 9: The end table on display for the community. Source: (Clouse 2011)

III. Community Engagement
This research culminated in a community-engaged design response. The student team identified two forums for their work, targeting community members who might be involved in the rebuilding effort in New Orleans. For a presentation at the *Focus The Nation Conference*, and later, an exhibit called *Salvations*, this team designed a poster documenting their process, a physical display (including the furniture piece) and propaganda that could be disseminated to challenge waste memes. In addition to highlighting the architectural salvage opportunities in post-Katrina New Orleans, the team also demonstrated a feasible strategy for upcycling material waste. The goal of this research thus changed; evolving from merely highlighting the amount and quality of trash generated by post-Katrina house-gutting to a commentary on the lack of a comprehensive building recycling program in New Orleans, inspiring ideas for direct action around the topic of material salvage.

4.0 Community Outreach
While not explicitly a community-engaged design process, the work of these students helped to illuminate the inherent opportunities for material salvage, ultimately inviting the public to take action. Their expressive diagrammatic design contributions, furniture, categorized materials, and maps of recycling yards were shared with the community at two public events. The team made this research available online, and using paper and beeswax also crafted hundreds of refrigerator magnets to serve as tactile reminders about architectural salvage, which were distributed for free to event attendees.

The challenging-but-necessary terrain of community-based design work makes academic exposure to the subject all the more critical. Mark Robbins contends that "it is our obligation as educators and architects to reveal the stunning complexity and nuances of community-based work,"(Pearson 2002, 2) whether through the lens of experiential education or by some other means. In the case of the material salvage research project, the simple act of *doing the work* had the effect of "simultaneously educating students in the realities of public service and educating communities about the value of design in achieving a positive future."(Pearson 2002, 13)

5.0 Lessons Learned
Tulane School of Architecture's student team found value in the garbage they inventoried, which led them to the conclusion that scrappers would benefit from a comprehensive building material recycling program initiated in New Orleans. This system could divert waste from overwhelmed landfills while providing the rebuilding effort with a plentiful source of high quality building materials. This kind of program would save energy and natural resources, create green jobs, reduce Hurricane Katrina's carbon footprint, improve the quality and diversity of the city's building stock, preserve the historic character of this city, and contribute to a smarter local economy.

For educators, this project demonstrates an effective model for research through experiential education, community engagement, hands-on building, and thorough material investigation. The architectural salvage research project, framed in terms of both research and advocacy, offers up a new model for architectural engagement. The deep field-based investigation of an issue, coupled with a more public and accessible sharing of findings, provides unique learning opportunities routinely neglected in a more traditional design studio curriculum. In researching material salvage through the context of a real-world problem, students were able to draw their own conclusions about the role of design in sustainable urbanism, community engagement and opportunistic place-based action.

In participating in a hands-on, community-based research project, students realized that engaged designers can become "key catalysts in shaping a positive future."(Pearson 2002, 5) This design activism demands professional re-framing, according to Patrick Coulombel, whose *Open Letter to Architects, Engineers, and Urbanists,* declared that "the profession of architecture must be reinvented to embrace a commitment to solving these fundamental problems of civil life."(Coulombel 2011, 291) Indeed, this type of design research project challenges students to develop an ethical attitude towards service-based practice that may mature and endure.

In the city of New Orleans, a man-made disaster was responsible for revealing the latent potential of public garbage flows. However, this issue-the problem of material waste and diminishing resources-transcends the geographic boundaries of the Crescent City. This project provides a proposition: that an inventory of endangered architectural gems, developed across regions and activated independently of crisis, could scale up to incite widespread environmental change.

Figure 10: A dumpster outside a typical gutted house in New Orleans. Source: (Clouse 2011)

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ENDNOTES

[1] Aristotle's oft-quoted experiential education view: "For the things we have to learn before we can do them, we learn by doing them."
[2] *The Green Project* has deconstructed several dozen houses through contracts, while *Mercy Corps* has finished at least twenty.
[3] *Mercy Corps, The Green Project, Habitat for Humanity* and *Rebuilding Together* are some of the organizations that specialize in building material salvage in New Orleans.

Articulating Cyber-History: Method-Based Historical Analysis and Problem-Solving

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ABSTRACT: George Santayana's adage, "those who cannot remember the past are condemned to repeat it" indicates a hinge between history and problem-solving, or the use of existing material and to create new solutions to contemporary problems. This paper articulates this aspect of applied history as "cyber-history" through analysis of research on historiography's emergence in Ancient Greece, finding correspondence with Michel de Certeau's concepts of productive consumption and tactical agency, and ending with possibilities for application to architecture curricula, rigorously fusing historical research, critical theory, and the projective work of the design studio.
The use of history as a guide for contemporary, projective activity has been apparent since its beginnings in the writings Herodotus and Thucydides documenting and seeking an understand of the events of the Greco-Persian Wars and the Peloponnesian War of the 5th century BCE. It is the nature of this *productive* aspect of history that cyber-history examines, specifically the production of new methods.
The work of Michel de Certeau provides us with a guide toward a creative/inventive history of practices, found in his distinction between strategy and tactics. *Strategy* is possible when the subject can be isolated from its environment and assume a proper place defined as its own. A tactic is activity that cannot utilize a *propre*, where there is no clear borderline to use in distinguishing an exterior party, or when the activity must take place in the territory of the other. Tactical discourse is suited for studying the production of design methods; if a project requires establishment of new ways of operating, then the designer has no *propre* from which to start. Cyber-history accesses the productive and inventive content of history, founded in a re-reading of Herodotus' movements and writings as fundamentally tactical, and continuing with adaptation of historical materials to similar method-generating experiments.

KEYWORDS: cyber-history, heuretics, Ulmer, CATTt Analysis

INTRODUCTION

The title of this paper should inspire several questions in the reader, the first being, 'what is cyber-history?'; skeptically followed by, 'why would we need such a thing?' The second part of the word *cyber-history* is familiar; *history* as research into and dissemination of information about the world for purposes of documentation, commemoration, and memory. History as memory is particularly important here, with the function of history as collective memory highlighting its use as a tool in learning, planning, and problem-solving, fueling George Santayana's famous adage, "those who cannot remember the past are condemned to repeat it" (Santayana 1922, 284). The aspect of historical research that engages contemporary creativity and problem-solving is focus of the present work.

The prefix "*cyber*" is recognizable because of its recent popularity but uncanny because its widespread use is evocative and not based on any specific meaning. Today, "cyber" evokes the vaguely digital, with cyberspace, cyber-art, and cyber-sex being digital, computer-based analogues of their physical counterparts. This prefix comes from the ancient Greek words *kybernân*, meaning "to steer", or *kybernet*, "stearsman/helmsman", and provides the root for the word "government". The root "*kyberne*-" comes to its present form and usage through the work of scientist Norbert Wiener, who used it to form the neologism *cybernetics*, his application of mathematical modeling to feedback systems of communication, response, and control. This fertile ground of work spawned developments in automation, artificial intelligence, and computing technologies, and also influenced researchers in anthropology (in the work of Gregory Bateson), sociology (Norbert Wiener's owns *The Human Use of Human Beings: Cybernetics and Society*) and economics (W. E. Deming). So, a *cyber*-history is not merely a digital history, but that specific component of historical research that is driven to utilize information from the past and present for decision-making and *guidance*. Its conceptual tools articulate the affective connections of persons to their environment that allow for the processing of information into materials suitable for creative work and invention.

This instrumental and highly pragmatic facet of history's use has been active from the beginnings of ancient Greek historiography, in the work of Herodotus, then Thucydides, who attempted to document and ultimately understand the world-changing events of the Greco-Persian Wars and the Peloponnesian War of the 5th century BCE. While their research became influential examples for countless writers, it was also used as practical information for later travelers and strategic material for further military campaigns, and many scholars believe that this application was one of the original intentions in developing the methods of historiography. The precise and collectively accessible memory provided by written empirical history has always been utilized for the production of *strategy.* It is the nature of this *productive* aspect of history that cyber-history examines.

This research contrasts with the usual concerns of historiography, namely the attainment of isometric relations between historically relevant information and its transmission. This makes it prudent to name the practices sought herein, to isolate it from and thus protect the work of conventional historical research. Cyber-history is not meant to replace history, as it could not be useful without the prevailing practices with conceits of objectivity, transparency, and propriety. Consequently, establishing the practices and values of cyber-history does not necessitate the avoidance of existing precedents in favor of obscure or more exotic material. If we wish to supplement established practices, then the use of familiar and accepted sources is necessary while also shedding new light on obscure territories.

1.0 TOWARD A TACTICAL HISTORY

1.1. Strategy vs. tactics

The work of Michel de Certeau provides us with a guide toward a creative/inventive history of practices, found in his distinction between strategy and tactics (de Certeau, 1988). According to de Certeau's representation of a classical military distinction, *strategy* is possible when the subject can be isolated from its environment and assume a proper place defined as its own. This proper place, or *propre*, serves the subject as a basis for conceiving relations with a distinct exterior, the objects of research. A tactic is activity that cannot utilize a *propre*, where there is no clear borderline to use in distinguishing an exterior other party, or when the activity must take place in the territory of the other (de Certeau 1988).

In tactics, fragmentary and heterogeneous elements are continuously manipulated to assemble opportunities, the agent constructing relative victories that cannot take place in a unified and stable space. Strategy, on the other hand, relies on the continued existence of a proper space with identifiable boundaries. Through this distinction, de Certeau presents us with an opportunity to reconsider the actions we perform in our field of study, indicating the possibility for a discourse that examines the multifarious production of 'ways of operating' (de Certeau1988, xix). For our purposes, tactical discourse is suited for studying the production of methods, and is far more appropriate for such a task than the object-based conceptual tools of history and criticism. To find examples on which to base a tactical inquiry of method as an alternative to object-based discourse, we can examine: Herodotus' *Histories*, Thucydides' *History of the Peloponnesian War*, and Xenophon's *Anabasis*, and the contributions made by each to early developments in historiography.

1.2. History and perilpous

Herodotus' *Histories*, roughly translated as 'inquiries' from the Greek word *ἱστορία* (Connor 1996), presented his investigation of the causes of the cataclysmic war between the Persians and the Greeks and possible explanations for the Greek victory in 490 BCE (Lateiner 1989). Herodotus traveled, questioned people of different Mediterranean cultures and gathered their stories together along with accounts of his experiences to produce a text that he called "a demonstration of his research" (Lateiner 1989, 7). In this aspect, Herodotus' 'history' is strategic, the communication to one's own culture of information about other people and their cultures in the context of events that must remain external to the investigator due to their location in an unseen past.

The nature of many of Herodotus' movements in gathering his material was also strategic, taking the established format of the *periplous* (Hartog 1988). For the ancient Greeks, the periplous was a circuit around the Mediterranean, beginning and ending in the same place, generally a safe port or the traveler's home. This is a kind of journey with a high degree of order and deliberation, and like any useful and identifiable typology, it is communicable and repeatable. The periplous also objectifies gathered information. Each element, whether descriptions of Herodotus' experiences or stories related by other informants, was placed in a specific physical location, relative to both the other elements in the collection and to a unified, Ionian geographic and cultural space. This objectifying tendency was common amongst Classical Greek historians, who privileged the solidity of the viewed object over the ephemeral quality of spoken or written language (Hedrick 1996). For early prose writers interested in documenting established truths, objectification was conceptual tool that allowed the author to sidestep this distrust of language. Greek historians after Herodotus would take the development of their craft along this tangent of objectivity for generations, following the empirical rigor of Thucydides, who generally avoided histories of the past, regarding reconstructions of all periods before his lifetime as mired in uncertainty (Lateiner 1989).

Thucydides attempted to remove uncertainty from historical method, focusing on his own personal experiences as a general in the Peloponnesian War. Cultural history, as attempted by Herodotus' inquiries into how and why the different cultures of Greece and Persia came to war, was abandoned as a project for at least a century after Thucydides focused the field of history on political and military narratives. After the popularity of Thucydides' *History of the Peloponnesian War* led to its widespread influence amongst historians in the 4th century BCE, historical accounts became annalistic, or focused on highly localized, singular events (Lateiner 1989).

1.3. Using Xenophon's *Anabasis* as a guide

Xenophon's *Anabasis*, written in the 4th century BCE, uses Thucydides' format of the first hand account to textually represent the movements of his army. But Xenophon's movements and their subsequent representation are exemplary for us in that they are almost entirely *tactical.* The *Anabasis* tells how 'The Ten Thousand', a group of Greek mercenaries hired by Cyrus the Younger to help overthrow his brother and take the Persian throne, made it out of enemy territory after Cyrus's defeat in battle. The title of the work ties it to the precarious situation of the men themselves, *anabasis* meaning a movement inland away from the coast. Unlike the *periplous* format, which stays along or close to the coast of the Mediterranean, the *propre* cultural space of the Greeks, *anabasis* as movement away from the known territory of the sea implies a venture into the unknown. *Anabasis* is mysterious, tactical, and profoundly inventive.

'Thálatta! Thálatta!', 'The sea! The sea!', is what The Ten Thousand shouted when they finally caught sight of their goal, the Black Sea. The sight of this sea meant they were near the colonial Greek cities strung along its coast, and they were one step closer to being out of enemy territory, and ultimately going home. It seems ironic that the majority of Xenophon's story of anabasis actually recounts movement *toward* the sea, or *katabasis.* But it is the tactical nature of the movements recounted that typifies the story: Xenophon documents the dynamic development of a 'how to', and in the process provides his readers with a manual for 'how to move' through enemy Persia effectively. Similarly, the value of Herodotus' immense work is not in its documentation of 'what happened', but rather 'how one finds it'. Herodotus, like Xenophon, is our guide through a territory so strange and harrowing that one must follow quite closely to reconstruct the journey (Purves 2010). When Alexander the Great invaded Persia in the 4th century, Xenophon's *Anabasis* was used as source material for military movements and ultimately for the writing of a new text documenting them: Arrian's *Anabasis* (Rood 2004). To follow only selectively, loosely picking and choosing material as one sees fit, as did Thucydides and Alexander, will produce a *different* path, and a new method.

2.0 HEURETICS: A DIGITAL RHETORIC FOR METHOD INVENTION

2.1. Invention in rhetoric

In the 17th century, the theologian Richard Burthogge wrote, "Ratiocination Speculative, is either Euretick or Hermeneutick, Inventive or Interpretive…" (Burthogge [1678], 48, quoted in Ulmer 2004, 33). It is only since the mid-16th century that *invention* and *method* began to be excised from rhetoric. The *method of invention* was, in classical rhetoric, seen analogically as a visit to the places or *topoi* of the topics to look for a statement (Ong 2004). Scholastic reforms in the 16th century linked method with *doctrina*/teaching and theory within a structure of logic that was formal and spatial. The space of this logic was highly abstract: it was conceived as being analogous to the space of geometry, creating the possibility of topics that can become arguments transformed into *scientific instruments*. This discursive space is the abstract space of the diagram: it is visual and comfortingly quantifiable. *Inventio* and *dispositio*/arrangement, displaced from rhetoric to a logic that is profoundly visual, become conceived by analogy with visually perceived spatial patterns and diagrammatic spatial arrangements (Ong 2004). The neat placement of discursive content in a geometrically stable space, a diagramable space, makes discursive movement a matter of hermeneutics, the logic of interpretation. Consistent with the removal of invention from the systems of logical discourse, the study of discourse interpretation (especially that of written discourse) has gathered a great deal of study under the heading *hermeneutics*, with sources and examples spanning from antiquity to the present, while its contrapuntal neologism, *euretics*: the logic of invention; has been forgotten and has yet to generate a field of its own to guide speculation.

2.2. From hermeneutics to heuretics

"Euretics," from the Greek "eureka"- I've found it!- the exclamation famous for being shouted by Archimedes during his naked run through the streets of Syracuse after having discovered the means to calculate density using volume while sitting in his bath, has recently been explored by Greg Ulmer to develop a rhetoric for digital media. Just as the film camera incited a wave of method invention in the early 20th century, digital media that includes the capability for working with text, image, sound, and movement simultaneously and rapidly through a common base of binary code, transforms media into a fecund invention apparatus. Just as writing enhanced humanity's memory, granting freedom to develop increasingly abstract systems of reason, digital media is a powerful prosthesis of human intellection. But unlike the written word, little has yet been done to establish a system of rules tuned to the rigors necessitated by digital media. Ulmer's *heuretics* is meant to be the speculative production of such rules: a digital rhetoric.

Hermeneutic discourse treats the interpretation of, or the finding of meaning in, extant materials through selective rearrangement of their parts to construct a new discursive document. This method uses extant works to produce new theories, concept, and arguments that establish value through their precedents. If there is a new problem that will require a new way of working to find an adequate solution, we need to invent this new way of working: we mush invent a new method. Heuretics will need to provide us with a way to invent new methods, to supplement the tools of Hermeneutics. Thus, the relevant question that guides heuretics is not the same as that which guides hermeneutics and criticism. Instead of asking "What might be the *meaning* of an existing work?"; the question guiding heuretics is: "Based on a given theory, how might *another* text be composed?" (Ulmer 1994)

2.3. The CATTt Generator

Hermeneutic logic must come after the heuretic moment of invention, for its goal is to see what has been made, and it treats the making process itself as something other, as coming from some other logic or discourse (Ulmer 2004). To better understand the process of method invention upon which heuretics is based, Gregory Ulmer examined the Western tradition of the treatise on method, from Plato's *Phaedrus*, through Descartes and up to Breton and the avant-gardes, to find common operations or elements; this collection forms what Ulmer calls the CATTt Generator (Ulmer 2004).

There are five components in the CATTt Generator, one for each letter. The first is a *Contrast*, a discourse, field or method known and a desired divergence from it. The inventor must begin by moving away from an undesirable example whose features provide an inventory of components made valuable through determining their exterior (Ulmer 1994) The second component is an *Analogy*, a discourse or method from some other field that offers a model for a successful way of working (Ulmer 1994). Next is *Theory*, a rigorously developed methodology from the creator's working discipline used primarily to offer weight and substance to the new creation.

> …[T]he theorist generates a new theory based on the authority of another theory whose argument is accepted as a literal rather than a figurative analogy. The new theory will include in one register a literal repetition of a prior theory…. (Ulmer 1994, 9).

The next CATTt components is a *Target*- the intended audience. The inventor must have an intended area of application that the new method will address, frequently identifiable in terms of the needs of an institution that desired the new method (Ulmer 1994). The final component is a final presentation format, forming the *tale* or *tail* of the CATTt The *tale/tail* is there to remind the inventor "that the invention, the new method, must itself be represented in some form or genre" (Ulmer 1994, 9).

André Breton's 1924 *Surrealist Manifesto* serves Ulmer as a relay, an example of how to appropriate a theory for the design of a method. The manifesto format, understood as a combination of narrative and argumentative essay formats, is taken as belonging to the tradition of the discourse on method (Ulmer 1994). Ulmer's proposal is to invent an electronic writing in the same way that Breton invented surrealism or Plato invented dialectics. To quickly illustrate how to identify the CATTt components in a treatise on method, Ulmer identifies Breton's components as: contrast- realist/naturalist literature; analogy- dreaming and scientific experimentation; theory- Freud; target- family and entertainment institutions contacted via changes in artistic practice; tale- manifesto (Ulmer 1994).

Using the CATTt Generator for analysis in this way underscores the fact that it is a simulation of *inventio*, the conditions of invention, and not the conditions themselves (Ulmer 1994). The conditions of invention, or what *actually happens* in the human brain to produce some new socio-cultural material, are as of yet only vaguely understood, approachable with a seemingly infinite array of research frameworks. The five CATTt components act as a simulator of the inventive act, mapping invention onto an experimental structure. The CATTt Generator allows an invention rooted in a particular historical and cultural moment, such as surrealism or modernism, to be simulated in a new method experiment that is easily documented and repeatable (Ulmer 1994).

CONCLUSION: CATTt ANALYSIS IN THE ARCHITECTURE STUDIO

The CATTt Generator is used to simulate *inventio*, the complex and obscure contingencies of invention, in method production. Just as Ulmer analyzed historic discourses on method to formulate the CATTt, it can in turn be used as a concise tool to analyze instances of historic method production. CATTt analysis is particularly well-suited to the pedagogy of the architectural design studio, offering a conceptual tool that can engage both architectural history and design, and decrease student anxiety by articulating the agency of the designer in method production. CATTt analysis places the student in the role of de Certeau's productive consumer. For de Certeau, consumption is devious and ubiquitous:

> It [consumption] insinuates itself everywhere, silently and almost invisibly, because it does not manifest itself through its own products, but rather through its *ways of using* the products imposed by a dominant economic order. (de Certeau 2002, xii-xiii)

In the studio, the student is asked to consume history as information used *toward the production of new work*. This is not a hermeneutic task, where the student as receiver is to decode a message sent by the teacher, but rather an activity where the student must use inference to fill a gap. The gap is a part of the assignment that cannot be conveyed by the teacher but nevertheless must be provided by the student, namely an individual method of production, the produced design project being an instance of that method.

CATTt analysis begins in the studio with the selection of a building to study. This can be relegated to the students, in which case they should choose a building in which they have personal interest and is sufficiently well-documented, or can be organized by the teacher. The number of buildings analyzed, and whether or not they are considered to form experimental sets, will alter the results of the studio, and should be carefully considered beforehand. The students then research the buildings, the narratives of their commission, design, and construction, their citations and discussion as exemplars or topics in criticism and architectural theory, and possibly their appearances in popular culture, attempting to formulate the most likely content for each component of the CATTt. Presentation of the CATTt analysis and studio discussion is documented by each student in a multimedia assemblage (a website is appropriate, but physical formats could also be prescribed effectively) containing the operative materials identified through their analysis. Gathering these assemblages together in a collective database of findings concludes this stage of the project.

Once the students have familiarized themselves with history, theory, and criticism of architecture through their analytical use of the CATTt Generator to simulate the *inventio* of precedents, they can begin using the CATTt Generator projectively, to *produce* a method to design a new architecture. Students can be provided with a program, site, clients, etc, in the manner familiar to studio pedagogy. Each student is then free to raid the CATTt database for the most appropriate components to apply to the new experiment in method production, carefully documenting the role played by each chosen component. If the professor is interested in pursuing this trajectory in the production of architectural poetics, each student can also begin mapping their own design *inventio*; A series of assignments can direct each student to identify their affective relationship with their chosen field of study and profession (Ulmer 2003). Armed with a collection of *inventio* simulations, the student has an index of architectural tactics, the value of each to be determined through their application to cross a gap, solve a problem, or produce the appropriate design amidst the dynamic contingencies of practice.

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The Moving Image: Research + Design Process

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ABSTRACT: As consumers and communicators of visual narratives, conducting film (cinema and digital video) research and filmmaking as an integral part of the architectural design process supports the designer's ability to develop and communicate architecture's narrative content. A film and architecture theory seminar and undergraduate design studio considers how film narrative is structured, multiple events through time are juxtaposed, and point of view is communicated. Film is not used as an illustration-in-motion of design projects but as the intellectual core intention of design process.
The author briefly introduces issues of place-making through research evidenced in the construction of the author's own film work, and how that work helps frame pedagogy. In the classroom, while film research, analysis, and practice are key components establishing design tactics, the foremost goal is developing visual literacy - for whom is the story told, why, and how is that story communicated? This question allows for discerning perceptions and depth of reflection. Three studio project themes are developed through film analysis and making: The Horizon Line, Dreams and Materiality, Action/Engagement and Consequences. This essay considers the studio process by examining Alain Resnais' *Hiroshima Mon Amour;* Alejandro González Iñárritu's *Babel* Terrence Malick's *Days of Heaven*; Maya Deren's *Meshes of the Afternoon*, and Michael Hanake's *Caché* with student work referenced. Studio self-initiated gallery installation and symposium leads the author to a contemplative conclusion regarding the promise and efficacy of film research and making in the architectural design process.

KEYWORDS: Film Research, Filmmaking, Design, Pedagogy

INTRODUCTION

A film (cinema or digital video) presents a story through subjective lenses- that of the filmmaker, and the viewing audience. The texture of a street surface, the building fabric of a city, storm clouds moving across a landscape, the quality of a mid-day sun that marks a house, a room, a wood floor, a face, can be understood as a system of inter-related parts telling a story that we, the viewers, interpret. One may identify with a story's protagonist, project individual desires onto a landscape, or imagine one's own possibilities in the narrative unfolding. In architecture practice, film (in this essay film is used as an inclusive term encompassing cinema and digital video) is often used to communicate and market work. While it is not unusual to use the art of film to study visual framing of place, issues of lighting, or to consider film editing as means to explore tectonic connections, this essay will focus on how film montage (images connected sequentially) presents our world to us, and, in turn, how the contemporary designer through observation and dissection of filmic information mirrors or challenges the times in which he or she designs. The goal of film analysis and filmmaking as a methodology for designing is simply to ask how our collective environment is interpreted and conveyed- by whom and for whom, and with what means? The process of answering this question elicits additional questions regarding context: culture, politics, community, and personal experience. Understanding visual information requires visually literacy. Visual literacy includes the syntax of images such as composition, scale, how content is communicated and interpreted inclusive of the cultural construction of communication. Because visual information is often interpreted through a cultural lens quite different than that of the image-maker, visual literacy includes negotiating what one may understand a priori to the observation with what one sees as a film sequence of images unfolds. The ability to question spatial configurations between characters, or characters' gestures or placement in a landscape, requires that those visual spatial constructs need to be actively "read", interpreted, and re-negotiated by the viewer with respect to cultural signs and the filmmakers point of view. By becoming visually literate, the designer discerningly perceives and assigns meaning to the world, and, in turn, may act more forthrightly as environmental maker and communicator.

1.0. FILM: ANALYSIS + DESIGN PROCESS

1.1. Intentions

I am a designer working with film as the core medium with which to perceive and understand the world around me. A 'story' of a place may not necessitate that I design a specific intervention but, first, affirm a 'story' through a film interpretation. By producing short films, my goal is to interpret place beyond the literal representation of street or façade, but rather consider place as a construct relying on a human dynamic where street and façade are malleable, experienced viscerally through character, and through memory over time. This dynamic can best be understood through inference, the imagination- fusing fiction with fact. It is how we practice life in the everyday because over time we accumulate images, we hold images suspended in our memory, and we act upon those images in concert with the temporal condition of our lives. How does one interpret images of the past in one's own time, and how do we communicate our intentions through images within our time? When designing space, how is the individual story constructed, how is the collective story constructed? How is architectural place narrative constructed- for whom and why? My investigations of these questions lead to developing pedagogy for the classroom.

For this essay, I will describe film sequences from historic and recent works: director Alain Resnais *Hiroshima Mon Amour*; Terrence Malick's *Days of Heaven*; Maya Deren's *Meshes of the Afternoon*; Alejandro González Iñárritu, *Babel*; Michael Hanake, *Caché,* and their relationship to studies conducted in a film and architecture theory seminar, and an undergraduate design studio. Specific details of montage (edited sequences) are isolated to discuss the multiple sensory observations heightened while viewing film. Montage details are differentiated by themes: Horizon and Time; Materiality and Dreams; Action/Engagement and Consequences as explored in the final project. Student work is referenced within the discussion of a film sequence, as that is the pedagogical process: analyzing films, and then approaching a design problem. I conclude with a discussion of the architectural studio's self-initiated gallery installation and department symposium. Actively engaged in film analysis and making while processing design, the studio posited the question of engaging film research and filmmaking as an integral part of studio process to the architecture department. In part, film analysis and interpretation leading to architectural space making allows creative opportunity to be free of assumed prescribed design restrictions. This conclusion is a reflection of the pedagogical process as the gallery installation, self-directed by the students, proved to be intellectually compelling and inventive, perhaps more so than some of the architectural projects often bogged down by perceived notions of architectural practice.

1.2. Discussion: Analysis

Architecture and film are, of course, not literal equivalents. Rather, film observation and analysis pose questions to broaden the intention or point of view of the architectural designer while in the process of designing. Each of us has a story to tell, and we do so through casual conversation, email, or through particular modes of creative expression. In *Time and Narrative Volume 1*, philosopher Paul Ricoeur's monumental work on narrative and temporality, Ricoeur eloquently states, "We tell stories because in the last analysis human lives need and merit being narrated" (Ricoeur 1984, 75). While Ricoeur is referring to literary narrative, the same sentiment applies to the visual narrative, and to the built environment. Indeed, an image may be more powerful a storyteller than the written word, as it is 'physical' evidence of a life lived, of flesh made visible by means of light on celluloid or projected through digital bits. And a physical construct simultaneously tells the story of its inhabitants and its own story as an object built of a time existing through time. History, ecology, culture, politics, economics, human psychology, materiality are leading characters in architecture's narrative plot.

2.0. THEME: THE HORIZON LINE AND TIME

From the Studio Brief: Create a short film. Use your own footage with archival footage to explore the *Horizon Line*. Consider: *Personal Space / Public Place; Cultural Space*; *Physical Space / Place; Emotional Space; Perspective defined by a frame / a boundary*; *A view outward defined by its opposite and vice-versa*

2.1. Films and Project Response

Theoretical implications of film montage (images sequenced through time) have been well considered since the early twentieth century. Russian director and theorist Sergei Eisenstein in his essay *A Dialectic Approach to Film Form* coined the term 'montage' or the assembly of images. Gilles Deleuze's work *Cinema 1* and, especially, *Cinema 2,* a rich inclusive discussion of filmmakers such as Eisenstein, Rosellini, Hitchcock, Goddard, Resnais considers how time and image may be negotiated. Deleuze's discussion necessitates the reader view the work of filmmakers noted. I am still journeying through Deleuze's volumes and films. For this section "The Horizon Line and Time", I will discuss a sequence from two very different films: *Days of Heaven,* directed *by* Terence Malick, and director Alain Resnais' *Hiroshima Mon Amour,* with respect to plot, camera techniques and time in each film's narrative structure.

2.2. Days of Heaven

Circa 1910: Itinerant workers travel from Chicago to the Texas panhandle during harvest season. Lovers Bill (Richard Gere) and Abby (Brooke Adams) pretend to be brother and sister to ingratiate them to a wealthy farmer (Sam Shepard). The film's narrator Linda (Linda Manz), Bill's sister, tells the story of these events that have past. For the viewer, events unfold through one character's point of view. We could consider, as the fictional character Linda perceives and conveys the narrative plot, the filmmaker may indeed be just a conduit for her story. Malick's careful visual and aural articulation of the landscape results in far shots (wide expanse with deep perspective) to close detail: the sound of tall wheat swaying plains, a red evening sky, grouse crunching long stalks and earth beneath their feet, the growth of a flower from seedling to full bloom.

The camera's focus on specific elements in the environment highlights the relationship the viewer has to the environment depicted. The horizon is a literal horizon; the camera position underscores the vastness of landscape as the horizon 'line' cuts the screen frame often in equal parts. The landscape's endlessness is a metaphor for the characters desire for freedom and, simultaneously, the endless terror of their less than ethical predilections. In Figure 1, migrant workers arrive via wagon and pass through the gateway of the farm. The physical horizon is seen in the background; the filmic horizon line is held at the center of the frame. The camera tracks the wagon train. The wagon train moves towards the right of the frame as the camera tracks toward the left enabling the sense that the horizon is stretching beyond the screen frame or boundary.

Figure 1: *Days of Heaven*, Terrence Malick. (The Criterion Collection, Paramount Pictures, 1978)

In the last frame of Figure 1 the farm gateway dissolves as the farmer's mansion appears (an editing transition or cross-dissolve). In the endless landscape of wheat stalks, the farmer's Victorian house sits slightly above the rest of the land, and is usually centered in the frame. Media historian Anne Friedberg in *The Mobile and Virtual Gaze in Modernity*, referencing Michel Foucault's work, *Discipline and Punish: The Birth of the Prison,* discusses Jeremy Bentham's 1791 panopticon device, an eight-sided space (often a tower) in which the center sits an overseer, unseen from those jailed. The overseer sees everything– a relationship that establishes power through surveillance. In *Days of Heaven*, the farmer visually sees everything from his central perch, but he does not *perceive* the real intention of the two lovers.

Malick's handling of the landscape functions at multiple scales: the materiality of the landscape, and the landscape as metaphor for the protagonist's perceptions and actions. As the narrative plot continues, the farmer discovers the ruse of Bill, Abby and Linda. As locusts consume the framer's wheat crop (Fig. 2.), the farmer starts a fire to stop the locust plague that will, of course, destroy his land. The last shots of the fire sequence present a band of orange yellow fire at the horizon line. The Horizon Line holds the promise of freedom but is imbued with each character's ambition destroying land and lives. Purposeful framing and camera movement may be fairly obvious, but the number of subjects or objects that move back and forth across the frame and against the direction in which the camera is tracking heightens our sensitivity to the multiple layers of the narrative plot that includes the landscape as a prime character.

Figure 2: *Days of Heaven*, Terrence Malick. Source: (The Criterion Collection, Paramount Pictures, 1978)

2.3. Hiroshima Mon Amour

Film is a temporal medium as is architecture. Place is experienced through time; architectural materials change through time. In a film narrative, time and memory depicted enables an audience to experience multiple events unfolding in the present-time, or, simultaneously, in the past, or future.

Director Alain Resnais' 1959 "Hiroshima Mon Amour", with a sparse and beautiful script written by Marguerite Duras, is one of the first of the New Wave French Films developed in the 1960's. The film takes place in Hiroshima, Japan, and addresses the horrors of the aftermath of the Hiroshima bombing and, simultaneously, the tragedy of a woman caught in the European War Theatre during World War Two. Lui (Eiji Okada), a married Japanese architect, and, Elle (Emmanuele Riva), a French actress from Nevers, France become lovers while Elle is in Hiroshima to act in a peace film. Both characters (He and She in English) are caught in their own personal history and remembrances while experiencing each other in the present moment. Each character threads the present through his or her past. *Hiroshima Mon Amour* is one of the first films where different points in time and place are juxtaposed seamlessly without dialogue pronouncement from a character. The audience negotiates a different landscape from the previous one seen as Resnais sequences Nevers with Hiroshima. Lui and Elle refer to each other with their respective place names: she to he, "Hiroshima", Lui to Elle, "Nevers". In *Cinema 2*, Gilles Deleuze asks of their relationship "Is this not the way for each of them to forget his or her own memory, and make a memory for two, as if memory was now becoming world, detaching itself from their persons?" (Deleuze 2003, 118). Here the Horizon line is an internal construction moving through remembrance, through time- the Horizon has a z dimension to the screens literal flattened dimension. Resnais uses tracking as a means to depict remembrance as a fluid continuum, as a spatial construct. As the characters' voice over spoken in the present (of cinematic time or film-time) calls out the place name of the other, Delueze refers to these memories as sheets of the past, and Resnais tracking shots as "continuums, circuits of variable speeds" (Deleuze 2003,119). Each character's experiences are not in chronological order as remembrances move forward to the present, and the present is experienced via the past. In this way, experience or events are continuously transformed- they are elastic.

Figure 3: *Hiroshima Mon Amour*, Alain Resnais. Stills from a sequence. Left frame: Hiroshima; Far right frame: Nevers. Source: (The Criterion Collection, Paramount Pictures, 1959)

Architecture student (Fig. 4) addresses issues of time as well as materiality in his video installation. Two monitors are placed facing each other. Each monitor presents a film of a person speaking. The characters, in separate films /monitors, each speaks a language the other does not understand. The films are viewed through a sheet of ice placed over the monitor. The ice slowly melts through the time of the installation presentation. At first, context and content are the same: the image is blurred, and communication between the two is strained. As the ice melts, images become clearer, and, over time, gestures, tonal nuance become familiar territory for the two characters as they begin to understand each other.

Figure 4: Student Work; left and middle: Video viewed through sheets of ice; Right: Video Installation (2009)

3.0. THEME: MATERIALITY AND DREAMS

Studio Brief: An element of the first film, The Horizon Line, is further developed. As a point of departure, consider two characters (literal or abstract) engaged with perceptual illusion and emotional resonance and/or illusion and cultural expectations. Create a short film and a series of study models (4-D: 3-D+time).

How we observe and interpret our experience while viewing a film is not a passive engagement but an active one as we negotiate our point of view with the point of view of the filmmaker. Film theory discourse regarding the cinematic "gaze"- the objectification of the subject (more pronounced regarding gender roles) on the screen addresses society's power politics. Through camera angle and placement on the screen, the subject places, us, the viewer, directly in that power discourse. When a subject is filmed depicting a vulnerable condition, we are often voyeurs upon the screen scene. As viewers we consider our relationship in space vis-à-vis the placement of the subjects on the screen.

Figure 5: *Babel*, Alejandro González Iñárritu. Source: (Paramount, 2006)

3.1. Babel

The last sequence of events in director's Alejandro González Iñárritu drama *Babel* is compelling. It is the denouement of the film's tripartite narrative plot. Indeed, the power of the "gaze" is exemplified in this last sequence as the subject / object relationship between viewer and characters unfolds. The camera frames, at a one-point perspective, at our eye level, a young women in profile standing naked at the edge of a balcony. As her arms, in tension, are held close to her body she is comforted by her father. We have come to know, through the film's textual and visual narrative, the woman is daring and fragile. The camera holds her at the center of the frame, slowly zooms out to reveal similar balconies of high-rise apartments– the urban fabric of Tokyo at sky level contains and mirrors the fabric of lives living in every apartment (we may surmise). An evening Tokyo skyline is articulated with steel structure and exposed joinery, with glowing transparent interiors. The overall hue is a deep blue while each apartment's yellow glow stops at a glass edge.

Modernity has created familiar territory for viewers of this 21st century Tokyo: steel and glass structures with streamlined articulate interiors of wood, plastic, and metal furniture, each room lit floats in the Tokyo night. At this moment, the young woman and her father are the only figures on a Tokyo balcony spatially extending the apartment interior connecting to every other Tokyo balcony enveloped in the night. The daughter and father's circumstances connects the human story to the architecture that contains their life, mirrors it, and allows us to consider what future consequences may evolve beyond the frame of the screen. Our conjecture beyond the narrative we are witnessing, within our own imagination, is the scene's power.

Figure 6. Final tracking and zoom in *Babel*, Alejandro González Iñárritu. Source: (Paramount, 2006)

Our "gaze" at close up is upon the naked woman, slowly stretching the experience of time passing as only film time can accomplish- through the camera lens. As the camera tracks back and zooms out, the city, too, is caught in our gaze. This is a beautiful and uncomfortable relationship we have to the characters and the city. Tokyo's architecture is not a passive container of events it is a living character for the viewer to negotiate, as do the film's characters. The specifics of the camera technique, the editing of the previous scenes (more frenetic pacing than what unfolds in this scene described which is slowly paced), the ability to connect technique, set, and pacing with character development, establishes our interpretation and understanding of the narrative. While film or cinema's connection to architecture is often relegated to a discussion of sets, or visual effects, -the ability to dissect specifics of a film's visual and aural montage, the camera technique used, and the editing structure of the montage allows us, architects, to consider how we tell our stories through design.

3.2. Meshes of the Afternoon

Meshes of the Afternoon, 1949-1959, is early independent filmmaker Maya Deren's surrealist self-reflective visual and aural (sound without text) experimental film. Deren challenges the viewer with highly personal symbolic imagery referencing Freudian psychoanalysis. Deren represents herself in the film- she is the main protagonist. The mysterious mirror faced character (Fig. 7) dressed in black carrying a white flower appears at intervals throughout the film. One could interpret the figure as Deren's nemeses, spiritual power, or her soul leading her, even taunting her as she struggles for self-identity.

Figure 7. Film still, *Meshes of the Afternoon*, Maya Deren. Source: (distributed by Mystic Fire Video, 2002)

Meshes of the Afternoon does not contain dialogue. Sounds composed and performed by Teiji Ito do not reflect how the object would actually sound, rather abstract sounds made by Japanese string instruments and isolated percussive instruments are heard. In the scene depicted in Figure 8, a key- in slow motion- falls down the stone stairs: sequential frames 3-6 presented in Figure 8 are each two frames apart, whereas frames 1 and 2 are 150 frames apart. Those 150 frames depict Deren at the door opening her pocketbook. The key, in slow motion, drops down the stone stairs accompanied by a loud percussive tin sound. Musical sounds speak for the characters and signal events that occur. This heightens our awareness of everyday objects, and heightens our anxiety as the film montage unfolds. Without the benefit of a traditional script, our interpretation of the film, through visual and auditory narrative, elicits a more personal, intimate, response. Figures 9 and 10 presents two student responses to "Materiality and Dreams".

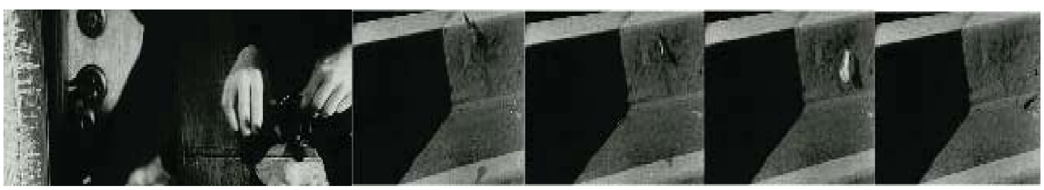

Figure 8. *Meshes of the Afternoon*, Maya Deren. Source: (distributed by Mystic Fire Video, 2002)

Figure 9. *Self-Portrait* **Figure 10**. *Objectivity/subjectivity:* Materiality and light

Student work (Fig. 9) compresses the ability of the self to see beyond the frame. Figure 10, is a thesis design of an art gallery. Light quality and materiality establishes the sequential rhythm through gallery spaces.

4.0. THEME: ACTION/ENGAGEMENT AND CONSEQUENCES

4.1. Studio Final Project

Project: "The 13th Floor"- 2100 sf. Two elements: a residence for a visiting scholar; a space for students or faculty (including a café); design intentions need to reflect the studio designer's filmmaking process.
The design studio considered the 13th floor (a floor unmarked in high-rise buildings) as an addition to an existing campus building. Using films researched, readings, and reflective essays, making films and physical projects, student interpretations included a parasitic component to the existing historic building. Figures 11 - 13 presents three projects: the 13th floor as a parasite resting, consuming, puncturing the building, or able to break off and find another host. Figure 13 presents light emitted in the landscape giving the illusion of a floating construct. However, when approached at different times of the day the structure is visible breaking the continuity of an academic quad.

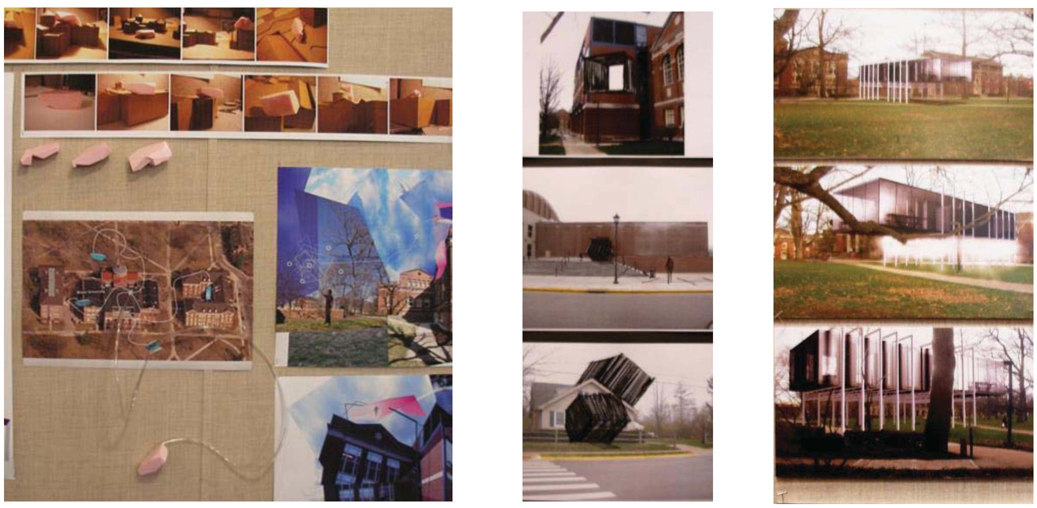

Figure 11-13. Undergraduate Design Studio –the 13th Floor

5.0. CONCLUSION

5.1. Reflecting on the Gallery Installation, and Student Symposium

Film research and filmmaking informs each designer's point of view and informs the assemblage of a project's parts- a physical manifestation of the intellectual content. Overall, my critique suggests that the final project product may not have been more measurably stellar than traditional studio methodology within the year of the studio. However, the intellectual engagement and processes explored resulted in participants challenged by larger issues of cultural place making with respect to interpreting visual (and aural) information in a story told. Participants learned to address visual work through a more critical lens, and similarly address their own design process. They engaged in previously untested processes- they took personal risks as makers. In that spirit, the studio initiated a gallery installation and accompanying symposium. My role was simply to get out of the students way, which I was very happy to do. This essay concludes with images of the installation and symposium.

5.2. Caché

In Michael Hanaeke's film *Caché* (Fig.14), a Parisian television personality Georges Laurent (Daniel Auteuil), his wife Anne (Juliette Binoche), and son Pierrot (Lester Makedonsky) receive a series of videotapes with menacing morbid drawings that reveal the front exterior of their house under surveillance by persons they do not know. After receiving a number of tapes, Georges becomes highly nervous that his past history will be exposed. During the French occupation of Algeria, a young Algerian boy Majid (Maurice Bénichou), whose family was murdered during the 1961 Paris massacre, lived at George's family farmhouse. George now comes to believe that his past betrayal of Majid is at the core of the sinister tapes and drawings, and seeks to find Majid. Perpetrator and victim are constantly changing roles in *Caché*.

Figure 14. *Caché*, Michael Hanake, Source: (Sony Pictures, 2006)

5.3. Gallery Installation, and Symposium

Partially influenced by the narrative plot of Michael Haneke's *Caché,* the studio placed cameras and monitors at various building locations. Spaces chosen reflect pedestrian traffic, richness of multiple sound sources or varying degrees of quietude. Cameras and monitors were placed to highlight difference in scale regarding close-up, middle ground, reflected and projected light, and silhouette as part of the installations place making narrative. In the monitors, visitors saw themselves and negotiated other filmic events occurring simultaneously in the building. During the week of the installation, past images filmed were viewed in present time. While the studio brainstormed the installation thesis, much of the event specifics unfolded during the process of installation, filming, and re-filming captured images. The department wide symposium allowed for a reflection of the gallery events as the students sought to generate conversation regarding department studio pedagogy to include film research, and filmmaking in the design process. Film research and making continues for these designers

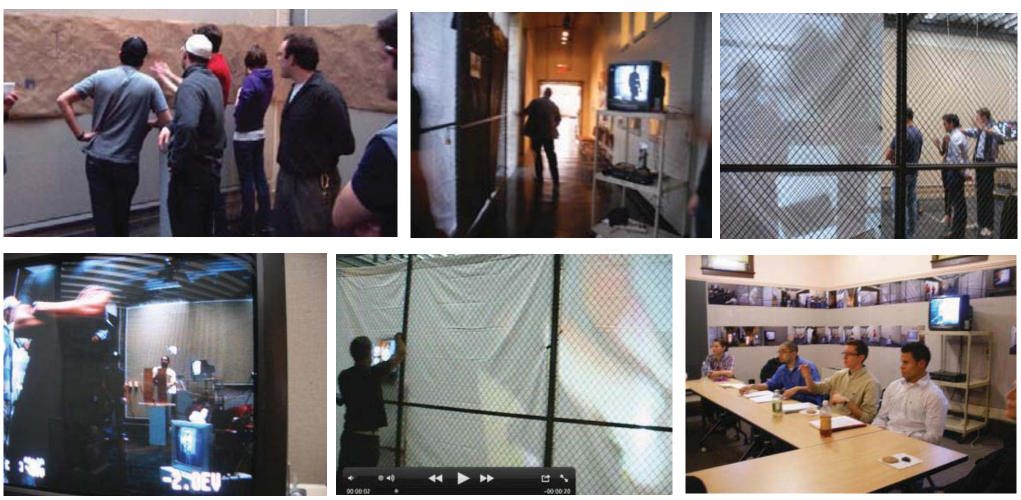

Figure 15. Top left: Studio Installation Workshop; Top middle to bottom row middle: Gallery Installation; Bottom right: Student and Faculty Symposium Session

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Visualizing Performance: Research Based School Design in Mazar-i-Sharif, Afghanistan

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ABSTRACT: This paper presents research conducted by graduate architecture students participating in the design of a school in Mazar-i-Sharif, located in northwest Afghanistan. During the course of a ten-week studio, students developed recommendations for improving the Afghan Ministry of Education standard school design. Achieving a higher level of performance for these institutions would enhance the overall student experience and potentially increase enrollment capacity. This paper sheds light on the benefits and advantages of architectural research and design in an area of development where architects typically do not participate. This project also demonstrates the influence data can have on the design process, and illustrates how students can visually communicate complex information resulting from research to others.

KEYWORDS: Afghanistan, Pedagogy, School Design, Development

INTRODUCTION

Major cities in Afghanistan have experienced unprecedented population growth in the past ten years due to the return of refugees, soaring birthrates, and the migration of people from the countryside to urban areas. The population is increasingly dominated by youth, with almost half under the age of 14. (UNdata, 2009) Of this group, only 50% are currently enrolled in school, with a still smaller percentage represented by female students. (UNdata, 2009) However, by 2020, the Afghan Ministry of Education plans for basic education enrollment to increase to 104% for boys and to 103% for girls. (Ministry of Education, 2012) The demand for schools is high in Afghanistan, causing overcrowding, and the necessity to operate on a shift schedule in order to increase enrollment. This problem is further exacerbated by the practice of closing schools during the coldest part of the year, in response to a lack of funds for fuel and poorly insulated classrooms.

Several international aid organizations are working with the Afghan Ministry of Education (MoE) to build schools around the country, and while many of these projects follow the standardized construction documents provided by the government, the actual performance and construction of these schools leaves much room for improvement. (Faureau, Jarny, & Dezuari, 2010) The standardization of details and form attempt to impose a uniformity of product, and mitigate life-safety hazards, but the school typology does not require a response to issues such as orientation, climate, or local needs.

Figure 1: Typical Afghan Ministry of Education school.
Source: (Ayni Education International 2011)

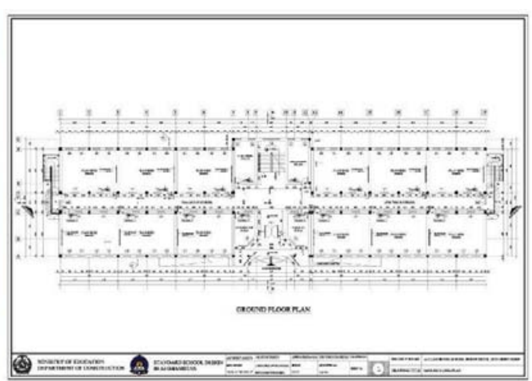

Figure 2: Afghan Ministry of Education school plan.
Source: (: Afghan Ministry of Education 2012)

In short, the schools meet some very basic requirements, while others are not considered. Despite its shortcomings, the standardized school typology in Afghanistan has been an important tool for facilitating school construction across the country in recent years, and will most likely be the primary model used for future educational infrastructure. (Fig.1 and 2)

This paper sheds light on the benefits and advantages of architectural research and design in an area of development where architects typically do not participate. Moving beyond the bare necessity of providing a roof over students' heads is a challenge, but even small improvements to construction and minor adjustments to local conditions would allow MoE standard schools to better serve students and the communities where they are located. With the goal of designing comfortable, flexible, and culturally connected schools, the overall quality of the student experience can be improved, and also allow for a planned increase in enrollment. It is a critical time for Afghanistan's youth, and every opportunity for positive change should be capitalized on, especially within the education system.

I. PROJECT DESCRIPTION AND METHODS

I.I Project Description

The research outlined in this paper uses the standard MoE school as a point of departure for new school designs featuring critical improvements. Architecture students at the University of Washington–using an actual school project as a subject of design research–have devised new strategies for improving the performance of the soon-to-be constructed Gohar Khaton Girls' School in Mazar-i-Sharif, Afghanistan. Seventeen graduate students participated in the "Afghan Studio" during the ten-week autumn quarter of 2012. While the work presented here is theoretical, there have been several opportunities for the student designs to influence decisions made by project stakeholders involved in the design and construction of the actual school. Beyond the actual project, the process of designing a girls' school in Afghanistan has benefited all of the parties involved, and the dialog initiated during the course of the studio continues well past the end of the quarter. This project was made possible by the collaboration between the department of Architecture at University of Washington, the Afghan architect Salim Rafik based in Kabul, Ayni Education International (Ayni)–a Seattle based aid organization committed to building schools for women in Afghanistan–and architect Robert Hull, from the Miller Hull Partnership. This unique partnership between an aid organization, practice, and academia, was conceived as a strategy for leveraging improvements to the MoE standard school plans. This project asserts that design can play an important role in the everyday life of people in developing countries, and that it should not remain solely in the domain of wealthily investors–as is often the case in contemporary Afghanistan. In addition, Ayni's mission, to "build bridges of understanding and mutual respect between Afghans and US Americans," was also furthered by the studio project. (Ayni Education International, 2012) Issues of gender equality, war, religion, and occupation were as much a part of the studio dialog as the pragmatic requirements of thermal comfort and budget, and brought the students to the heart of global realities in an immediate way. Achieving a balance, between technical and cultural demands, was key to the studio's success.

I.2 Studio Research Methodology

Gohar Khaton Girls' school is located in the center Mazar-i-Sharif, Afghanistan's fourth largest city. Not far from country's most famous and holy shrine of Hazrat Ali, the school is tucked at the end of a dead-end street, in a courtyard next to the Balkh Ministry of Education. The existing school is currently in a state of disrepair, and long overdue for major renovation and maintenance. (Fig. 3)

Figure 3: Existing Gohar Khaton Girls' School in Mazar-i-Sharif. Source: (Ayni Education International 2012)

For this reason, and its prominent position next to the Ministry of Education, government officials gave Ayni special permission to construct a new school on the site that departs from the MoE standard plans, with the goal of creating a showcase for the Balkh Ministry of Education.

In order to create schools that are viable and accepted institutions, Ayni places great emphasis on building ties with community leaders, and their schools are only constructed where the organization is invited. After its construction, the Gohar Khaton School will be run by the Afghan government, and integrated into the existing education system. The complex is to provide classrooms for K-12 classes, serving at least 3,500 students or more a day. To achieve such a high enrollment, the school will be used on a rotation basis, with groups of students coming to class at different times throughout the day. The population in the city is growing rapidly, creating an urgent need for education facilities. It is expected that the enrollment will grow well beyond the expected 3,500, and the school must be designed to accommodate this rapid expansion. The students attending the school will come from all ethnic backgrounds found in the region: Tajik, Pashtun, Uzbek, Hazara, Turkman, Arab, and Baluch. Because girls are typically not allowed to walk very far from home, most will be coming to school from nearby neighborhoods.

Many schools in Afghanistan are connected to either a limited, unstable power supply. In addition, schools typically operate on little or no budget, leaving no funds for heating fuel. The project in Mazar-i-Sharif is no exception, and demands that the school be designed to operate essentially off-the-grid. High-tech equipment, such as photovoltaics, are not economically feasible for most schools in Afghanistan, and are also difficult to maintain in such a harsh environment. The architect Salim Rafik was commissioned by Ayni to design the school, which is slated for construction in 2014. Concurrently, students at the University of Washington were given the same site and program as a theoretical studio project. It was clear from the outset that the architect's computing capacity would be limited, and because of this, he was open to having access to various master plan options and building form studies informed by environmental performance analysis–something the students could easily generate. Balancing daylighting with solar gain became an important focus of the studio research, and is a critical factor in any serious proposal for improving the MoE schools. As I will further elaborate on in the next section, the data from programs such as Ecotect and Radiance influenced design decisions, from material choices to opening placement and sizes. Here, quantitative data generated by the students in the studio had a direct influence on qualitative design decisions.

In addition to thermal performance and daylighting, the students also identified school expansion, community outreach, and material cost and availability as areas demanding more focused research. Because it was not possible for the students to visit the site due to security risks, site data was gathered through multiple methods. Information about construction materials, for example, originated from literature provided by the French NGO, Groupe Energies Renouvelables, Environnement et Solidarités (GERES), and information relayed to the students by the local contractor involved in the school construction. Information about the school community came from mapping surrounding neighborhoods, a field site visit and interviews conducted by studio instructor Robert Hull, and Ayni Education International's board members. A literature review of sources covering Afghan culture was also completed, which included books by Afghan anthropologists such Thomas Barfield and writings by Nancy Dupree. Because women's issues in Afghanistan are particularly challenging for Westerners to grasp, the students also read several essays from *Land of the Unconquerable: the Lives of Contemporary Afghan Women*, a book examining the realities of life for women in both rural and urban Afghanistan. Two of the most important documentations of traditional Afghan architecture, *Afghanistan: An Atlas of Indigenous Domestic Architecture,* and *Traditional Architecture of Afghanistan* were also invaluable resources for the studio work. These books are currently the only comprehensive source for studying traditional Afghan architecture. In addition to literature resources, we were also fortunate to have Robert Hull on the studio team. Hull was involved in the design and construction of over 40 schools while in Afghanistan during the 1970's as a member of the Peace Corps. Students also consulted with Abdul Chahim, an Afghan structural engineer involved in several school construction projects in Afghanistan. The architect Salim Rafik proved to be an effective consultant as well, and was able to critique the student proposals midway through the project. All of these resources influenced the student design work, with some aspects of research having more visible influence than others.

The project required consulting a broad spectrum of sources, spanning from the cultural to the pragmatic. Examples in the next section will illustrate how the students began the design process by searching for very tangible data, from the cost of building materials to the amount of pupils that could humanely fit into a classroom. The students soon discovered that just below the surface of numbers and facts, lay cultural and political connections, influences, and implications of a broader order. Research into building material availability in Afghanistan, for example, will soon bring one to matters of corruption, scarcity, and environmental degradation. A study of class size tells the story of population growth, the urgency to educate the masses, and the unbearable conditions that young people are willing to suffer in order to receive a few hours of instruction each day. With the ultimate goal of devising ways for improving the MoE schools, the students soon found themselves making decisions requiring careful consideration against the backdrop of a politically and culturally loaded milieu. In moving from the research phase into the design phase, a process of critical inquiry was initiated by the students, which brought many important questions to the fore. The pursuit of these questions would continue to shape the work throughout the duration of the studio, and would also influence discussions between the students and the other project stakeholders.

2. "VISIBLE RESEARCH" IN STUDIO

2.1 Graphic Catalysts for Dialog

"The purpose of evidence presentation is to assist thinking." Edward Tufte (2006)

Visual communication of research information became an important part of the studio in several ways. The project structure required that the students communicate their research findings to non-architects, namely to the board members of Ayni. Much of the initial research, compiled by the students and presented to Ayni for review, became a catalyst for discussions with the board members and brought attention to issues that they had not considered when building schools previously.

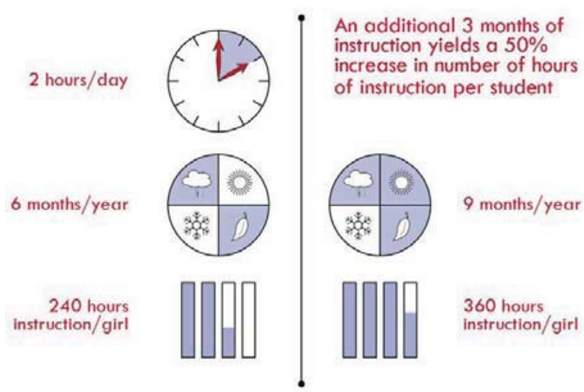

Figure 4: Better thermal performance increases instruction hours.
Source: (Garland 2012)

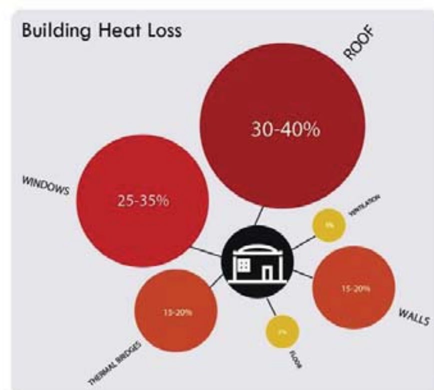

Figure 5: Areas of heat loss.
Source: (Esmaili 2012, Faureau, Jamy, & Dezuari, 2010)

The students' graphic representation of information also raised important questions about the actual school and its execution, and became the basis for more detailed research during the design phase. One of the main topics of discussion at the outset of the project was how to improve thermal comfort, particularly in winter. Increasing thermal performance would provide a better learning environment, and permit the school to remain open during the coldest months of the year. This, in turn, would allow for increased enrollment, more instruction hours, or the use of the school for other purposes during the times it typically would have been closed. Figure 4 was used to communicate this possibility to Ayni. Strategies for increasing the thermal performance of the school were considered by the students, such as insulating the building (many MoE schools are not insulated), the use of thermal mass, and building orientation. Adding insulation was the only option that would increase construction costs, and would require further discussion with all of the project stakeholders. The potential of either increasing enrollment or instruction hours was an exciting possibility for the aid organization, and investing in insulation appeared to be a viable option, though it was determined difficult and expensive to insulate the walls. Using figure 5, the students demonstrated to Ayni which parts of the building would be most prone to heat loss. This diagram began an important conversation with the board members about where best to invest money for insulating the school. It was recommended that at minimum, the roof should be insulated, and less expensive measures would need to be taken in order to compensate for heat loss in other areas.

In addition to facilitating discussions about how best to improve comfort and increase enrollment, figure 6 illustrates how the students represented given project data in a form that highlights conditions requiring further investigation and research. With this diagram, the students presented the actual school budget in graphic form. The students and Ayni were surprised by the amount of money spent on furniture, finishes and equipment. This graphic began a more detailed investigation into the causes of the higher expense, and it was found that one of the most expensive items in the budget were the standard school desks imported from

China. The students proposed ideas for fabricating the desks locally, and also brainstormed with the Ayni board members about other possibilities for reducing the FF&E costs without sacrificing quality.

These are just a few examples of how the students used the visual representation of data to communicate, question, and ultimately to begin a dialog with Ayni about the critical issues facing the school project. As the quarter progressed, the students continued to consider how best to present their design work to the Ayni board members in ways that were accessible and understandable.

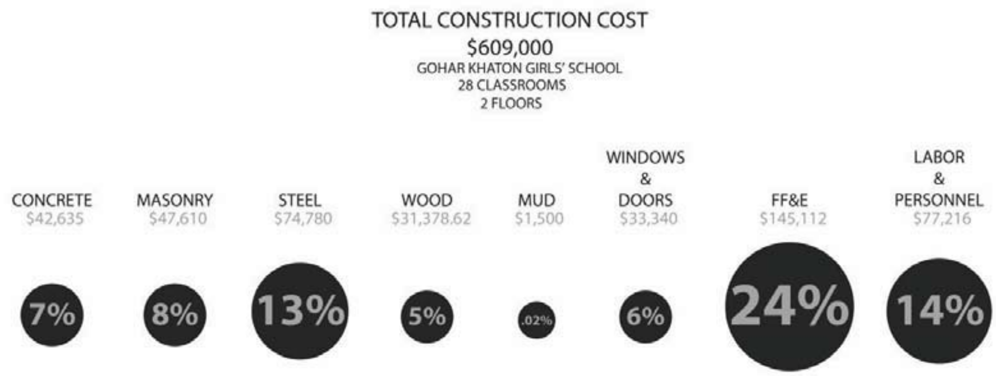

Figure 6: Graphic representation of the school construction budget.
Source: (Esmaili 2012)

2.2 Visual Decision Making Tools

Apart from communicating important research information to others, the students also used visual representation as a tool for making design decisions. Figure 7, for example, convincingly illustrates information about a fact that was already common knowledge for the students in the studio–most industrially produced building materials are imported into the country. The graphic representation added power to the facts the students already knew, making abstract material flows more tangible.

Figure 7: Map of imported building materials.
Source: (Esmaili 2012)

This map's influence was to be felt for the duration of the project, and played a crucial role in the students' decision to minimize the use of imported goods such as cement and steel, and to investigate other options closer to the construction site. The students discovered that local labor and materials could have many positive benefits for MoE school projects, from stimulating the local economy, to decreasing construction costs, and reducing transport induced CO2 emissions. The map was the starting point for many of the studio projects, leading to different outcomes, which I will now describe in further detail.

2.3 Research in the Student Design Process

Student team A began the project by studying the possibilities of using locally produced brick for their school design. Fired brick is a common material in Afghanistan and has a long tradition of use in the country, but has fallen out of favor as concrete has become more prevalent in contemporary construction. While exploring the advantages that traditional Persian brick patterns could offer their project, the students were struck by the idea that the material could accomplish several functions simultaneously. Using masonry would not only support local industry and labor and give the school its character, it could also act as a shading and screening device, thermal mass, and it could serve as the vertical load-bearing structure if designed correctly. The goal to maximize the performance of brick in the school set the parameters for the duration of the project research for team A.

Using a combination of sketches and digital simulation, the students studied how different masonry patterns and their percentage of openness affected the light entering the classroom. Several of these studies were generated in order to achieve the desired lighting conditions in the classrooms year-round while insuring shading during the summer months.

Figure 8: Initial sketch of masonry screens. Source: (Esmaili and Kamara 2012)

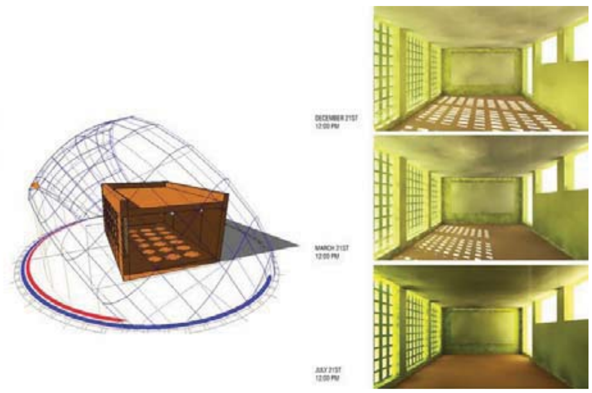

Figure 9: Ecotect and Radiance studies of masonry screens. Source: (Esmaili and Kamara 2012)

These studies also took structural stability and the required percentage of thermal mass into consideration. Throughout the design process, team A used the graphic side-by-side comparisons of their lighting simulations and sketches to make informed decisions about their project. (Fig. 8 and 9) Because the students were working in teams, the graphic output from the analysis became an effective way to reach a group consensus, by allowing for a quick assessment of options. Using software such as Radiance to optimize traditional masonry patterns is an interesting undertaking, and points to possibilities for future study. Although it was not within the scope of this project, the research could be taken further by using Rhino/Grasshopper and Diva to study an even greater number of masonry configurations.

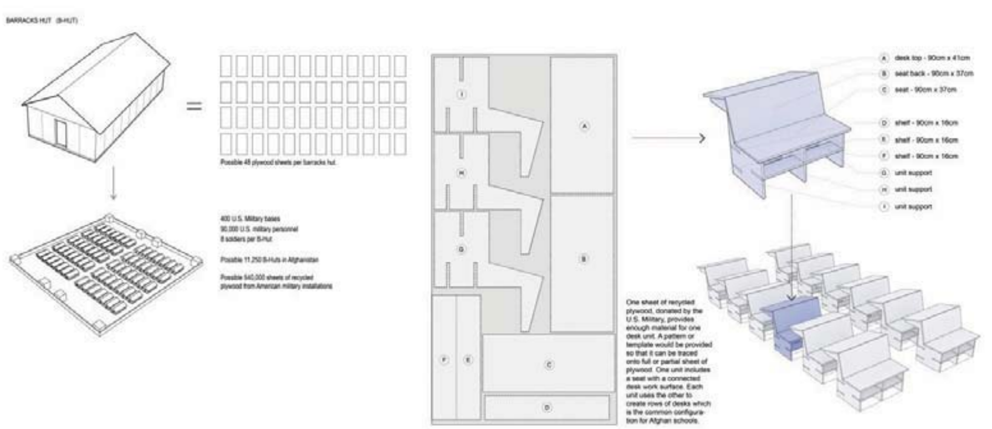

Figure 10: School desks made from dismantled NATO barracks. Source: (Thies 2012)

While researching potential sources of materials for the school, Team B discovered an unlikely source, NATO bases. In the initial scenario proposed by the students, salvaged wood from four hundred soon-to-be decommissioned barracks would be used for constructing school desks. Figure 10 was used to communicate how this might be accomplished. This idea was so compelling that it inspired one of Ayni's board members to take the proposal to a military contact in Afghanistan. The student research unveiled an enormous source of wood that had been imported into a country currently suffering from mass deforestation. Although it was not calculated, we can probably assume that there is more wood available in NATO bases than in all of what remains of Afghanistan's forests. This initial idea was expanded during the development of team B's project, where the salvaged NATO wood was employed to form "sunspaces" for the school. The project combines what is essentially a US American construction system with the MoE standard design for a masonry school. The lightness of the wood permits maximum solar heat gain in winter, and the thermal storage capacity of masonry holds warmth and coolth–reducing daily temperature swings in the building.

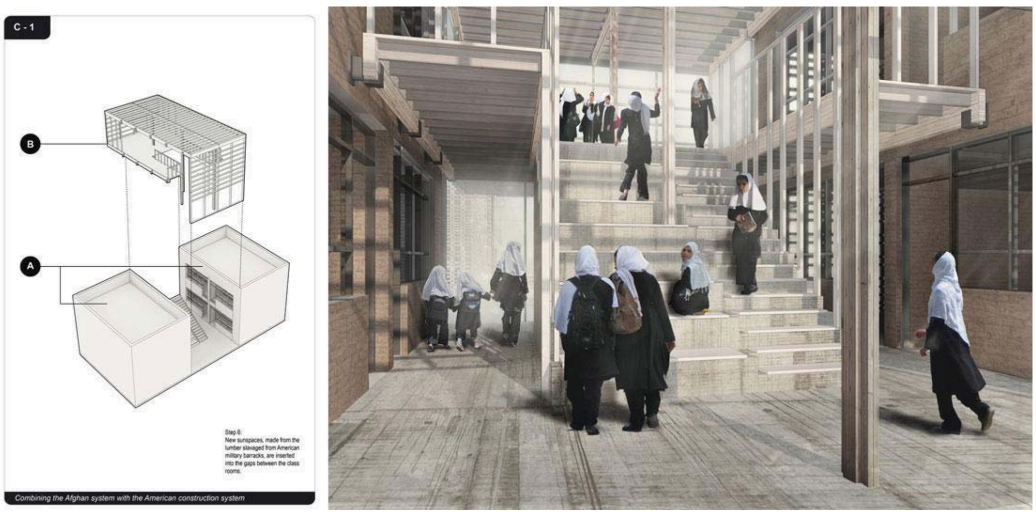

Figure 11: Wooden sunspaces for gathering and generating heat. Source: (Thies and Garland 2012)

The sunspaces also bring added value to the school curriculum by offering larger, covered areas for gathering and space for much needed vocational training. (Fig. 11) This solution is pragmatic, while offering a subtle critique of the NATO occupation.

One of the most important, and evocative visual tools used by the students were the rendered perspectives. In a sense, the perspective in figure 11 is the culmination team B's project research, with the power to convince or to the possibility to dissuade. Team C's project further illustrates this point.

Figure 12: Optimized Afghan vaults create pleasant, daylit classrooms. Source: (Lang and Crofoot 2012)

Initial research of traditional Afghan vault systems was informed by Ecotect lighting analysis, and a new vault typology was developed that evenly distributes daylight in the space. Final simulations using Radiance were used as the basis for interior classroom perspectives. (Fig. 12) The classroom perspectives were of particular importance to those reviewing the student projects, as they reveal the quality of the space, and were the final benchmark used to judge the success of the projects. Creating renderings that simulate important aspects of reality such as daylight, while retaining an element of abstraction, was critical for the project representations. The renderings have also become an effective vehicle for increasing the project's public visibility, making it very accessible to a general audience. This is an important aspect to consider, as the renderings bring attention to significant issues not often in the public eye in the US.

CONCLUSION

The research generated by the students in the studio did ascertain several options for improving the MoE standard schools, from optimizing systems utilizing local building materials to improving daylighting and thermal performance. There were other recommendations generated by the studio not mentioned here– discussing these would be beyond the scope of this paper. It is important to reiterate that the student work was purely theoretical, and was only intended as a recommendation. It is up to Ayni, the architect, and the local community to decide what will work best in the field. The student design research points to areas requiring further study, and it also provides glimpses of what the MoE school designs could look like if they were allowed to adjust and adapt to their local context. The students did initiate important discussions about critical issues, and brought attention to areas that have been previously been overlooked. How these recommendations influence the final design of the school remains to be seen. The Ministry of Education is permitting a bespoke design to be built in this instance, but whether the political will exists to make more substantial policy changes in the future is unclear.

The student work changed the thinking of the Ayni board members, but designing in a real-world scenario also benefitted the students. Working with an aid organization demanded that the students adopt a new means of discourse. Using the graphic representation of research findings became a useful tool for communicating with non-architects, as well as an excellent method for making team design decisions. In order to develop improvements for MoE schools, the students had to acquire a detailed understanding of the local context as defined by cultural, social, environmental, and market influences. The lessons of designing in Afghanistan extend well beyond the parameters of thermal comfort and structural stability. In their endeavor to create appropriate school designs, the students grappled with the development of an optimized technology that achieves a careful balance between technical analysis and cultural expression. As the late Egyptian architect Hassan Fathy observed, "Science can be applied to various aspects of our work, while it is at the same time subordinated to philosophy, faith and spirituality." Designing a girls' school in Afghanistan became a catalyst for studying the conditions of traditional and contemporary culture in the country, opening the students' minds to circumstances beyond the scope of a typical studio.

Afghanistan has a long history of instability, strife, and war–today's headlines do not report a better fate as NATO troops begin to withdraw from the country. As of this writing, we are hopeful that the new Gohar Khaton School will be built, bringing change to the lives of many young women in Mazar-i-Sharif. Ayni Education International estimates that for every girl educated in their schools, seven to eleven family members are also positively affected. (Ayni 2012) A single school can touch the lives of many people, and design can play a major role in improving that day-to-day experience. We hope the new Gohar Khaton School will set a positive precedent for future schools built in Afghanistan.

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Integrated Practice and Architecture Education: The Evolution of a Pedagogy

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ABSTRACT: Integrated Practice and Integrated Project Delivery are becoming the norm in architectural practice and therefore must be addressed in architecture education. Architecture programs are also continuously facing pressure from the profession and the collaborative architectural organizations to integrate the profession into education. This has been encouraged through programs such as the various NCARB awards. However, if architecture programs do not take the lead and begin to create programs that address professional education issues, such as integrated practice, the decisions will start to be made for them.

This paper is about nascent research on integrated practice being conducted in an architecture program through the design studio. A three-week charette consisting of teams of architecture, interior design, and building construction students has been conducted for the past two years as an experiment in integrated practice and its impact on learning in architecture education.

Data was collected through surveys completed by the students through five surveys conducted throughout the three week time period. The first survey was a combination of quantitative data collection in the form of demographic information and qualitative data collection in the form of open-ended questions. The next three surveys were spaced out at certain intervals along the length of the charette and were specifically open-ended questions. The final survey was a reiteration of the qualitative questions from the original survey to gauge any changes in perceptions and knowledge since the administration of the first survey.

This paper will discuss the final results of the data and how that will affect the formation of the integrated practice charette for the next three years of the project. The paper will also propose best practices for using this type of project for a full semester studio, as well as for use by other architecture programs.

KEYWORDS: building information modeling, collaboration, interdisciplinary, integrated project delivery, millennial

INTRODUCTION

Ove N. Arup may have written that “Integration and collaboration have been preached ad nauseum…” but never before has integration and collaboration had a better opportunity of reaching its full potential than now. Architects are taking the lead on Integrated Project Delivery (IPD) and are the most experienced and informed of all AEC professionals in the definition and use of this important project delivery method (Kent and Bercerik-Gerber 2010). However, the majority of architects who are using IPD, and are the most experienced with IPD, are AIA members that have been in practice for fifteen years or more. Principals are also the most frequently reported as having experience on an IPD project (*2010-11 BIM/IPD SURVEY RESULTS-SUMMARY* 2011). Architecture education has a unique opportunity to increase the number or architects experienced in IPD by educating the younger generation of architects, starting with our students. This paper will discuss a recently formed integrated practice studio that teams students from architecture, building construction science, and interior design in a three-week charette. The discussion will focus on the implementation of IPD in design studios, the benefits of working with Millennial students, and the structure of the project. Quantitative and qualitative data was collected during the execution of the charette to gauge student knowledge and perceptions on IPD and the allied professions involved in this project. The information gathered from the students will be discussed in terms of methodology and the data results. Additionally, a comparative analysis of the professional structure of IPD and its applications to an integrated practice studio will be discussed.

1.0 THE IMPLEMENTATION OF INTEGRATED PROJECT DELIVERY IN DESIGN STUDIOS

1.1. Architecture Education

Boyer and Mitgang challenged the architecture education and professional community in 1997 with their report *Building Community: A New Future for Architecture Education and Practice: A Special Report*. Many issues were raised in this seminal report, but integration has come to the forefront not just due to this challenge, but also based on changes in the AEC (Architecture Engineering Construction) industry over the past fifteen years. Integrated Project Delivery (IPD) may have become to the fastest growing form of project delivery since the American Institute of Architects (AIA) issued the first contracts referring to Building Information Modeling (BIM) in 2008 (Sabongi 2009). There is no mention of IPD in the NCARB 2007 Practice Analysis of Architecture, and "Collaboration/Cooperation" is the 7th most important change wanted in the field of architecture at only 4.97%. However, the upcoming NCARB 2012 Practice Analysis of Architecture should show a significant increase in the importance of IPD and BIM for the field of architecture (*NCARB 2007 Practice Analysis of Architecture* 2007). This increase in significance has already been shown in architecture education through the recent 2010-2011 BIM/IPD Survey Results conducted by the Association of Collegiate Schools of Architecture (ACSA). Autodesk and the ACSA partnered to gather information on the integration of BIM and IPD in architecture curricula. Administrators at 37% of ACSA accredited or candidate programs responded with the following results:

General Use of BIM

- 75% of respondents use BIM in studio courses
- 60% of programs use BIM in non-studio, required courses
- 63% use BIM in elective courses

Integrated Project Delivery

To assess this area of the curriculum the survey asked respondents how they are using collaborative design strategies in studios.

- 77% teamed architecture students at the same level
- 33% teamed architecture students at the different levels
- ~50% teamed architecture and non-architecture students
- 63% teamed architecture faculty in the same studio
- ~33% teamed architecture and non-architecture faculty
- ~50% used non-architect critics or instructors during the term (outside of reviews), with engineers being the most mentioned discipline of these students, faculty, or critics

Use of BIM in Studio Courses

- 40 (70%) of all respondents use BIM in an undergraduate design studio.
- In which levels is BIM used?
    - Undergraduate Studio (figures comprise all respondents, regardless of degrees offered)
        - 1st Year Studio (4%)
        - 2nd Year Studio (21%)
        - 3rd Year Studio (35%)
        - 4th Year Studio (51%)
        - 5th Year Studio (26%)

Collaborative Design Strategies

Please indicate how you are using collaborative design strategies in design studios? Check all that apply

a. Teaming architecture students at the same year level – (77%)
b. Teaming architecture students at different levels – (33%)
c. Teaming architecture students with non-architecture students – (47%)
d. Teaming architecture faculty in the same studio – (63%)
e. Teaming at last one architecture faculty member with a non-architecture faculty member – (32%)

Material Skunkworks: Building Technology for Future Architects
by Ryan Salvas and Robert Sproull

f. Using non-architect critics or instructors during the term (not just during reviews) – (51%)

Disciplines of non-architecture students, faculty, critics or instructors included in the IPD studio (35 comments)

- Engineering (any discipline): 23 mentions
- Other Discipline: 21 mentions
- Landscape Architecture: 13 mentions
- Interior Design: 11 mentions

- Graphic or Industrial Design: 9 mentions
- Urban Design or Planning: 8 mentions
- Structural Engineering: 7 mentions
- Mechanical Engineering: 5 mentions
- Business: 5 mentions
- Other Engineering Discipline: 5 mentions (*2010-11 BIM/IPD SURVEY RESULTS-SUMMARY* 2011)

These numbers show that not only are architecture programs utilizing BIM and IPD in design studios, but that it has become an integral part of studios in many cases. What these numbers do not show is how BIM and IPD are being used in design studios. When 75% of respondents use BIM in studio courses, is it a required technology, or do students choose this tool? Also, is BIM taught as part of the studio, or is full immersion and knowledge required by the time students need to use it in studio? These types of questions will help to further the research and conversation on how best to implement IPD and BIM in design studios, and they will be addressed in this paper on our integrated practice studio.

1.2. Building Construction Education

Building construction education programs have not been as successful as architecture programs in implementing IPD and BIM into that curriculum. A survey by Farid Sabongi found that 62% of respondents feel that BIM education in undergraduate construction curriculum is inadequate. This is despite the data that shows that 75% of respondents to the survey think that BIM will increase in the marketplace over the next five years. Additionally, only 10% of building construction programs are addressing BIM in any way (Sabongi 2009). The project discussed in this paper will posit suggestions on how best to use IPD and BIM in a design studio to prepare students in the allied disciplines of architecture, building construction science, and interior design for their future as professionals.

2.0. THE BENEFITS OF WORKING WITH MILLENNIAL STUDENTS

Understanding the traits of Millennial students is another important part of implementing an integrated practice studio. The article "Generation NeXt Comes to College: 2006 Updates and Emerging Issues" by Mark Taylor notes important traits and issues inherent to teaching Millennials. There are both positive and negative traits on how these students view their college education and knowing both allows a proactive pedagogy that can engage the students without capitulating to their consumerist mentality. The traits Taylor discusses include:

- The change from the conforming Millennial, similar to the college students of the past, to the entitled consumer.
- Delayed adolescence that is becoming the norm and is leaving students unprepared to enter the workforce.
- The digital dependence of students in college life.
- Pressure on higher education due to the increasing international competition of the "flat" world.
- Increasing calls for reform outside of higher education due to critical evaluation by the public.

Faculty and staff have also added to the information Taylor has collected on Millennial traits. Given that faculty and staff see students in a more detailed fashion, this information differs somewhat from the initial traits Taylor identifies. William C. Durden, President of Dickenson College sees students having traits that are considered an "emerging stereotype." Durden notes that Millennial students:

> …expect high grades without significant effort and often just for showing up; demand comfort and luxury more than a rigorous education; see themselves as consumers and expect services, and extended and direct personal attention on demand; have little respect for authority and show distain for collegial and social rules of conduct, instead asserting personal privilege; fail to differentiate between civil exchange of reasoned ideas and shouting personal beliefs, yet grow defensive when faced with constructive criticism; and have a naïve sense of the future (Taylor 2006, 2:48).

Additionally, Durden describes Millennial students as having the idea that

> facts don't really matter; what matters is the uninhibited, unedited, and immediate assertion of your egotistical options and thereby, the preservation of your self-esteem at all costs. It truly is all about you (Taylor 2006, 2:49).

Postmodernism is also very influential to Millennial students because they were born in this era and are very influenced by its ideals. Research by scholars such as Lyotard, McAllister, Sacks, and the former president of the Czech Republic, Vaclav Havel, show the relationship between Millennials and Postmodernism. This research states that Postmodernism tends to be pessimistic because there is more possibility, but less certainty. Higher education, on the other hand, is based on the Enlightenment, and the idea that science, reason and optimism would lead the way. These contrasts create friction between higher education and our current students, and also formulate these additional Millennial characteristics discussed by Taylor.

- Consumer orientation – *The "customer" is always right*
- Entertainment orientation – *Education should be fun!*
- Entitlement – *You get what you pay for…or at least show up for*
- Instant gratification – *A reflection of the fast food culture of the United States*
- Short event horizon – *Lack of long-term planning, critical thinking, and problem solving skills (which happen to be a requirement for architects and architecture education)*
- Adaptability and pragmatism – *Flexibility and open-mindedness*
- Excellence – *Grade inflation and little effort for much reward*
- Skepticism – *Postmodern trait that puts personal experience over information*
- Cynicism – *Right and wrong does not matter as much as someone's agenda*
- Safety issues – *Overprotected, Millennials do not take responsibility for their own safety*
- Stressed – *Not currently able to handle the stress of higher education*
- Civility issues – *Emotionally repressed and difficult to engage, "Are you talkin' to me?"*
- Intellectually disengaged – *Bored, constantly tardy, and only concerned with what they will be graded on* (Taylor 2006) [1]

Solutions suggested by Taylor to utilize these traits and teach Millennials include moving from the teaching model to the learning model, prolonged student engagement, the creation of significant learning experiences, developing meaning through real life application, requiring students to engage by having them bring needed information to class, multiple learning options, and facilitation of high level learning instead of rote memorization. The incorporation of integrated practice in a design studio can harness the ideas of Taylor, and the traits of Millennials to create a successful course that educates and connects our students to the architecture profession. The structure of the studio allowed the use of some Millennial traits such as:

Useful in a General Collaborative Studio

- Preparing students to enter the workforce
- Harnessing their digital dependence by using BIM
- Using a design competition to foster significant effort
- Introducing IPD to encourage respect for the knowledge and authority of others
- Project presentations to allow for the civil exchange of reasoned ideas
- Exposure to IPD and the allied professions to give students a better understanding of their future
- Collaborative teams to allow students to be adaptable and pragmatic

Specific to this Integrated Practice Studio

- Site, precedent, market, and LEED research to show that facts do matter and are important to synthesizing information needed in IPD
- A project of a campus facility to further engage the students and address their possible consumer and entertainment orientation by being able to better their surroundings
- A project duration of only three weeks to challenge instant gratification and short event horizon by having the students see the positive and negative of short project periods

Not all Millennial traits were able to be fully engaged, but future research and more in-depth analysis of this studio project will allow development to see if other traits can be included.

3.0 PROJECT STRUCTURE

3.1 Organization

The project was a three-week charette where fourteen interdisciplinary teams of students from architecture, building construction science, and interior design proposed ideas to redevelop a recently abandoned student-housing complex on campus into eco-housing. The project was a design competition with a monetary reward sponsored by a large local construction company to promote IPD in design studios. The studio was conducted by three architecture faculty, one building construction science faculty, and one interior design faculty. Students were organized into teams of four to five students, depending on the amount of students in each allied discipline. All teams had at least two architecture students, one building construction science student, and at least one interior design student. The student teams began with site verification and research on the site, precedent studies, market research on housing, and LEED requirements. These initial verification and research assignments helped to build team spirit and allowed the students to learn about the skills and knowledge of their teammates while they got to know one another. In addition to their research, the students learned about IPD, BIM, and Lean Construction from representatives of the large construction company that sponsored the studio. This allowed the students to see the professional application of IPD and BIM and then learn how they can relate it back to their collaborative studio. Once the students had built some camaraderie on the first assignment, they began their design using the information collected during the site verification and research. The students worked face-to-face in a typical studio environment that was located in the School of Architecture Building. The face-to-face format of the studio structure and the short time frame of the charette forced communication because the students had little time to make and implement decisions. This forced the students to spend minimal time apart, and decreased the use of email and other distance-based communication.

The students presented their developing work at a mid-review a week and a half into the charette. The reviewers were the university campus planner, the university sustainability coordinator, and the facilities director of the housing complex. This presentation provided the students with valuable feedback from the client, while also getting the opportunity to work on preliminary board layout and presentation techniques. The last week of the charette included desk critiques by the various faculty in the studio with each team to help refine and finalize the ideas for the competition. The final presentations began with gallery-style presentations where faculty and students from the three departments, as well as invited guests, and representatives from the large construction company came and reviewed all of the student projects in an informal manner by walking around the School of Architecture gallery presentation space. The top three teams were chosen earlier by the faculty in the studio to narrow down the number of formal presentations and decisions on who the winner was by the sponsor of the student design competition. After the gallery-style presentations the top three student teams presented their designs to the university sustainability coordinator, the two representatives from the large construction company, and various faculty from the three departments. The top three teams were then ranked in order of first place, second place, and third place by the university sustainability coordinator and the two representatives from the large construction company acting as the client and sponsor of the competition. The combination of a more relaxed gallery-style presentations and formal presentations was intended to give every student team the opportunity to present, and defend, their ideas while giving the winners of the competition more emphasis by focusing on their work in a formal presentation. This increased the student engagement by showing the importance of trying to be one of the top three teams, in addition to the monetary reward.

3.2 BIM and IPD

The studio required that BIM be used to develop and create the project design. The researchers agree with Randy Deutsch that BIM and IPD must be synthesized together for IPD to be successful. Therefore BIM was an integral part of this integrated practice studio. The synthesis of BIM and IPD also reflects the synthesis of information that students in AEC education must learn to do so it is seen as an important element of this studio development. Students had varied experience with BIM, which influenced the team dynamic, and resultant project development and quality. Various student comments note the discrepancy of technological skills between the different students on the team. This is a result of the combination of third year architecture students with fourth year (senior) building construction science and fourth year (senior) interior design students. The Integrated Practice studio facilitates most of the points of ideal synthesis proposed by Deutsch in his article “Notes on the Synthesis of BIM” by creating teams composed of architecture, building construction science, and interior design students who work together from the beginning to the end of the project to create a solution to a design problem (Deutsch 2010).

The students used Autodesk Revit 2013 as the tool to facilitate the BIM in the charette. Revit allowed the students to share files to increase the ability of the students to work on the same project while working on separate parts on the project. These files were brought together similarly to the way that Autodesk AutoCAD used external references to allow collaboration amongst various design disciplines. This allowed the students to also see where there were conflicts in the building information that was created by each discipline. The architecture students used Revit to create the exterior building shell renovations and modifications, while the interior design students used it to create the interior renovations and additions. The building construction science students were then able to access the Revit files as they were being created to critique in regards to construction methods and budget. The building construction science students were also able to use this information to create their project phasing plans to facilitate the overall construction planning of the proposal, which, in turn, helped to finalize the project budget proposal for each group. This was the general method of BIM implementation in the studio but not every group was as skilled or as experienced as others who were more successful in fully using this method.

4.0 METHOD

4.1 Survey Instrument

Five surveys were conducted throughout the three-week charette and all were intended to gauge the student perceptions of IPD and the allied professions are various points throughout the project. The first survey was conducted during the first day of class, but after the project was introduced to the students. This survey consisted of quantitative questions to collect demographic and curricular data, and open-ended qualitative questions to allow students to give feedback on questions about IPD and the allied professions. The three primary faculty that organized the studio charette worked with a faculty member in the Department of Psychology to construct the surveys and to analyze the data. Qualtrics was used to conduct all five surveys through an online link that was sent via e-mail to all of the students in the integrated practice studio. A new email was sent to students for each survey. The second survey was conducted five days later at the end of the first week of the charette. This survey, and the next two surveys were follow up questions to gauge the students' opinions and what they were learning in the various stages of the studio. The third and fourth surveys were also conducted one week after the previous survey at the end of each week. The final survey asked the students the same basic questions as the qualitative questions on the initial survey. This survey was conducted on the day of the final presentations, but before the students presented. (Fig. 1)

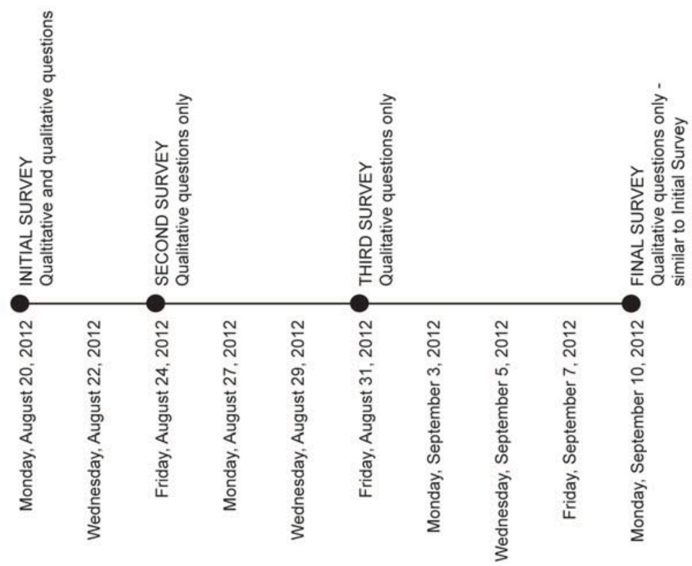

Figure 1: Timeline of Survey Distribution. Source: (Author 2013)

4.2 Data Results

The demographic data showed that sixty-seven students participated in the studio and survey with a make-up of 37 architecture students, 14 building construction students, and 16 interior design students. (Fig. 2) The average age of the students was 21 and the ages of the students ranged from 19-29. The majority of the students were in-state (67%) and the gender distribution of the class was 40 males to 27 females.

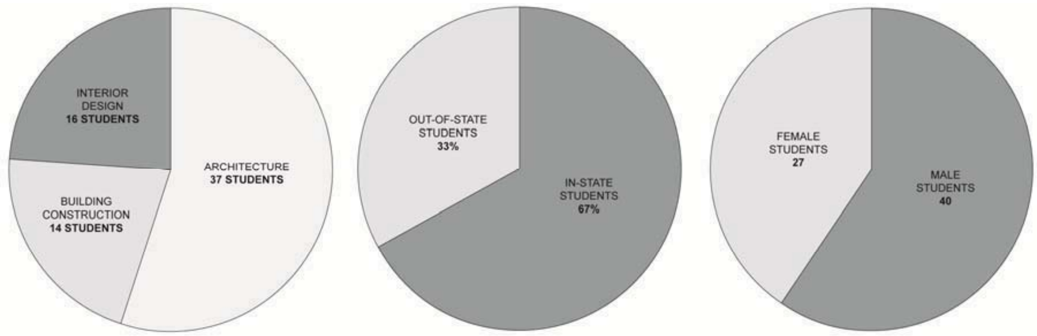

Figure 2: Student Demographic Data. Source: (Author 2013)

The data in experience with collaborative projects and interdisciplinary work showed that 100% of students had at least participated in a group project, with only 57% having worked on an interdisciplinary project. When asked about their experience on the interdisciplinary project those students rated their experience as a 3.2 on a scale of one to five with one being the least positive and five being the most positive experience. Despite this neutral response to interdisciplinary work 100% of students felt that it was important to work on interdisciplinary projects while in school. Most students (93%) expect to work in a collaborative setting once they graduate. Working in a small company, plans to start their own business, and uncertainty of their post-graduation plans were reasons given as to why the remaining students did not feel that they would be working in a collaborative setting. The students anticipated working with architects, constructors, interior designers, engineers, and landscape architects. (Fig. 3)

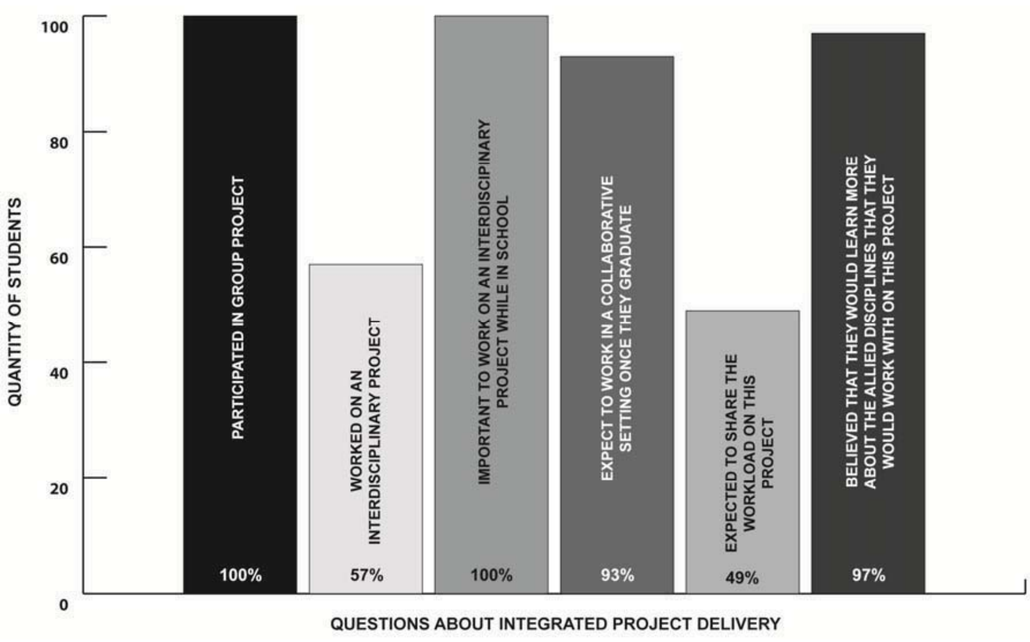

Figure 3: Integrated Project Delivery Pre-Project Question Data. Source: (Author 2013)

When asked to define Integrated Project Delivery the students tended to use the same basic ideas noted in the AIA definition. "Integrated Project Delivery (IPD) is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction (*Integrated Project Delivery – A Working Definition* 2007)." Students in their definitions stated ideas such as collaboration, shared knowledge bases, and an improved project delivery and outcome.

Nearly half of the students (49%) expected to share the project workload, but when the students who disagreed were asked to explain the reasons behind their response none of the students chose to do so. However, the students who did expect the workload to be shared explained their answer by indicating that they felt that each discipline would contribute according to their area of expertise and level of knowledge and that they needed to collaborate to be successful. The majority of students (97%) believed that they would learn more about the allied disciplines that they were working with on the project and explanations of this response indicated that the students understood that each discipline had knowledge specific to their major that they would be able to contribute and share as part of the collaboration. The progress surveys garnered responses that showed that students were learning a lot about their partner disciplines. A variety of comments demonstrated the range of experiences from positive – "…everyone is good at what they are responsible, and whatever a person does not know, other disciplines are there to aid each other" – to negative – "the one weakness I have noticed is that each field's design process is very different…" On the other hand, the students were beginning to see the limitations of IPD and understanding the issues to be addressed to achieve a successful project.

The post-competition survey asked the students to rank their experience on the project, and similarly to the average response about collaborative and interdisciplinary work on the pre-competition survey the average response was a 3.2 on a scale of one to five, with one being the least positive and five being the most positive experience. When the students were asked whether they would be interested in participating in another collaborative experience the average response was a similar 3.0 on a scale of one to five, with one being unlikely and five likely. Difficult group dynamics was indicated as a reason for students' reluctance to participate in a collaborative studio in the future. Yet, students with a more positive response stated that they felt the project was realistic to what they will encounter in their professional careers. The students also agreed, at a rate of 93%, that the incorporation of interdisciplinary projects into educational settings is important. When collaboration in education was seen by some students as a concern, students did not feel that the educational setting could mimic the real world conditions of IPD in the profession. The majority of students did, however, note that collaboration improved the overall project outcome. (Fig. 4)

5.0 COMPARATIVE ANALYSIS

5.1 Similarities Between IPD in Practice and Education

The most important thing that the professional and educational aspects of IPD share and must address is the importance of relationships and the barriers created by the social constraints of the allied professions. Deutsch reminds us of that fact when he quotes the GSA's Charles Hardy in his article "Notes on the Synthesis of BIM". Hardy is famous for stating "BIM is about 10% technology and 90% sociology," and Deutsch reiterates that we must focus on the social aspects of integrated design (Deutsch 2010). Understanding the evolution of the world-views of the stakeholders in building design and construction is also important and Ryan Smith analyzes this in his article "Socio-Technical Practices." Smith posits that the various parties involved in construction have diverged since the Renaissance, with disastrous consequences. This is further exacerbated by traditional construction contracts, which focus on winning the project instead of creating the best product possible. Defining the knowledge and resultant boundaries for each profession is important to overcoming this long-established barrier to an efficient and well-constructed project (Smith 2011). This is also important to a successful integrated practice studio to help the students understand not only their abilities and limitations, but also those of their partners. IPD in professional practice also has basic themes that run throughout most projects and research on the subject that can correlate to integrated practice in the design studio. These include:

- Early involvement of all parties
- Shared risk and reward
- Multi-party agreements
- Collaborative decision-making and control
- Liability
- Jointly developed and validated performance goals (Smith et al 2010)

The studio is organized to have the students working together from the first day of class to make sure that there is early involvement of key participants. Risk and reward is shared through the grading process and design competition reward stipend. The assignments were written so that all team members receive the same grade, no matter who does what parts of the project. Additionally, there were monetary rewards for the top three teams that supported the reward aspect. The assignments also acted as the multi-party agreements, or "Integrated Form of Agreement," to make sure all students knew what the expectations were for the project and how they would be graded. The teams were a balance of all three allied disciplines, however the teams contained more architecture students purely due to enrollment. The interdisciplinary teams were organized based on individual student strengths and traits to enhance the collaborative decision-making necessary in IPD.

Even though the hypothetical project in the integrated practice did not involve any real risk or liability to the students they were still reviewed by their faculty in relation to risk and real-world issues in the design and possible implementation of their project. The one element of IPD not initiated by the students was development of the performance goals. The faculty developed these as the studio charette was developed prior to the beginning of the course. The lack of student experience in the professional realm of design and construction necessitated the faculty control that aspect. However, future studios could be organized to help the students develop the performance goals as a first assignment to begin the studio.

While the professional aspects of IPD that result from socio-technical variables that Smith notes are important, and the research into the more contentious components of IPD such as liability insurance and contracts that Kent and Becerik-Gerber outline are also important , just as important are the aspects of AEC education that foster the continued disparate views of the stakeholders (Smith 2011, Kent and Becerik-Gerber 2010). Educators have a particular opportunity to not only utilize design scholarship to address the transformations in the building industry on a professional level, but with their students as well.

5.2 Barriers to IPD

The social aspects of the AEC industry are one very large barrier to the success of IPD, but there are other barriers categorized by Ghassemi and Becerik-Gerber. These include legal, cultural, financial, and technological (Ghassemi and Becerik-Gerber 2011). The limitations of a collaborative studio including students from architecture, building construction science, and interior design allow only the exploration of two of these barriers: culture and technology. Culture ties directly into the social aspects discussed above and are evident in the fact that some in the construction industry still believe that the IPD contract type is needed. Nevertheless, the same respondents to the survey by Kent and Becerik-Gerber also noted that relationships were more important than contracts. Another positive development in the evolution of the culture of the AEC industry is that the majority of the AEC industry company owners who are experienced with, or at least informed about, IPD believe that it is the future of project delivery methods (Kent and Becerik-Gerber 2010). IPD training is also considered a part of culture, and students must be trained in IPD at the beginning of the project because it is not guaranteed that all students, even within one discipline, will be equally educated in IPD (Ghassemi and Becerik-Gerber 2011). However, students must come to the studio already trained in BIM. Sabongi shows in his research that most AEC education programs feel that fitting BIM into an already tight curriculum is a challenge, and an IPD studio also has other ideas to focus on and implement. Therefore, a prior working knowledge of BIM by the students, and the AEC educators is imperative. Trust-building activities and tools are also needed to change the culture of the AEC to embrace IPD. The activities suggested include collaboration, coordination, openness, honesty, and transparency (Sabongi 2009). The faculty in the studios worked to promote these trust-building tools by meeting with the interdisciplinary teams and helping the teams overcome any individual issues and conflicts. Design studios also have these traits inherent through the development of studio culture and student bonding by working together. This integrated practice studio fosters collaboration and the students worked face-to-face in their interdisciplinary teams. All student teams worked in one large studio space in the School of Architecture building because it happened to have a space large enough to hold all of the students in the studio. The students spent a lot of time together as this was a quick, high-intensity charette of three weeks.

The integrated practice studio did not face all of the same challenges to integration of technology as those of professional AEC firms, such as collaborating with subcontractors, or translation and liability issues. However, the studio did benefit from the positive aspects of integrating BIM into the project process. The use of BIM built the student relationships, increased collaborations, and enhanced communication. This was due, in part, to the fact that not all students were educated in BIM. Even some of those who were educated in BIM were not knowledgeable enough to fully participate in the creation and development of the BIM model. These students instead participated through the development of project phasing and pricing, as well as project presentation. Other technological barriers not mentioned as being an issue for AEC professionals by Ghassemi and Becerik-Gerber ended up being barriers for the integrated practice studio. Many students were not versed in graphic design and development tools, such as Adobe Photoshop, Adobe Illustrator, and Adobe InDesign. These technological barriers seem to be unique to AEC collaborative studios and, just as with BIM, should be addressed prior to the start of a collaborative studio.

CONCLUSION

This integrated practice studio charette will be conducted for the next three years so various ideas and issues will continue to be investigated during each new iteration of the project. Barriers that educators can address through integrated practice studios are fear of change, lack of IPD awareness, limitations of technology, cultural barriers within the industry, falling back on tradition, and an unwillingness to try something new. Despite these barriers the majority of AEC industry company owners were willing to work on IPD projects, showing a bright future for our students to enter the workforce being prepared to work on IPD projects.

Integrated practice studio projects can address these barriers by giving students the opportunity to begin working together to create trust, respect, and good working relationships before they enter the profession. Educators must provide the leadership that is required to get this type of education off the ground and help move our students into the world of IPD. Considering the lack of certainty on the part of AEC professionals on how environments will be created to encourage and support IPD, educators also have the opportunity to educate their students to facilitate the creation of these environments when they transition into the profession and utilize what they have learned about collaboration.

Faculty need to define the scope of work, specific project goals, clearly define roles, relationships, and responsibilities between the project participants because the students are unable to do that due to their inexperience with design, construction and integrated practice. This will help create a team spirit of win-win for every team member and foster an environment of trust and mutual support. The AEC faculty should also act as the owner in an integrated practice studio to frame the scope and expectations of the collaboration and the project. Additionally, students have trouble synthesizing information, so we must foster that process as educators since synthesis between IPD and BIM is so important to collaboration.

The qualities and characteristics that building owners look for in IPD teams relate to the same qualities and characteristics that AEC employers will begin to look for in the graduates of our programs. Integrated practice studio projects give our students the education and the advantage by placing them in a collaborative environment before they graduate. IPD in education not only addresses the barriers noted above, but also addresses the ideas generated by Boyer and Mitgang on the scholarship of integration, the integration of knowledge, and a more integrated curriculum. We can engage the university campus, other allied disciplines, and create a climate of integration that benefits both architecture education and the profession (Boyer and Mitgang 1997).

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ENDNOTES

[1] Millennial character notes in italics are those of the first author.

Passive Aggressive Education: Infusing Passive House Principles into the Curriculum

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ABSTRACT: In 2006, recognizing the impact of buildings on global climate, the American Institute of Architects adopted the 2030 Challenge[1]— an initiative to reduce the building sector's dependence on fossil fuels and mitigate greenhouse gas emissions. Recent professional training in the building methods of the Passive House concept in the U.S. promises to reduce space-conditioning energy use by 90% compared with conventional buildings. The Passive House method sets target performance criteria that must be met during construction. Education and training for design professionals involve intensive classes on building science principles of envelope construction, thermal comfort, heat gain/loss, ventilation, shading, orientation, and calculations of total primary energy use. Implementing Passive House principles into the curriculum suggests a variety of educational opportunities for enhanced student involvement, engagement and understanding of ways to address the 2030 Challenge. The intent of this paper is not to describe software platforms or passive cooling/heating concepts. This paper describes and explores the workings of courses and examples of faculty-student discourse at 3 institutions (Miami University, North Dakota State University and the University of Oregon) to infuse the curriculum through seminars and design-build studios for a real-world community project. The delivery process of curricular innovation reveals several barriers to embedding concepts into the curriculum, but greater dialogue on concepts and principles, construction techniques, energy targets, and the need for collaboration among building professionals (designers, contractors, engineers, and consultants).

KEYWORDS: education, primary energy, curriculum, ventilation, passive house

INTRODUCTION

In 2006, recognizing the impact of buildings on global climate, the American Institute of Architects adopted the 2030 Challenge — an initiative to reduce the building sector's dependence on fossil fuels and mitigate greenhouse gas emissions. In 2010, a quarter of a million people from 47 countries participated in a Global Emergency Teach-in[2] conducted by Architecture 2030 calling for the community to make changes to the curriculum by adding a requirement to all design studio problems: "*the design shall engage the environment in a way that dramatically reduces or eliminates the need for fossil fuel*." All courses should achieve ecological literacy in design education. The recent partnership between the DOE Challenge Home program and the Passive House Institute US promotes a common goal of reducing energy consumption in the residential sector by the Year 2020[3]. Educators are beginning to train students in Passive House principles.

In the past 6 years, professional training in the building methods of the passive house concept in the U.S. promises to reduce space-conditioning energy use by 90% compared with conventional buildings. The passive house method sets target performance criteria that must be met during construction. Performance can be calculated using software to predict moisture transfer within the building envelope (WUFI-ORNL/IB); potential thermal bridging (THERM/LBNL): and, validation (or invalidation) of building performance targets (Passive House Planning Package (PHPP) spreadsheet). The passive house method is a design concept, which uses superinsulation as a means of reducing the mechanical system to an absolute minimum (it is an "active system" which uses a heat recovery ventilator to operate); whereas a passive solar heating system, "consists of south-facing glass …for solar collection and thermal mass for heat absorption, storage and distribution. (Mazria, 1979).

This paper describes efforts at 3 institutions (Miami University, North Dakota State University and the University of Oregon) to infuse PH methods into the curriculum via seminars and design-build studios. Albeit anecdotal, the intention is to show how such electives fill a perceived gap in education where students are not getting an in-depth understanding of analyzing complex building science topics such as vapor diffusion and thermal bridging. Each institution's course description will include class organization, student outcomes, course format, required materials, and indicate where it is offered in the curriculum. Most importantly, faculty and student perspectives to the barriers to implementing the course, innovative teaching methodologies, impacts of new software tools, and examples of faculty-student discourse will give background stories to implementation and future offerings.

1.0 MIAMI UNIVERSITY - SEMINAR

1.1 Class Organization and Outcomes

The Department of Architecture and Interior Design at Miami University offers two course options for students to engage in the study of Passive House: a Passive and Low Energy seminar and a Passive House Malta Summer workshop. Both elective courses are offered to graduate and undergraduate students; predominately third and fourth year architecture students and several graduate students. The courses are now run in succession with the intent that students who enroll in the Passive and Low Energy Seminar will follow up the experience with the Malta workshop. Both courses are new offerings in the department and are entering their second year of instruction.

The Passive and Low Energy course meets 3 days a week for 50 min each session. The focus of the course is Passive House design as a means for achieving Net Zero construction. Students are instructed in the importance of airtight construction, super-insulation, thermal bridge-free design, solar heat gain, ventilation, and hot water systems to achieve Low and Net Zero results. Students also explore PH energy modeling software (PHPP or WUFI Passive)

The Passive House Malta Summer workshop is conducted every other summer. Our initial offering was in the summer of 2011. Seventeen students traveled to the 15th International Passive House Conference in Innsbruck, Austria for one week, and then to the island of Malta for three weeks. In Innsbruck, students attended an introductory full-day seminar, held by Dr. Wolfgang Feist, one of the founders of the Passive House Institute in Germany. Students were expected to attend all general sessions of the conference, workshops held during the conference, attend the building trade show, and participate in an all day building tour of various PH projects under development in the area. Following the conference, we proceeded to the island of Malta, were we studied traditional Maltese stone construction and current concrete construction methodologies. Students were introduced to heat transfer analysis software (HEAT2 & THERM) and were required to analyze the thermal qualities of current Maltese construction and offer alternative solutions to improve the thermal performance of the construction.

1.2 Barriers to Implementation

A working knowledge of Passive House concepts and techniques, and familiarity with the PHPP energy modeling software is difficult to accomplish in a 16-week semester course that meets just 2-1/2 hours per week. A companion studio that runs parallel with the course would be beneficial so students could apply PH concepts to their studio design projects and test them using the PHPP. Some students who took the seminar course followed up the next semester with an Independent study design studio and were successful at achieving PH designs. Although it was an independent study, increased faculty involvement was necessary to help the students complete the PHPP analysis

One of the biggest barriers to the implementation of Passive House in our department is the "bias/influence" that LEED has in the minds of some the faculty and many of the students. Energy standards obtained through branded certification processes hold great allure to students and many feel that a LEED accreditation will ensure chances for employment upon graduation. To that end, the PH organization is actively working on a student level Certified Passive House Consultant (CPHC) designation. The difference is that the PH is based on building performance rather than point acquisition and the students gain more useful knowledge in the testing and training required to be a CHPC.

Passive House construction techniques of super insulation, triple glazed windows, minimal heating systems (depending on climate), ventilation and extreme air tightness challenges the way that building envelopes have been traditionally designed. In architecture departments, where the aesthetic appeal of the design is the predominate focus of a studio's criteria, getting faculty and students to embrace the strategies that will ensure higher building performance is often a challenge. There is a lot of material to cover in a short amount of time.

1.3 Innovative Teaching Strategies and Impacts of Tools

The Passive and Low Energy seminar course has a focused research project that has been effective at making students aware of the energy implications of their design and construction strategies. Students are assigned a multi-phased research project of construction details and work in teams of three. This research includes three parts: 1) Investigation & Familiarity, 2) Analysis, and 3) Full-Scale Mockup. The assignment is detailed as follows:

Part 1: Investigation & Familiarity
Identify a light wood (2x4, 2x6) framing construction connection detail that you will study in depth. You may pick from the following list or you may find another detail.

Exterior wall to roof (flat roof with parapet)
Exterior wall to roof (sloped roof with exterior overhang)
Exterior wall to roof (vaulted ceiling)
Exterior wall to intermediate floor
Exterior wall to floor slab
Exterior wall to crawl space
Exterior wall to slab (shallow foundation)
Exterior wall to interior wall
Exterior wall at corner

Each team member identifies a different source for the detail. Students may consult the library or Internet for sources. Once a detail is identified, students are to hand draw the detail @ 1”=1’-0” and note the materials and indicate the total R-value of the wall. Any media is acceptable. The objective is to become familiar with the components of the detail and to practice detailing. A 3D file using Sketchup or Bonzai3D is also required to reveal the various layers of the construction.

Part 2: Analysis
The selected construction detail is then put through a thermal analysis using the free version of HEAT2 (a PC-program for two-dimensional transient and steady state heat transfer). Students are to revise the original detail to eliminate any thermal bridging and re-evaluate using HEAT2 (PC-based program examining heat transfer). After elimination of the thermal bridge, the new construction detail is redrawn at 1”=1’-0” making note of all necessary air sealing to achieve air tightness. Students then construct a new Sketchup or Bonzai3D model of the revised thermal bridge free detail.

Part 3: Full-Scale Mockup
Teams construct a **full-scale** model (1”=1”) of the revised thermal bridge-free construction detail. The model should be built with impeccable details and should be easily portable (maybe on wheels), exploring different exterior wall siding systems or roofing systems that could be used, and providing manufacturers’ information/literature on all products used in the model. In some cases, students might have to contact manufacturers to request small sample materials. A final presentation includes the model, all documentation, analysis, and 3D models.

The most successful part of the research project was the analysis. Students are able to visualize the impact of various construction details in a way that they were not able to do before. Through the analysis exercise, they can visually verify the energy performance of a design solution. Least successful was the full-scale construction mockup. This was probably due to several factors: a) inadequate time to complete the mockup; b) students had little or no experience with actual building construction, and limitation to accessing material resources -- resulting in a lot of vinyl siding and rigid insulation solutions.

1.4 Interdisciplinary Collaboration

The course involved several guest speakers from the profession, but since it was the first course offered in the department on PH concepts and techniques, we relied on the expertise of the instructor as a Certified Passive House Consultant and building professional.

1.5 Examples of Faculty/Student Discourse

Students have several opportunities to engage with various faculty in conjunction with both PH courses. At the end of the semester, the Passive and Low Energy seminar students held an open house to display their semester work. Faculty were invited to a poster session in which the students engage in discussions about their analysis results and mock-up. The first session was challenging for the students, as they had to defend a design approach that is radical to how most architects practice. The mockup remained on display for several weeks in the architecture building.

The students from the Malta workshop exhibited their work at a university-sponsored venue, the Cage Gallery, featuring travel photographs, high performance building manufacturer samples, drawings and large-scale thermal analysis print outs of researched details. The exhibition was on display for two weeks and was well attended by students and faculty.

As a result of the mock-ups and student exhibition, several faculty have referenced the materials produced into their course instruction.

2.0 NORTH DAKOTA STATE UNIVERSITY – PASSIVE HOUSE DESIGN/BUILD

2.1 Class Organization and Outcomes

In 2011, a 3-semester Design/Build course was offered at NDSU with a goal of designing, constructing, exhibiting, certifying and occupying a Passive House (PH) structure. Students engaged several clients, consultants, governing authorities, manufacturers and researchers. They provided design and energy solutions for four different sites to prospective clients using Passive House Planning Package (PHPP) and full-scale construction as primary modes of investigation through various stages of design and implementation. One of these projects moved forward to pre-certification and construction.

DESIGN SEMESTER SUMMARY & OUTCOMES (Spring 2011 – 1 studio of 6 credits with 22 students): Students researched, analyzed and designed through scaled and full scale investigations, completing typical phases of a design project such as schematic design, design development, construction documentation and specifications. Experts and studio faculty introduced building science and PH principles during visits to certified structures in the region. In addition to PHPP, Athena and USGBC LEED for Homes provided a comprehensive approach to measuring environmental impacts. Studio instructor used WUFI and THERM to further the energy analysis by the students. Students constructed full-scale modules of various construction systems such as Structural Insulated Panels (SIP), double wall stick frame, solid wood construction to analyze super-insulated PH performance for a cold climate. Emphasis on developing careful craft with construction techniques and strictly following safety protocols prepared students for the construction semester. Students experienced fundraising, marketing, budgeting, client – contractor – consultant – collaborations.

a. End of semester exhibit, Fargo ND: Full scale PH super-insulated walls, roofs and floor connections and educational materials for PH concepts (250+ visitors).
b. Completed construction drawing set and specifications in preparation for construction semester.
c. Marketing and fund-raising to raise \$20,000 in cash funding and \$80,000 in-kind product donations.
d. Faculty and Design/Build studio partnered to apply for energy education grant: Granted \$46,000.

CONSTRUCTION SEMESTER SUMMARY & OUTCOMES (Summer 2011 – 2 seminars of 3 credits each with 15 students): Students and studio faculty completed pre-certification of the cabin with Passive House Institute US (PHIUS) after which students constructed a 650 nsf PH cabin in St. Paul, MN at the Eco-experience exhibit. Exhibit lasted ten days after which the students dismantled the various modules and created installation instructions and a labelling system for re-installation at the permanent site. The modules were transported to the permanent location.

a. Eco-Experience Exhibit: Invited by the Minnesota Pollution Control Agency, Design/Build studio exhibited a full scale PH cabin. 300,000+ visitors over a period of 10 days.
b. 45-minute presentations: teams of two (student and faculty) gave on their research focus at the Eco-experience;
c. PH educational materials: students developed, made, installed and distributed materials to engage various age levels. Materials ranged from interactive games for children to understand PH concepts to sophisticated numerically verified models for the knowledgeable visitor.
d. Published construction video: two construction cameras photographed construction progress every 2 minutes.
e. Published a website: dedicated to Design/Build NDSU (www.ndsudesignbuild.com) where students published personal blogs as a course requirement.
f. Radio and television interviews: articles and blogs published by media about NDSU Design/Build, (including Minnesota Public Radio).

DOCUMENTATION SEMESTER SUMMARY & OUTCOMES (Fall 2011 – 1 studio of 6 credits with 14 students): Based on the work of the Design & Construction semesters, the students translated months of documentation (photos, writings, models, drawings, full scale modules and document sets) into two books.

a. Studio published Voices & Chronology. Voices contains four one-page articles written by each student. Chronology documents the process of 2011 Design Build in essays and photographs. Introductory essays by faculty are included in both books.
b. Faculty published a conference paper in the proceedings of the Passive House National Conference 2012 titled, PH as a University Design/Build Start-Up
c. Faculty published a conference poster at the Passive House National Conference, 2011.

2.2 Barriers to Implementation

a. PH Design/Build projects are multi-semester efforts that produce better than code-compliant completed structures. This entails finding the right clients, projects, donors and funding resources that can support a multi-semester applied-research effort.
b. Quality and reliability of donated products designed to meet a very stringent performance can create logistics and performance problems.
c. Full-scale construction studio strained limited resources. As an investigative and generative tool, it meant that the studio required more space, tools and workshop time than the average studio
d. Intensity of time required to meet learning goals would have been more successful if all the classes students were taking were related to Design/Build over the course of three semesters. However, this results in a high concentration of Design/Build credits. Subsequently, classes worth fewer credits were offered but the workload involved created incredible time pressures on faculty and students involved which resulted in a severe workload and credits earned mismatch;
e. Students had inconsistent preparation in building science fundamentals;
f. Dearth of locally manufactured PH certified building products at a reasonable cost;
g. Even though Design/Build can be greatly beneficial in creating a deep understanding of energy and performance issues, there are very few legal frameworks that allow such projects to be covered under practice laws such as general and professional liability insurance.

2.3 Innovative Teaching Strategies and Impacts of Tools

a. Design/Build and PH taught together allowed for in-depth understanding of an integrated design process. PH principles, concepts and computations created a framework of stringent performance requirements which impacted architectural form, orientation, detail and craft, requiring students to understand every part of the building system, form and detail and comprehend its interdependencies.
b. Full scale building from day one of the semester was the primary analytical, investigative and generative tool and allowed students to understand and translate PH concepts into a built construct.
c. On the first day of the semester, students were required to build a section of the typical stick-frames code-compliant wall. This set the tone for the semester requiring students to be resourceful about finding and assembling materials at short notice with limited financial resources, understanding building science principles, building code compliant structures and paying detailed attention to craft, care and quality.
d. Multiple project types (new construction, existing renovation, single family and multi-family homes) allowed students to understand PH concepts and use PHPP to enter data and interpret results.

2.4 Interdisciplinary Collaboration

Several professionals, experts, authorities, manufacturers donated time, experience and expertise.

a. **Primary collaborations** allowed the students to engage with people as they would in a typical architectural practice: Engineers, product vendors, experts such as co-director Katrin Klingenberg from PHIUS, clients, governing authorities such as the Building Code authority, State Historical Society and Department of Natural Resources and building inspectors.
b. **Secondary collaborations** allowed the students to experience what it means to be an entrepreneur and find funding for opportunities. Students engaged in pricing, bidding, budgeting, marketing and fundraising and logistics planning.
c. **Tertiary collaborations** with construction supervisors, licensed trades, contractors & builders allowed students to experience the construction side of the building industry. They became familiar with safety protocols, OSHA rules, hands-on experience with construction methods, logistics and liability issues.

2.5 Examples of Faculty/Student Discourse

The discourse in the Design/Build studio was captured by the students in the Documentation semester in a publication called *Voices*. The topics chosen by students do not comprehensively address the various areas of interest but do reveal the pre-occupations of the group and those issues that the students found were unique to the studio. Following are some samples of the student articles:

Collaboration and authorship (or lack thereof): Questions of authorship do not emerge in the typical design studio since students primarily work on individual projects. In the Design/Build PH studio several authors created one work. Projects and roles were constantly traded such that labels such as designer, manager, specification writer etc. were not assigned to people. Only the work received labels and almost everyone in the studio made a contribution to the development of almost every component. This collaboration model left deep impressions on several students who wrote about this approach in *Voices*..
Do-It-Yourself: The lack of reasonably priced, locally available certified PH building components created a culture of Do-It-Yourself innovators. This resulted in various components that were designed and manufactured by students. It also created an “us versus them” culture where the students measured their innovations against the purchased and donated products that were incorporated into the constructions. Ultimately it created a “your waste is my treasure” discourse.
En-LARGE-d scale: Typically students make scaled artifacts while in this studio they were asked to make full scale investigations. Typically students present their end of semester work over a very short duration from a few minutes to few hours. At the Eco-experience exhibit students presented the PH cabin for twelve days, twelve hours a day for over 300,000 visitors from all walks of life. Typically, the student budgets for finishing and presenting a studio project might take an investment of a few hundred dollars at the most. Here the fundraising demands were to the order of $100,000. This enlarged scale on several fronts allowed the students to experience the decision-making involved in professional projects. The studio discussion often focused on the differences in scale between the typical studio project and the Design/Build PH studio.

3.0 UNIVERSITY OF OREGON - SEMINAR

3.1 Class Organization and Outcomes

The Department of Architecture at the University of Oregon offered a four-credit seminar course in the Spring Term of 2012 called Passive House Design and Detailing. This course fulfilled an advanced technical elective requirement and was offered to undergraduate and graduate architecture students. There were two prerequisites for the course: Building Construction and Environmental Control Systems I, since the students needed a basic understanding of wood framed construction, passive strategies, thermal comfort, and heating and cooling systems to adequately engage the material. The course met twice a week on Tuesday and Thursday for 1 hour 50 minutes over the ten-week term. Typically, a lecture on a specific aspect of the Passive House concept was given on Tuesday; on Thursday, the students were assigned an in-class activity that complemented Tuesday’s lecture material. At the end of class on Thursday, a take-home exercise, which the students completed in pairs, was assigned and due the following week. The last four weeks of the term, the students worked in pairs to develop the design of a small passive house for a hypothetical site in Eugene, Oregon. In lieu of in-class activities during the final four weeks, we held in-class checkpoints for the final project to keep the students on track. Faculty and local professionals attended a poster review session on the last day of class to provide feedback to the students on their final projects.

Throughout the term, we collaborated with the Center for the Advancement of Sustainable Living (CASL), a student-initiated program at the University of Oregon. CASL is renovating a small single-family house – the CASL house – near the University of Oregon campus using Passive House principles. Many of the activities and exercises during the term asked students to investigate aspects of the CASL design, including the assemblies, connections, and mechanical system. Several of the students enrolled in the course were also involved with the construction of this project. During one course period, the students had the opportunity to visit the CASL house and see Passive House strategies implemented firsthand, including advanced framing, types and applications of insulation, and the heat recovery ventilation system. During this visit to the CASL house, we also conducted a blower door test and showed the students how to interpret the results.

We received a small grant ($5,000) for the course and used this funding to invite guest speakers during the term. The guest speakers were given a lecture topic to cover during the first hour of the course, and were asked to share examples of their own work during the second hour. In some cases, they led the week’s in-class activity. Guest speakers were selected based on their experience/expertise with PH and related software tools. We were fortunate in that there were many professionals involved with Passive House in our region of the country. All of our guest speakers were located on the west coast; most were located in Oregon or Washington and within driving distance of Eugene. For this reason, we were able to make our relatively small grant go a long way.

We were also fortunate to have several students in the department who were Certified Passive House Consultants and provided instructor support throughout the term. These students had a strong understanding of PH principles and the associated software and were able to provide support to the students during activities and exercises, as well as assist in the development of course materials.

3.2 Barriers to Implementation

Because of the high level of knowledge and software expertise required to design PH buildings, we found the guest speakers to be a critical component of the course's success. The speakers had first hand experience with PH projects and brought a unique perspective regarding their particular discipline and expertise. Had we not received the grant that allowed us to pay the guest speakers for their travel expenses, we would likely not have been able to invite them. The grant also allowed us to hire teaching assistants, who played a key role in providing instructor support as mentioned above. For these reasons, a lack of funding would significantly hinder the ability of the course to be offered in the future. However, since the course materials are now in place, it is more likely that this course could be offered again without relying as heavily on guest speakers and teaching assistants to supplement the instructor's lectures, activities, and materials.

Though the guest speakers generally stayed on topic when asked to cover a particular aspect of PH, it would be beneficial to provide them with an outline of the material to be covered ahead of time so they can properly incorporate the material into their lecture. Our approach was to have a brief conversation with the guest speaker about the lecture topic and the material to be covered, though a written outline would likely be more effective in preventing course material from being inadvertently omitted.

The availability and/or expense of software tools used in the course created some challenges. THERM and WUFI, which analyze thermal bridges and moisture transport, respectively, are available for free download. However, the free version of WUFI is limited in its functionality, and the full version is prohibitively expensive for students. The lack of availability of an I-P version of the Passive House Planning Package (PHPP) during the time this course was offered also presented challenges. If we had easier access to the necessary software, we would have likely dedicated more class time to learning it. Ultimately, we did not dive into the software as much as we would have liked.

Depending on their level in the program, some students had not yet taken their required Building Enclosures course when they enrolled in this seminar. While these students were at a slight disadvantage with some of the course material, including envelope detailing and moisture management, they will likely be more prepared to tackle Building Enclosures after having completed this elective course.

As mentioned previously, the CASL house offered a unique opportunity for students to engage a real world project in their coursework. However, there were some challenges in collaborating with CASL due to scheduling. Our course schedule and the schedule of the CASL house design and construction did not always seamlessly align. In the future, the instructor would need to engage CASL (or a similar project) well before the start of the course to find where there might be opportunities for collaboration.

3.3 Innovative Teaching Strategies and Impacts of Tools

Throughout the term, we always introduced concepts and calculations before introducing related software. For instance, the students completed an annual heating demand calculation by hand before being introduced to the PHPP. Additionally, the students plotted the thermal gradient across a wall assembly and located the dew point before being introduced to WUFI. This emphasis on understanding the concepts and calculations behind the software before being introduced to the software itself was very effective; the students were able to engage the software in a more thoughtful way when they had an understanding of some of its underlying principles.

We found that the students responded better to class activities when they were asked to use the software tools for design rather than verification only. The exercises were most effective when the students had to analyze a condition, interpret the results, and then respond to the results with a change in design. For example, the students were asked to model an assembly in WUFI, interpret the results, and then make design changes to the assembly to improve its performance. The emphasis on using the software as a design tool rather than simply a tool for verification was a major theme in the course.

3.4 Interdisciplinary Collaboration

While we did not collaborate with other disciplines or departments outside of architecture in this particular course, we see opportunities for this type of collaboration in the future. We did however engage a variety of professionals from other disciplines as guest speakers. Students in engineering and construction programs would be interested in the material, as the topics include HVAC design, plumbing design, renewable energy systems, and construction means and methods. It is worthwhile to note that our guest speakers included contractors, architects, and engineers. Each brought a unique perspective due to their education, background, and experience. We feel that this diversity in discipline contributed to a rich learning environment.

3.5 Examples of Faculty/Student Discourse

Throughout the term, we set aside time for class discussion and question/answer sessions, particularly when guest speakers were present. During one course period, we divided the students into groups and provided them with a list of questions intended to generate a critical discussion of the PH approach, its applicability to various climates, and alternate approaches to low energy construction. We feel this open dialogue is an important aspect of any college level course, even when the topic is a technical one.

The conversations around PH topics seemed to spark curiosity, inspire the desire to delve more deeply into topics, and created stir demanding that the department offer more courses on the topic. This year, two adjuncts taught a class at the CASL house that was about implementing, testing, and installing components in the CASL house on campus.

Further, graduate students were required to submit a one-page research prospectus on a PH topic. This assignment was intended to help graduate students generate ideas for further research in PH topics. Ultimately, our hope is that some students will engage faculty for guidance in carrying out their proposed research project as an independent study or master's thesis.

CONCLUSION

The authors have proposed the PH curriculum as a means of exposing students to analysis tools like WUFI and THERM, but also our intention was to collaborate and to begin a dialogue on ways to infuse the curriculum with new courses that address the 2030 Challenge, Clearly, our focus was on academic courses, rather than mimicking professional training. The courses provide tangible methods and tools for students to learn at multiple scales, and linking technology/science to design integration is difficult administratively, but with efforts at several levels it can be resolved successfully. Three different models shown in this paper (see Table 1) include raising awareness and increasing understanding of traditional building science concepts/principles, including envelope construction, thermal comfort, heat gain/loss, ventilation, shading, orientation, and calculations of total primary energy use. All involve real-world examples, thinking and doing exercises, applying principles/concepts in a real, hands-on activity. Lessons from the faculty and student discourse are valuable as the authors hope to help other institutions do the same.

TABLE 1. Matrix of curricular structure for 3 passive house courses at 3 universities

Institution	Class Type	Students	Level	Duration	Credits
Miami University	elective seminar summer workshop	20-25 17	UG: 3rd year+ G: 1st year+ UG: 3rd year+ G: 1st year+	16-week semester 4 weeks	3 6
North Dakota State University	Design/build studios (Spring & Fall) Design/build seminar (Summer)	22 14	G: 4th year + G: 5th year G: 4th year + G: 5th year	15–week semester 8-week semester	6 (per studio) 3+3 (summer)
University of Oregon	elective seminar	30	UG: 3rd year+ G: 1st year+	10-week quarter	4

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ENDNOTES

[1] http://www.architecture2030.org/ Established in response to the climate change crisis with a goal to achieve a dramatic reduction in the climate-change-causing greenhouse gas (GHG) emissions of the Building Sector by changing the way buildings and developments are planned, designed and constructed.
[2] http://architecture2030.org/action/2010_imperative_global_emergency_teach_in
[3] DOE Challenge Home and PHIUS+ Passive Home Certification - A New Partnership to Promote Zero and Plus Energy Homes, Katrin Klingenberg, Proceedings of the 7th Annual North American Passive House Conference, September 28-29, 2012, Denver CO. DOE has targeted 70% energy savings by the Year 2020. The PHIUS + program integrated with the Challenge Home Requirements provides a way to meet the 2020 goals right now.

Material Skunkworks: Building Technology for Future Architects

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ABSTRACT: Traditionally seminar teaching of construction systems utilizes several methods to convey information: readings from established texts, topical lectures, and iconic case studies, all sequenced and formatted to follow the Construction Specification Institute's (CSI) organization of topics. While these techniques have their value, this overall method tends to arrange and prioritize information into a series of material silos; (wood, masonry, steel, etc.). This often results in an isolated, desk bound learning experience that fosters passive engagement by the student. It tends to meet NAAB's first goal of understanding a topic, but falls short of conveying an ability to apply the new ideas encountered in building technology classes. This paper outlines an adjusted approach where information is organized and taught to expose translational learning opportunities through an applied knowledge of construction materials and methods.

KEYWORDS: Architecture, Pedagogy, Materials, Construction

INTRODUCTION

The development of construction materials since the industrial revolution has exponentially expanded the palette of the architect. Today's 'material-copia' provides a broader opportunity for architectural possibility while simultaneously increasing the chances for its misappropriation. Teaching students how to take advantage of this expansion, while understanding their complex assemblage, is essential to their development as future architects. Interested organizations such as NAAB, NCARB and the AIA have differing requirements for developing architects with knowledge of building technologies and the ability to apply associated concepts. Each of these organizations establish different baselines for meeting practical objectives during one's education, internship and throughout their career, but the responsibility of establishing the foundation of this education falls on the shoulders of building technology educators in architecture programs.

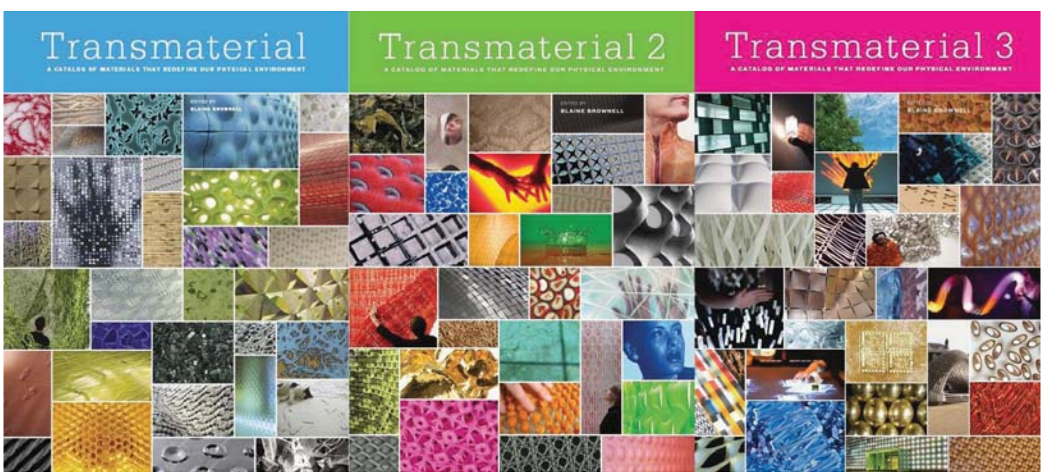

Figure 1: New material catalogs compiled by architect Blaine Brownell. Source: (http://transmaterial.net/)

Materials and Methods of construction knowledge standards are policed through the National Architectural Accrediting Board, (NAAB), who set guidelines for all topics that lead to an accredited degree of architecture. NAAB categorizes the knowledge to be conveyed into different realms and setting student performance criteria (SPC's) for each topic within them. Schools must prove that they meet these conditions through the recurring process of accreditation. NAAB does this to ensure the public and potential students that an architecture program meets a *minimum* level of quality. There are three specific SPC's that relate directly to building technology materials in NAAB's accreditation guidelines. The first covers building envelope systems and requires that students understand their basic principles, appropriate application, and expected interior environmental performance. The second SPC, building service systems, requires students understand the basic principles related to mechanical, electrical, plumbing, fire protection, and vertical circulation systems. The last SPC, building materials and assemblies, essentially requires students to understand materials' inherent properties and their assembly.

Post-graduation the National Council of Architectural Registration Board's, (NCARB), as well as state licensure boards establish knowledge standards through the requirements needed to pass the Architectural Registration Exam (ARE). In its study guide for the exam, NCARB indicates five specific content areas related to materials and methods of construction; principles, environmental issues, codes and regulations, materials and technology, and project and practice management. The categories correspond directly to broad topics rather than specific classes taught in architecture programs, and there are overlaps across course syllabi in materials and methods, environmental controls, and professional practice. Under material properties the study guide organizes the materials and technology section in a similar way to many materials and methods classes. It distinguishes the topics similarly to their CSI classification; Masonry, Metals, Wood, concrete, other and specialties. Historically this has proven to be appropriate, as the topics are heavy on traditional materials; however as a requirement for passing the exam it tends to deemphasize innovative explorations by grouping all the remaining topics into the 'other' category.

Once interns have obtained their registration, the American Institute of Architects (AIA), establishes basic knowledge standards through continuing education guidelines in health, safety, and welfare topics (HSW). These are defined on the AIA website as 'Technical and professional subjects, that the NCARB Board deems appropriate to safeguard the public and that are within the following enumerated areas necessary for the proper evaluation, design, construction, and utilization of buildings and the built environment.' These are categorized into several sub-topics. Those that relate to building technologies are building systems, design, environmental topics, and materials and methods.

All of these organizations set their own baseline for the appropriate make-up and amount of knowledge required of architects as it relates to practice. For schools, these standards help to establish the direction and goals of their materials and methods of construction sequences. However requiring students to take courses on these topics does not necessarily guarantee an understanding of the basic knowledge required by these organizations. In the face of an ever evolving palette of available materials schools must constantly ask themselves how to develop graduates that can and adjust their courses accordingly.

1.0 MODES OF TEACHING MATERIALS AND METHODS

1.1. The Traditional MasterFormat™ Model

Most of the current popular texts adopted by instructors for Materials and Methods of Construction classes organize material in a manner that roughly follows the logic set forth by the Construction Specifications Institute (CSI) in their MasterFormat system. It establishes a standardized numbering system for the organization of all specifications required to construct a project. Traditional these have numbered 16 total divisions, but they have grown recently to 50 in 2004. Many of the new divisions are left unused for future expansion of the system, as CSI also understands that the material palette is growing.

In materials and methods texts this organization has naturally and frequently followed the earlier 16 division CSI layout. For example, MasterFormat Division 2-Site Construction would correspond closely with a chapter on foundations, while broader topics like Division 06-Wood and Plastics would encompass several chapters in a text book. Instructors who closely follow these texts find themselves discussing entire topics at one time. The subject of wood is presented from its harvest, through its manipulation into a building material, and finally into its use in assemblies.

As a method of systematizing the information this is versatile yet specific, and it works for an industry that that must manage the use of virtually any material the architect may introduce to a project. However, it tends to utilize an organization of knowledge that is required in practice, rather than one which accounts for the layperson level of understanding possessed by most beginning design students unexposed to the industry and its standards. It is possible that there is a more efficient method for teaching students, specifically those focused on Architecture.

1.2. A New Material/Assembly Model
In an attempt to streamline the teaching of materials and methods of construction, the faculty at Auburn University's School of Architecture, Planning and Landscape Architecture, (SoAPLA), has been developing an alternative method for course delivery in this sequence of class topics. Traditionally these courses followed a survey of information set forth in well-established texts that utilized several methods to convey information; readings, topical lectures, and iconic case studies that might culminate in a large scale drawing project or detailed model. The faculty recently questioned whether this model best fit the NAAB requirements for an 'understanding of' or an 'ability to apply' knowledge gained in the class, and set out to design a syllabus that ensured it.

The first major shift that occurred was at the level of the curriculum. The materials and methods topics at Auburn are taught in a pair of three hour courses. Previously, the first occurred at the beginning of second year, and it typically covered all topics on foundations, wood, and masonry. The second came later in the curriculum. Materials and Methods II was typically taken at the end of third year and covered all topics on concrete, steel, roofing, glazing and interior finishes. The faculty shifted the second class to immediately follow the first. They are now taught in consecutive semester during second year.

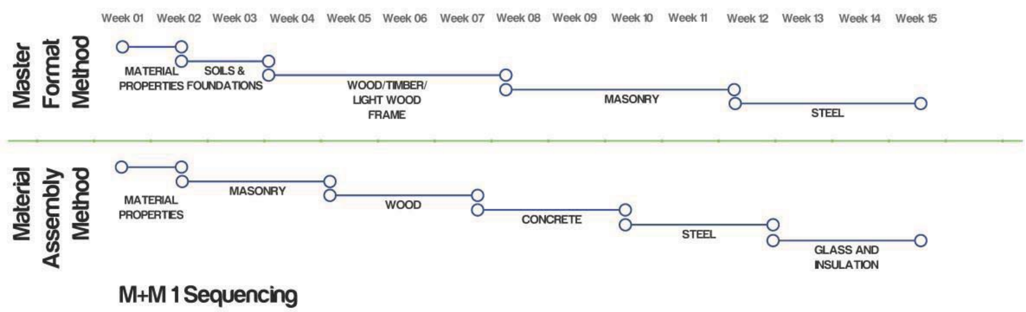

Figure 2: Comparative diagram showing two models for Materials & Methods 1. Source: (Sproull 2013)

The subsequent and more complicated shift occurred within the courses themselves. The instructors abandoned the CSI MasterFormat organizational system, instead categorizing the information into two broad topics taught in separate classes. The first course now focuses on materials while the second centers on assemblies. This configuration of information benefitted the students in two ways. First it divided the topics into processes that happen to materials before arriving on-site in M&M1 or after in M&M2. The first course now covers any transformations related to processing from raw materials to building materials including pre-fabrication of typical construction elements like trusses or open web steel joists. The second class focuses on material are arrangement and connection. These differences in course foci are evident in the learning outcome strategies found in the assigned readings, course lectures, and most acutely in class projects. The new structure provides a clean divide between *learning through making* in M&M1 and *learning through drawing* in M&M2. Projects follow these methodologies on an ever increasing procession of complexity throughout the entire calendar year.

The second advantage of the new information configuration was its ability to emphasize the hybridity of actual construction processes, techniques, and assemblies that exist in practice. Today's assemblies typically require an understanding of many different types of materials. In this respect, covering standalone materials from beginning to end in M&M classes isolates their particular properties from all others. An example of this would be the typical residential brick wall; historically consisting of solid stacked masonry but now replaced with veneer. Where understanding masonry was previously enough to understand the assembly, one now must understand wood framing, fasteners, insulation, and thermal and vapor barriers. It has become a collection of materials, and this requires a different organization of the course information.

The rapid expansion of the architect's palette makes educating future architects a challenge. The end goal is a constantly moving target, and the body of knowledge is continuously increasing. This expansion often means architects are far less informed about what they are specifying. By focusing on materials and their properties in the first class, it sets up a methodical framework by which future architects can educate themselves about the materials they employ. They are essentially being taught how to learn. This method of organization still meets all of the requirements set forth by NAAB, and provides knowledge required for the ARE. However, it does so by removing the silos where these topics have traditionally existed allowing an emphasis on hybridity found in typical design and construction today.

The strength of the material/assembly model is the concentrated redundancy of themes that occurs through this method. The first class covers materials, and seems to present this set of topics as isolated from assemblies with redundancy occurring in the persistent discussion of material properties found in the covered subjects. However this is actually the result of a 'planned deception'. In reality, while all the projects covered in the course focus noticeably on the materials themselves, they are carefully crafted to convey an underlying lesson regarding assemblies in the given medium.

2.0 MATERIAL SKUNKWORKS

2.1. Skunkworks in the Classroom

The Skunkworks Division of the US based Lockheed Aircraft Corporation was formed in 1943 by Kelly Johnson to directly respond to threats of a new class of German jet fighter. Johnson and his team designed and built the XP-80 in only 143 days, seven less than was required. What allowed Kelly to operate the Skunk Works so effectively and efficiently was his unconventional organizational approach. He broke the rules, challenging the current bureaucratic system that stifled innovation and hindered progress. His philosophy is spelled out in his "14 rules and practices."

Figure 3: Skunkworks team discusses XP-80. Source: (http://www.lockheedmartin.com/us/aeronautics/skunkworks.html)

The Material and Methods sequence at Auburn loosely employs these rules, specifically Johnson's rule #2, 4, 9, and 14. These rules and a brief explanation of their applicability to the Materials and Methods curriculum are outlined below:

> *2. Strong but small project offices must be provided both by the military and industry.*

To this rule, the Materials and Method curriculum employs projects and assignments merging small, familiar student teams with a single invested industry partner.

> *4. A very simple drawing and drawing release system with great flexibility for making changes must be provided.*

The Materials and Methods sequence places a heightened emphasis on planning, but not necessarily comprehensive planning, which can stifle experimentation. Lectures, case studies and students assignments all reflect the importance of iterative learning through constant drawing, making, and testing. The curriculum teaches students that making is as much working with timelines and schedules as it is working with tools.

> *9. The contractor must be delegated the authority to test his final product in flight. He can and must test it in the initial stages. If he doesn't, he rapidly loses his competency to design other vehicles.*

Even though students are working in teams on projects, each team member is solely responsible for the work they produce, and are graded accordingly. Therefore active engagement at all levels of the curriculum is expected. Because the Materials and Methods is designed as a network of lectures, case studies, site visits, and projects, student engagement at all levels and facets is critical to student success.

> *14. Because only a few people will be used in engineering and most other areas, ways must be provided to promote good performance not based on the number of personnel supervised.*

This final rule is arguably the most integral to the Materials and Methods curriculum. Many of the projects delivered in Materials and Methods I require an applied understanding of both materials and assemblies. However, given the limited structure of the class, the lectures can only feasibly elaborate on the topic of material properties and not material assemblies. The second class in the series, Materials and Methods II covers assemblies more thoroughly in lectures. However, one cannot logically separate materials from assembly and vice versa in reality. For that reason, although material properties is foregrounded in the first class, a discussion of material assemblies is actively backgrounded in all aspects of the course, most notably through the projects and workshops. The following outlines the project sequence for Materials and Methods I, and in particular how a Skunkwork method of operation functionally translates to students in the course.

2.2. The Three Little Pigs

Materials and Methods I focuses on the basic materials that architects specify and build with today and have used throughout history. While lectures and readings play a significant role in student understanding, hands-on exercises make up an important part as well. As a requirement for student's final grade, students are asked to complete a series of projects centered on the production of materials, namely masonry, wood, and concrete, or affectionately dubbed "The Three Little Pigs". The investigations take the form of a uniform 5" cube, and specific requirements vary by the material being used.

Craftsmanship of the final product is of utmost importance; as is an understanding of the process the students utilize to produce the objects. In this regard, for all of the investigations, the students are required to document all of their work. This includes not only study models and prototypes, but also photographs, videos, sketches, calculations, tools, formwork, etc. Each material study culminates in student presentations made to the class and critics, and the documentation serves to support the student work.

The three focus areas (masonry, wood, concrete) correlating to a specific cube project are sequenced such that they contain approximately 3-4 lecture classes, 2 workshops, and one site visit per material topic. The order of the lectures, site visits, and workshops are sequenced such that they are ultimately in support of the assigned material project which directly relates to the material topic.

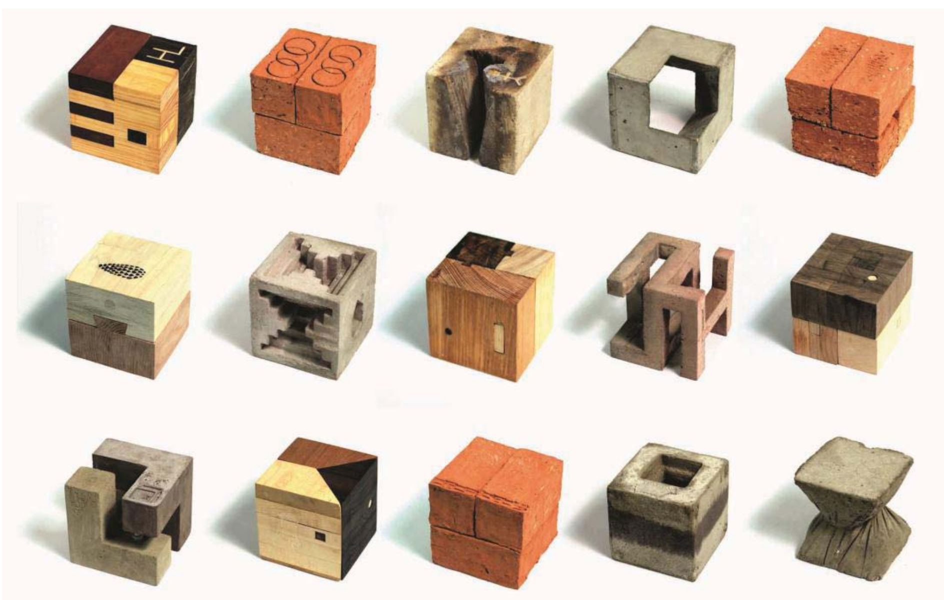

Figure 4: Examples of student work from *Three Little Pigs*. These projects teach an understanding of assemblies through a directed study of specific materials. Source: (Sproull/Salvas 2012)

2.3 The Masonry Cube

The first material cube in the series is masonry - specifically the brick. Each student group is asked to produce four stackable clay masonry units precisely measuring 5" long x 2 ½" wide x 2 ½" tall, when stacked produce a cube that is a uniform 5”. The student bricks must be well crafted objects, and must possess an identifiable pressed mark that is unique to the group.

This project benefits from collaboration with the Department of 3D Arts at Auburn University who provides the students with an introductory workshop on clay forming and rules of thumb, and at the end of the four week project timeline fires all of the student bricks in their kiln. The project also benefits from a relationship with Jenkins Brick in Montgomery, Alabama, which operates as a brick manufacturing plant. After the students are given the assignment, and have enough time to contemplate all of the issues and opportunity the project provides them, they are asked to formulate all of their questions and direct them toward the professionals at Jenkins Brick.

While at Jenkins Brick students are exposed to the full process of brick making, from clay extraction, material mixing, forming, pressing, drying, firing, all the way to project management and design. The students are witnessing a production scale version of the process they are currently being asked to enter. The students understand the many benefits of the experience and are eager to ask questions, both broad and pointed relative to their brick assignment and the role of materials in design and architecture. The site visit ends with Jenkins Brick donating a 5 gallon bucket of raw material to each student team for use in their brick project.

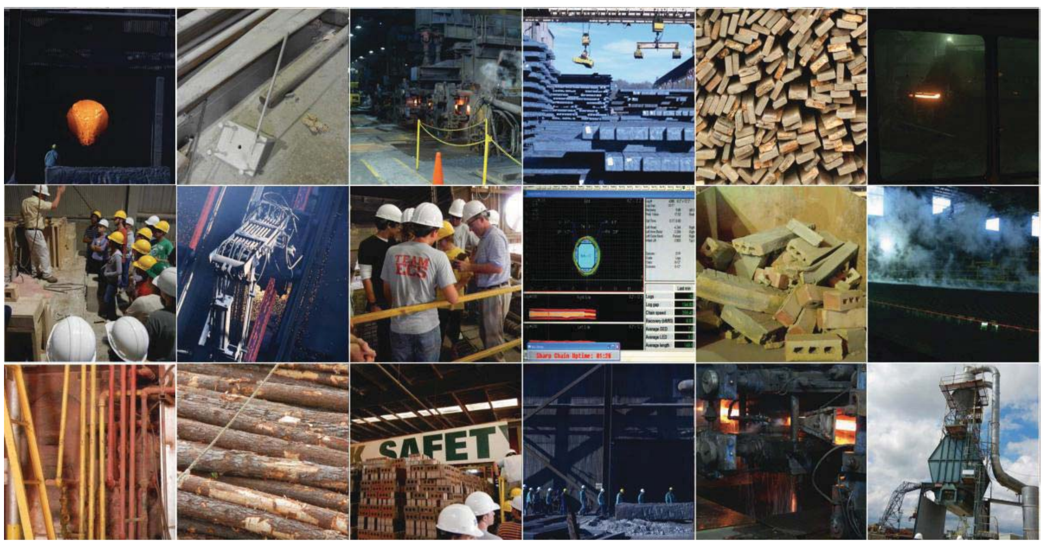

Figure 5: Montage of images from student field trips to industry collaborators. These provide a industrial scale comparison to the small hand-crafted blocks produced by students. Source: (Sproull/Salvas 2012)

2.4 The Wood Cube

The next installment in the investigation of materials deals with wood. In this study each student team is asked to design and precisely make a solid 5” cube. Each cube must be made up of three separate major pieces of wood connected with friction joints. The students are not allowed the use of any type of mechanical fasteners or glue in their production of these joints (glues are only permitted in the lamination of wood). The joints must be designed such that the constituent pieces remain together no matter how one holds the cube. On any given project no joint type may duplicate another. Each block must possess the same identifying mark that was used on the bricks.

This project benefits from a heavy dependence on SoAPLA’s Wood Shop, and in particular its custodian Steve Protzman. Students are required to pass a series of design sign-offs before they are allowed to begin wood working. They must first obtain approval of their design from the Materials and Methods instructors, at which time they can then approach Steve Protzman for design sign-off. Only after both endorsements may that student manipulate the raw materials. In addition, the woodshop requires careful coordination and no more than two student groups are allowed to work in the woodshop at any one time. This ensures the appropriate amount of instructor to student attention and that all safety measures are followed.

The wood cube assignment also greatly benefits from a collaboration with Frasier Lumber and Van Nostrand

Custom Cabinets, both located in Opelika, Alabama 15 minutes east of Auburn University. The first year of the material cube assignments, faculty and students visited Frasier Lumber at the onset of the wood cube assignment. Although it was incredibly informative and insightful, their focus in the wood industry was more removed from the student assignments and it was more difficult for the students to engage. Therefore the year after the faculty decided to partner instead with Van Nostrand Cabinets. Their focus was more on material connections and less on material processing. The students were able to see first-hand the process of taking raw materials and transforming them into a finished product through the utilization of both digital and manual processes. Like Jenkins Brick, Van Nostrand Cabinets donated off-cut hardwoods to the students for free, eliminating or greatly reducing the cost that the students had to pay out of pocket for the assignment.

Figure 6: Example of documentation by students working on a concrete cube project. To complete this project it essential for the students to understand how to assemble the elements of their design. Source: (Sproull/Salvas 2012)

2.5 The Concrete Cube
The final installment of the material cubes deals with concrete's versatility relative to form making. It may be used to create both straight edges and organic curves. Using this as provocation student teams are asked to create a single monolithic 5" cube with a visible void or multiple voids within it. Students are allowed to remove up to two corners from the cube however they may not be adjacent to each other.

Primarily, the cube must demonstrate the plastic nature of concrete. Although the final cube foregrounds the use and mastery of concrete, equally integral to the success of the project is the craft and precision used in the formwork, which is primarily made of wood. The final project is the synthesis of the two previous cube assignments, merging the careful understanding of the manipulation of a plastic building material, as in the brick cube, paired with the precision and craft learned in the wood cube. This final cube is a complex assembly, deconstructed to leave only the concrete artifact. Due to the complexity of the assignment, and the emphasis on innovation, experimentation is expected and accounted for in the duration of the project. The students are given approximately 8 weeks to complete the concrete cube assignment, twice as long as either the brick or the wood block assignments.

The concrete cube project again benefits from an orchestrated collaboration with SoAPLA's Architecture Wood Shop and Steve Protzman. At this point in the semester, the students have had sufficient exposure to the woodshop, and the students are able to work more freely without as much instructor supervision. Their concrete formwork reflects their experiences in the last two material cube projects, and is better for it. Industry collaboration on this cube comes from Castone Corporation, a precast concrete fabricator in Opelika, Alabama. Similar to the past collaborations with industrial partners, Castone allowed faculty and students to take a tour of their facility as well as ask questions. They also provided the students with a variety of aggregate sizes and concrete dyes to use should they desire to. In more complex designs Castone worked side by side with the students to with specialized concrete mixtures.

CONCLUSION
In schools nationwide, there are many new building technologies education models being explored – especially as they relate to materials and methods. The premise for the variation on the traditional version presented here stems from the idea that a better understanding of course material is a result of applied and

theoretical student work. For materials and methods this involves both hands-on and paper assignments that balance between the big ideas and smallest particulars of any given project. Auburn's modification to its more traditional model is unique in that while it re-organizes the course material completely it simultaneously manages to emphasize all the same topics as well. By focusing the first class on the materials, it allows the faculty to covertly teach lessons about assembly; a topic that is hierarchically more complex than the topic directly foregrounded in the investigation.

Materials and Methods 2, while not covered in this paper, will continue this trajectory. It too clandestinely conveys idea about more complex subjects while focusing on a seemingly obvious topic. While folding in discussions regarding materials, the second course, again through carefully crafted projects, uses assemblies to covertly teach spatial and formal relationships as they relate to material properties. This is done with the intent of seeing that the principles covered in class are understood as well as applied in other studio based classes.

A Case Study on Case Studies

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ABSTRACT: Case study methodology is arguably among the most misunderstood and/or misused research techniques in architecture schools and practices alike, even if there are promising cross-, multi-, and trans-disciplinary exemplars. As architecture is not only inherently an interdisciplinary field, but also increasingly a knowledge-based discipline in terms of both the profession and the scholarship, this paper looks at the education of architectural research methods in general, and that of the case study method in particular, in order to detect the value of case study methodology in design research. It must be pointed out, though, that the case study method is not regarded below as an educational tool per se (like the case study models used in education of medicine, business and law among others), nor as a resource of web-based case study systems and other collections of antecedent building projects. The 'architecture' of case study research design is not the focus of this paper either, although it is briefly discussed with regard to data generation. Instead, the goal is to define the terminology and techniques related to case studies as an architectural research method in academia. Multidisciplinary perspective in embedded and holistic case studies is the primary framework of this paper, including both quantitative and qualitative research.

KEYWORDS: architectural research, case study, integrative evaluation, qualitative research, thick description

INTRODUCTION

While case studies as research methodology have been controversial, to say the least, they have also been instrumental in many disciplines, such as law, business, medicine, psychology, sociology, cultural anthropology, engineering, and urban planning. In architecture, case study is a frequently employed term, yet, not particularly well defined as a research method. In architectural jargon, it seems to mean anything from a true case study to a simple precedent study, sometimes used even just as a synonym for an 'example.' Furthermore, on the AIA's *Architecture 2030 Challenge* website, for instance, the "Case Studies" are more project descriptions than holistic studies of cases in relation to the complex dynamics of their context, which is one of the definitions of a case study; not alone including other characteristics such as explaining causal links, developing or testing a theory, generalizing to theory, and using multiple sources of evidence (Groat and Wang 2002). Although case or precedent studies have successfully been employed as means of design research in architectural practices or educational tools in many architecture schools, we do not discuss this type of usage of case studies here. Instead, we focus on the definition of a case study as an architectural research method in academia. Therefore, to clarify and define architectural case studies within the interdisciplinary realm, the primary, though not only, theoretical framework of this paper is Roland W. Scholz and Olaf Tietje's *Embedded case study methods: Integrating quantitative and qualitative knowledge*, in which particularly the discourse on environmental sciences is relevant to architectural research.

Based on the above study, this paper looks at the two types of research designs, the embedded case studies and the holistic case studies,[1] from the perspective of design research with a focus on buildings, which Scholz and Tietje do not address. Supplementary, trans-disciplinary perspective is provided by the views of Pauwels and Matthyssens on the ontological and epistemological premises of case study method in international business. The goal of this examination is to find out whether case studies can successfully inform design decisions and solutions in the field of architecture, which is naturally an important part of evidence based design. Hence, we examine some studies conducted by architecture doctorate candidates, since those function as *cases in point* by demonstrating the role of various types of case study research strategies in design research, or practice-based research (PbR) like it is usually known in Europe. In addition, these studies represent a number of unexplored approaches and possibilities in the education of research skills. Those include such conventional data collection techniques as Post Occupancy Evaluations (POE), fieldwork, interviews, surveys, and the kind, but also embrace more novel approaches like memory sketching, Japanese *anime* and *manga*, and other visual means of analyses.

Unlike common case studies providing mainly quantitative data, this paper discusses qualitative research as a supplementary part of this methodology. For one example, instead of considering POE merely from the perspective of building performance in technical, ecological or any other tangible point of view, these case studies also emphasize the experiential aspects of architecture. In this respect, the emphasis is on phenomenological thick descriptions, as opposing to mere project descriptions. In other words, the focus is on deep understanding of a case within its context, analyzed from multiple points of view in order to provide means of holistic interpretations of empirical inquiries within real-life contexts.

1.0. INTEGRATIVE DATA EVALUATION

According to Scholz and Tietje, most skepticism about case studies is caused by nontransparent knowledge integration, especially in embedded case studies with multiple methods for data generation. They argue that this is why "integrative evaluation – an evaluation that integrates viewpoints from such diverse disciplines as ecology, economics, and sociology – is crucial component of case studies" (Scholz and Tietje 2002, 3). For this process, they suggest a synthesis of knowledge integration that can be divided into four categories: integration of disciplines, systems, interests, and modes of thought. As for methodology, they point out that case studies should not only use multiple sources of data and evidence, but also that the "methods should employ direct and participant observations, structured interviews, and surveys, and they can also include experimental design, focused interviews, open-ended interviews, archival records, documents, and scientific data from field and laboratory […] This remains true regardless of case design" (Scholz and Tietje 2002, 13). In other words, also in architectural case studies triangulation between methods, not just between sources of data and evidence, is crucial.

Additional reason for skepticism is, no doubt, the conventional call for scientific objectivity. In the context of multiple case study research in international business and the 'architecture' of such research design, Pauwels and Matthyssens discuss the ontological and epistemological premises of qualitative research "that departs from a time- and human-free objective reality towards a more context-bound intersubjective reality […], in which the social world is to be understood from the point of view of the individuals who are directly involved in the events that are investigated" (Pauwels and Matthyssens 2004, 127). They go on arguing that "Multiple case study research aims at closing the gap between the objective of the study and the object of the study. In this respect, we explicitly aim at capturing the subjectivity that is embedded in the object" (ibid). In architectural research, this can be seen as an invaluable approach in interpreting the interrelationship between the built environment and its users, from the perspective of the latter.

However, Pauwels and Matthyssens also point out the significance of reducing the researcher's subjective impact on the study. For this, they suggest principles of Four Pillars and a Roof (appealing simile for architects). Pillar 1, theoretical sampling, is based on selecting both typical and atypical cases, as opposing to a number of analogous cases. In this process, the analyses of atypical cases produce contrasting results, though for predictable reasons, and create theory-driven variance and divergence of data. Pillar 2, triangulation, is naturally one of the basic 'pillars' in qualitative research in general. For Pauwels and Matthyssens, it serves two purposes; it reduces random errors and increases internal validity of a study. Pillar 3, pattern-matching logic, is based on the fundamental scientific pattern model according to which, for instance, events can be explained in relation to sub-elements so that together they constitute a unified system. Pillar 4, then, deals with analytical generalization, meaning testing the validity of research outcome and/or theory development against extant theories. Finally, the roof encompasses validation by juxtaposition and iteration of the pillars that support it. In short, this amounts to deliberate, ongoing checks of validity and invalidity through concurrence of data and findings, both existing and emerging theories, case selection and data collection, and other internal and external reference points (Pauwels and Matthyssens 2004). These principles are reminiscent of Scholz and Tietje's integrative evaluation with emphasis on multiple sources of data and evidence. For our purposes, they indicate that architectural case studies, too, should accurately employ the four pillars and the roof. As pointed out by Pauwels and Matthyssens:

> The omission of one of these pillars has a baleful influence in the methodological quality of the study and causes the roof – the ongoing validation process – to collapse. Yet, these pillars are only qualifiers: relying upon them is necessary though not sufficient. Each of the pillars should be operationalised and interwoven in a way that best fits the research questions and gives an optimal answer to the operational challenges of the study (Pauwels and Matthyssens 2004, 131).

One example of an embedded case study, in which the researcher combines quantitative and qualitative data, is an ongoing doctorate project with the initial topic of inquiry whether the impact of a building, in this study that of a house, on its users is actually the same as the architect claims/ wishes; as a comparison group the researcher has analogous user-designed-and-built houses (i.e., the atypical cases). The research design includes such quantitative strategies as performance analyses, census information of the occupants, correlational questionnaires among them, interpretive-historical analysis of the context, and visual scrutiny of pre- and post-occupancy floor plans, supplemented by qualitative data from critical analyses of writings on these buildings, open-ended interviews among the occupants and the architects, as well as participant observations in the target buildings. In a significant role of knowledge generation in this POE is naturally case study method, as the houses are the cases, including fieldwork, followed by an open-ended survey with which the researcher is seeking to understand the occupants' own perception of their real-life setting. How successfully this bricolage can be integrated, interpreted, and evaluated is challenging and remains to be seen.

Another example of an ongoing embedded case study deals with a relatively wide topic of looking at Chinese geomancy (*fengshui*), environmental psychology, and biophilic design. In this instance, too, the area of interest is the users' perception of buildings and their own setting, though the primary objective is the architect-client relationship and communication during the design process; in other words, this is a pre-occupancy evaluation focusing on the future user. In addition to a very comprehensive literature review of these three separate schools of thought with examples of their design principles (pillar 1), the thesis goes on identifying differences and similarities of these principles (pillar 2), pattern models underlying the logic of all three (pillar 3), and then testing the conclusions against extant phenomenological views on perception of place (pillar 4). The 'roof' is a design project on a real site for a real family (though hypothetical as client) testing and validating the research results attained by the four 'pillars.' Thus, this design research case study highlights feedback from the client and the impact of that on the design. The goal is to validate the research results and design solutions based on – or perhaps better with this metaphor, resting on – the theoretical framework by juxtaposing them with the extant theories on *fengshui*, environmental psychology, and biophilic design, as well as general theories on architecture and perception. As in the previous example, the challenges are considerable in not only crossing many disciplinary and cultural boundaries, but also in integrative data evaluation deriving from these diverse fields.

2.0. THICK DESCRIPTIONS

In an article "Experimental Cultures: On the End of the Design Thesis and the Rise of the Research Studio," David Salomon refers to Michael Joroff and Stanley Morse's essay "A Proposed Framework for the Emerging Field of Architectural Research" in a 1984 compilation of articles titled *Architectural Research* in which they ranked the research methods used by architects, from the least to the most objective: "1. ad hoc observations, 2. design, 3. review of precedents/ current knowledge, 4. manifesto, 5. normative theory, 6. development/ scholarship, 7. social science research, and 8. laboratory/ physical science research" (Joroff and Morse 1984, cited in Salomon 2011, 34). In other words, the required level of objectivity was a pre-denominator in this classification of architectural research methods. It is worth noting that case study method was not even mentioned. As Salomon continues, "Eighteen years later, Groat and Wang's survey *Architectural Research Methods* expanded upon and fleshed out Joroff and Morse's list, stressing the importance of qualitative methods" (Salomon 2011, 34).[2]

Well, it has now been more than ten years since Groat and Wang's survey was published and has been used as a textbook in numerous architecture schools across the world. It, together with general paradigm shift in academia, seems to have had some impact on architectural research, in which qualitative paradigm with emphasis on the interaction between the researcher and that being investigated is accepted, in contrast to the now almost thirty-year-old view above focusing on subject-object distinction. However, despite the substantial and increasing amount of publications on architectural phenomenology and perception of place during the past three decades, added with Groat and Wang's extensive discussion on qualitative research and case studies in architecture, certain lack of precise definitions (or imprecise usage of those) still remains in the discipline of architecture with regard to terminology, methodology, and validation of case studies. This is particularly true with holistic case studies in which knowledge integration "is ruled almost exclusively by the principles of qualitative research" (Scholz and Tietje 2002, 13). Moreover, as Scholz and Tietje stress, there is a fundamental difference between embedded case studies, discussed above, versus holistic case studies. While the former typically involve an analysis of more than one case and are not limited to qualitative analysis alone, the holistic case studies almost always rely on a single narrative of phenomenological descriptions and interpretations (Scholz and Tietje 2002). Again, for the purposes of this paper, we could conclude that the distinction of architectural case studies depend on the topic of inquiry and whether that requires multiple of single case studies.

One example of a holistic architectural case study that relies on interdisciplinary approach, narrative of interpretive-historical research, and phenomenological thick descriptions, is a doctorate project that focuses on ways of creating sense of place in elementary school environments. The primary proposition of this study is that because the age when children attend elementary school is also when their identity and view of the world through cognitive development is at its height according to numerous studies in numerous disciplines, architects should have a profound comprehension of these factors. Hence, in addition to many other issues for which space does not allow discussion here, the argument of the study is that sense of place is created and strengthened by diverse functional aspects, conceived realm with aesthetic value, personal participation and achievement, thermal comfort, and articulated spatial distinctions within, not between, indoors and outdoors. The chief technique of data generation in this study was memory sketching method with which the researcher was exploring the perception of their own setting among students of three elementary schools. Based on the findings derived from these case studies and extant theories, such as those by Hegel, Heidegger, Lynch, Relph, Norberg-Schulz, and Tuan, the researcher came up with five "place generators": edge, boundary, center, path, and threshold (Rieh 2007) for further applications in design. In this occasion, the researcher was already well versed in phenomenological premise (which could be challenging for some doctorate candidates), while the primary challenge was the age of the target subjects in elementary schools. Like always in qualitative field research with the focus on people and how they make sense of their own setting, the study required consent from the university's committee of human studies and, due to the age group, considerable efforts in the scrutiny of the research throughout its duration was required as well. In many schools, the researcher also faced resistance from the administration and parents for allowing the fieldwork in certain premises which narrowed the selection of cases.

The holistic case study above deals with three actual sites, though, as previously implied by Scholz and Tietje, multiple case research design is not necessary in this category. An example of a holistic single case study is one focusing on the interpretation of a particular neighborhood in Tokyo called Ikebukuro, even if the ultimate aim is to offer a new method to interpret Japanese urban context in general (i.e., generalizing to theory). In very short, this study was a result of the researcher's long-term interest in and studies on Japanese culture, including not only Japanese architecture, but also and particularly Japanese popular culture of *manga* and *anime* (Japanese cartoons and animations), which served as the theoretical framework of the phenomenological interpretations and thick descriptions. After somewhat lengthy contemplations, it was decided that the methods of Japanese cartoons would be the most efficient way in interpreting the researcher's own experiences in Japan, perceptions of her informants there, and a way to re-present those experiences and perceptions to the audience. Among many other methods not discussed here, the ultimate means of interpretation was, therefore, a cartoon with which the researcher both explores and communicates the results of her fieldwork in Ikebukuro by integrative evaluation with an emphasis on the multisensory experience of the environment and the time-space quality of this context (Weatherford 2011).

CONCLUSIONS

A common denominator in both embedded and holistic case studies discussed here – without evaluating one better than the other – is the role of fieldwork in ensuring multiplicity of data and evidence as well as comprehensive descriptions of the setting. Since fieldwork has often been a valuable means in cultural studies, it quite naturally is a method in cross-cultural or culture-specific architectural research as well. Moreover, field studies have been successfully incorporated in scholarly, strategic, and applied research, as well as in case study and design research on numerous architectural phenomena; either as quantitative or qualitative research for background studies on contemporary issues, historic preservation and other forms of design scholarship.

First of all, since the above studies deal with cross-cultural, culture-specific, and/or interdisciplinary research, they exemplify the definition of architectural fieldwork with regard to other multi-, cross-, or trans-disciplinary views, providing new insight into the language of architecture and expanding the discipline's research resources. Second, fieldwork is an integral part of these studies, emphasizing such regional issues as climate-specific sustainable design, community involvement and participatory design, indigenous cultural values and context, and sense of place. Hence, they serve as examples of a paradigm shift in architectural research by representing not only changes in the applications and approaches to technology, but also changes in architectural interpretations, that is, a non-Euro-America centralized perspective. Third, this emancipatory paradigm, focusing on the dynamics of power (between social, cultural, ethnic, gender, and other sub-groups), underlines the global-local distinction of critical regionalism, accompanied by the holistic nature of the discipline of architecture. In short, while the online "global villages" might offer an interesting alternative, fieldwork in physical environment still is a valid data collection technique especially in case studies, although it should pursue toward new paradigms and diverse views.

Characteristically for qualitative research, this paper, too, is open-ended in terms of conclusions. Further, not only is it an ongoing project itself, but so are some of the example case studies above. The aim, in addition to defining some key concepts in architectural case studies, is to seek feedback from the discourse in a conference on architectural research. In summation, all the above examples are descriptive, not just exploratory case studies. Contrary to the goal of the latter, that is, to gain insight into a setting or phenomenon, they use "a reference theory or model that directs data collection and case description" (Scholz and Tietje 2002, 12) which is one of the definitions of descriptive case studies. Yet, while all of the characteristics of case studies, whether they represent embedded or holistic case studies, can be found in the examples discussed, none of these studies alone includes all of them. In doctorate projects with limited time and resources, the comprehensive strategies, such as replication logic is naturally difficult to employ, while integrated data evaluation is definitely the most challenging task for doctorate candidates. In architectural education, however, the distinctiveness of case studies should be a task regardless of the difficulties in executing those, exactly because of their challenging nature.

Due to the aforementioned shortcomings, it appears that architecture schools should apply much more interdisciplinary approach with regard to the education of architectural research methods in order to ensure true integrative data evaluation. This might be stating the obvious, but it still deserves attention from the standpoint of architectural case studies. Also, although some of the studies above demonstrate interesting new approaches, one challenge in teaching architectural research methods definitely is over-emphasis on established methodology (as rules to follow) and under-emphasis on the role of creativity and intuition in research, even innovation of new methods. As Scholz and Tietje argue: "It should be mentioned that, as in architecture, developing projects in the field of the environmental sciences is an art. One must have a special feel for it to do it well, and the importance of this should not be overlooked; in many such cases, the artistic design is a determining factor for success" (Scholz and Tietje 2002, 26-27). From the perspective of design research, particularly that of building design addressed in this paper, it could accordingly be argued that the process of architectural research, including architectural case studies, should be as creative as is the design process itself.

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ENDNOTES

[1] A holistic case study is based on a qualitative approach that relies on a narrative, phenomenological description and understanding of a case. An embedded case study, in turn, is not limited to qualitative analyses, and usually involves multiple cases or units (Scholz and Tietje 2002, 9).
[2] In this reference, a secondary source is intentionally chosen in order to inform the audience about the development of architectural research tradition within the past three decades.

Building a Computational Culture: A Pedagogical Study of a Computer Programming Requirement

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ABSTRACT: As computational design becomes increasingly important to architectural practice, curricula must be updated to teach new outlooks and skills to the next generation of design students. Over the last two years, UNC Charlotte has tested a curriculum that emphasizes computational thinking and methods. The core of this curriculum is a required course that introduces over 70 students a year to the fundamental ideas of computation through exposure to programming in a design context. This paper describes our teaching methods and our findings from a study of the course, which includes attempts to measure student outcomes, attitudes about computing, and the application of computation after the course. The results of our study, which suggest an inclusive methodology and emphasize the cultural dimension of this pedagogical task, may help schools in the planning and implementation of their own courses that introduce computational design.

KEYWORDS: Pedagogy, Computational Design, Computational Thinking, Computer Programming

INTRODUCTION

Computational design is becoming increasingly important within the architectural discipline. In today's profession, CAD and 3D modeling alone are not enough to address the need for more economically and ecologically sustainable buildings. Computational methods such as parametric models, generative algorithms, simulations, and digital fabrication assist in the design and construction of buildings that are not only aesthetically innovative, but performative as well (Kalay, 2004). In order to stay competitive in a globalized market, architects will need to know not only how to use these tools, but how to integrate, modify, and write their own. Once an exceptional specialization, computational design will soon play an essential role within architectural practice and research.

This trend presents a challenge for architectural educators. How will schools teach their students these new ways of working? At the moment, the answers to this question are incomplete and unsatisfactory. First, what should be taught and where does it belong in the curriculum? How does computation fit within the subjects that architecture schools already must teach, especially when curricula keep growing in scope due to new requirements? Second, technology changes constantly. The software and techniques that students learn in their initial years could be insufficient or obsolete by the time they graduate from architecture school. What can schools teach about computation and design that will help students learn future tools?

Determining the pedagogy is another problem. Many architecture students are hesitant to learn computation because they think it will be difficult or too far removed from how they envision design (McCullough, 2006). Furthermore, there is evidence that computation is a difficult subject to teach and learn. Computer science, for example, has an attrition rate of almost 30% (Roumani, 2002) and a surprising number of graduates cannot design and write simple programs (McCracken, et al, 2001; Bennedsen and Casperson, 2007). Even accomplished computational designers admit there is a steep learning curve (Burry, 2012). Thinking in terms of explicit, procedural abstractions is hard, especially when, as Seymour Papert argues, there are no traditions of this within our own culture (Papert, 1980). In short, if the goal is to someday teach computation to all architecture students, more research is needed.

Towards this end, this paper describes the development of a required course in computational design and the results of a pilot study to assess its effectiveness.

1.0 Computational Thinking in the Curriculum

The School of Architecture at UNC Charlotte spent several years developing a curriculum that addresses computational design throughout the undergraduate and graduate sequences[1]. A core idea of the curriculum

is that our courses are not focused on developing fluency in particular kinds of software or tools, but rather *computational thinking*. We believe that if our students have the skills and mindset to use computation well, they will be able to adapt to changes in technology and possibly even participate in those changes through their own innovations.
Computational thinking is not a new idea. In 1961, Alan Perlis, an early pioneer in computer science, argued that computer programming should be a requirement of a liberal arts education (ibid.). His reasoning was that process plays a critical role in all fields, and the computer enables one to interactively create and run processes. Perlis believed that students should learn programming, not so they could run a computer, but because it is a means of learning about process.

Of course, learning to program does teach a great deal about how to operate computers. One of the most difficult parts of computation is translating one's thinking into the computer. To do this, a person not only has to know about their own field's processes, but also about the capabilities and limitations of computers, the commands, logic, and inputs/outputs of the software, and how to break down an idea into rules and steps for the computer to follow. Knowing about both human and computational processes endows a person with a powerful way of working and a means of understanding any computational device they may encounter (Sheil, 1983). This is the essence of computational thinking[2] – the ability to work well with computers.

Some may argue that students do not need to study programming to learn computational thinking, and, instead, there might be other ways to teach students how to think about process and approach computing. This may be true. However, two things must be made clear. First, programming does not necessarily mean writing code, so this is no reason to avoid it. Whenever a person authors instructions for a computer to follow, whether it is with visual programming (e.g. Grasshopper, Scratch, etc.), scripting, or by setting the controls in a simulation, etc., this is arguably a form of programming (Blackwell, 2002). What matters is the thinking involved, not the interface. Second, it makes sense to learn about process in terms of the dominant representational medium of the day, which is computing. Transfer of abstract ideas is difficult to achieve, so it is best to teach lessons that are as close as possible to the concrete objective (Perkins and Salomon, 1989). In a single semester, transfer of specific contextual ideas is much more likely (Palumbo, 1990). Therefore, if we want architecture students to learn computational design, why would we start to teach logic and process in anything other than the computer? While it may be possible to use other metaphors to learn about process, programming is most directly relevant.

The goal of the curriculum is to create what we call a "computational culture" in our school. By teaching computational thinking to all of our students, we hope to affect the values, attitudes, and beliefs they bring to their studies. We are not looking to create a school full of software programmers, but rather we want students to learn about computation early, so we can build upon it in other courses and have more critical conversations about its use in design. When everyone in our school learns computation, the students will see it as something they can participate in – not something than only computer people or other schools are able to do. In short, our objective is to make computational design as commonplace and as useful as 3D modeling has become. Not everyone has to make it his or her focus, but an architect needs to be able to understand its potential role in design and recognize when it applies. We believe one of the best ways to prepare our students for the future of design is to immerse them in a culture where computation is the norm and not the exception.

2.0 Teaching Methodology

The foundation course in our computational sequence is called *Computational Methods*. It is attended by our third year undergraduates as well as graduate students (in either their first or second year, depending upon whether they are in a post-professional or pre-professional program, respectively). The total class size is over 70 students. To the best of our knowledge, it is the only required course in computation that is taught this early in a professional architectural curriculum. It was taught for the first time in fall 2011. A second iteration followed in the fall of 2012.

The primary objective of the course is to teach students the fundamental concepts of computation. The secondary objective is for students to learn specific methods for applying these ideas in a design context. Our vehicle for this is computer programming. To be clear, we do not propose that learning programming necessarily makes one a better designer. Rather, it can assist designers if used properly. The aim of the course is not to train great programmers but to instill a greater awareness of computation in architecture as well as other fields, so that students can approach it critically – whether they choose to use it or not.

2.1 Active labs

The class meets twice a week, first with a lab session and then with a follow-up lecture. This might seem backwards, as it would be more common to use the lecture as background to set up the concepts for the lab, but the arrangement is deliberate. Educational research suggests that students learn best when they have the opportunity to work with ideas in a concrete form first, and in the abstract later (Bransford et al, 2000). Before the labs, students learn commands and procedures through online videos we produce. This kind of information is explicit and does not require much student / teacher interaction. Once the students learn the basic software technique, we use our labs to introduce the underlying computational concepts in a hands-on way, by giving our students situations where their existing knowledge must be extended to solve a problem[3]. This is sometimes referred to as inquiry- or problem-based learning (Gallagar, 1997). For example, from a previous lesson, students know how to loft a single list of parametrically generated curves, but in the following lab, they would need to learn about data structures in order to create several lofts from multiple lists of curves – i.e. lofting a list of lists. Through a guided series of questions, students work together to discover and teach each other new concepts. This pedagogy is different from most computing tutorials, where the instructor merely tells students the concepts.

Our lab pedagogy is a marked contrast from the typical computing lab, where students follow along with passive tutorials that are dependent upon the instructor and the speed of the lesson must accommodate the slowest learner. In our “active” labs, the instructor is there to answer questions and coach, but the students work at their own pace. Later in the week, the lecture abstracts the lessons, reinforcing and clarifying the concepts and placing them within a historical and architectural context through the use of examples and precedents. It is not yet clear whether this format results in better learning, but it seems to improve engagement. In their course evaluations, many students cited the role of the labs in overcoming their apprehension about programming.

2.2 Assignments

In general, there is not much design in the course – or rather, the design exercises are highly controlled. The first version of the course taught us that it was difficult for our students to both learn about computation and to produce meaningful design artifacts at the same time. The cognitive load was much too great. The active labs are part of our effort to be clearer and more focused about what we ask students to do, while at the same time challenging them to solve problems creatively. To practice their skills, the students produce weekly lab reports, where they write their solutions to the lab problems and describe their thought processes. The report prompts are designed this way so students have experience externalizing their thoughts and communicating with others about computational processes.

Additionally, we have two major projects that introduce limited design into the course. The first is a precedent study, where students extract a parametric assembly from an existing project and apply it in a new context. This assignment works well because students do not have to invent the assembly; they only need to decipher and implement it. The second project is their final project, where they must take a design of theirs (either current or previous) and use computation to iteratively study some aspect of it in a data-driven way. Using a design of their own allows them to jump into the project with a program, site, and a building that are familiar. This way, they can focus on using computation to explore or revisit problems. As a final exercise, it is motivating and relevant, and a good way to review the lessons from the course.

2.3 Technology

One of the pedagogical principles of *Computational Methods* is that learning how to think is more important than learning tools. This being said, the first tool that students are exposed to is important in providing motivation and forming their earliest opinions about computation. For this reason, the most recent version (fall 2012) of the course is taught exclusively in Grasshopper, which is a visual scripting language for Rhinoceros (McNeel, 2012). Earlier, we taught the course using both Processing (a scripting language for Java) (Reas and Fry, 2011) and Grasshopper, but the students did not find Processing as relevant. The benefit of Grasshopper is that it builds upon the Rhinoceros skills they learn in their second year and the output is expressed as Rhinoceros models, which they can directly apply to studio projects. The disadvantage is that, with Grasshopper, it is not possible to talk explicitly about concepts such as looping constructs, subroutines, and object oriented programming, which are important computational ideas. The reception for the Grasshopper lessons has been overwhelmingly positive, however. In fact, after taking the course, several of our students explicitly asked to learn Processing. *They want to learn to code.* This is a positive outcome for an introductory course and further evidence that the right tools can be motivating.

2.4 Course Topics

The following is a rough outline of our syllabus, to provide some idea of the topics we cover and the manner in which we approach them:

- Week 1 - Parametrics: Introduction to the strengths of computation and how computation is applied in architecture. Introduction to basic parametric constructs in Grasshopper.

- Week 2 - Variables: Covers more of the Grasshopper interface, simple geometric components, constants, controlling variables, setting up relationships (dependencies), and basic transforms (i.e. move, rotate, and scale). The first part of the lab covers object positioning as it relates to parametric dimensions. The second part examines proportional transformations (related, dependent variables) using a parametric column form.

- Week 3 - Repetition and Loops: Covers the repetition of data in Grasshopper (i.e. creating lists) with the Series and Range components. Also, one- and two-dimensional systems for positioning and transformations, and the use of the Graph Mapper for visual generation of numerical data patterns. Data structures for looping (lists of lists) are briefly introduced. In the lab, we create: a parametric "tower" with repeated transformations; numerical patterns (e.g. sine waves) from equations with Graph Editor; "Spirograph" demonstration with stacked repeated transformations.

- Week 4 - Distributions, References, and Cull: The idea of "distribution" combines the notion of variables (e.g. coordinate locations) with repetition to create dependent parametric constructs. We implement distributions of parametric objects (e.g. points along a curve) and referenced (locally-oriented) geometry over curves and surfaces. We also study the basic Cull (remove / delete) components to create rhythmic patterns in repetitive constructs.

- Week 5 - Parametric Design Process: Begins with a thorough review of 3D modeling topology - points, curves, surfaces - and then describes the thought processes and methods used in the creation of a parametric masonry wall. Topics include: script design, task decomposition, and iterative script refinement.

- Week 6 - Procedural Diagrams: Our midterm lessons describe a method for creating 2D diagrams to visually explain how a script generates a form. The underlying premise of this exercise is that showing someone code does not provide a useful explanation of how a parametric system works. By learning to create informative process diagrams, we can better communicate our design intent.

- Week 7 - Debugging: We explicitly discuss and practice strategies for problem solving and debugging programs. Debugging is an essential part of the programming / computational design process, but is seldom covered in much detail.

- Week 8-9 - Adaptive Parametric Patterns: This two week review unit covers some general and advanced algorithmic methods for adapting parametric patterns to different contexts. Specifically, we explore: referencing surfaces and matching curves to surface forms; review of surface aligned frames; using frames to create local coordinate systems for shifting and transforming points; the Box Morph object for adapting arbitrary geometry.

- Week 10 – Algorithms: This week focuses on algorithm development: the design of reusable logical constructs for architectural projects. As a demonstration of these principles, the lesson provides an overview of attractor concepts (an algorithm that references distances within a parametric system) and different applications of attractor systems in design and architecture.

- Week 11 - Data Structures and Manipulation: This series of exercises covers basic list operations: list length, extracting indices, accessing list items, removing list items, shifting lists, combining lists, etc. Building upon these lessons, we generate structural framing patterns that deal with points, lines, and surfaces derived from subdivided surfaces. These patterns make use of several kinds of data access and filtering, and review earlier lessons in topology.

- Week 12 - Metric-Based Design Components: This week integrates with lessons from our daylighting and building systems courses. It covers several basic algorithms that use sun angle as a driving parameter: variable louvers, warped louvers, apertures / openings, light canons, light shelves.

- Week 13 - Conditional Logic: Introduces the basic concepts and components involved in conditional (rule-based) logic. We cover the use of the Dispatch component with the Larger / Smaller, Equals, and Modulo components. Examples include: 2D containment patterns, filtering geometry based upon coordinates and height, and 3D intersections as a basis for subtractive and additive modeling.

- Week 14 - Randomness and Generative Design: Our final week surveys some basic algorithms for randomness in architectural contexts: erosion, "Pick and Choose", "jitter", etc. We follow this with a brief discussion on the concept of randomness and order in art and design. Finally, we talk about Processing and carrying the ideas of the course beyond Grasshopper and into generative design.

The order of topics – especially our choice of final topics – is not what you might find in a typical introductory computer science course or textbook. We did this deliberately to make sure that students were exposed to ideas in their most explicit form before we added more layers of abstraction and automation.

The course is not intended to be comprehensive, in terms of either computation or Grasshopper. Rather, it is meant to give students strong background they can immediately apply to their work in other classes. As the lessons increase in complexity, we revisit ideas in several different contexts to create depth. We believe this is the best way to encourage students to retain the material in the long term.

3.0 Assessment

To study the effectiveness of the course, we collected data through an online post-class survey. The survey was voluntary and included multiple choice questions and the opportunity to provide short written answers. 53 out of 72 students participated in the survey. University course evaluations provided additional written feedback for the study.

Our first concern was whether students felt the material applied to them, as programming is not a skill many architects feel they can or need to master. Measuring this is important because educational research suggests that if students, particularly older ones, do not see the application of what they are learning right away, it can be de-motivating (Pugh and Bergin, 2006; Lepper, 1985). We seem to have succeeded at capturing their interest. In response to the question: “How relevant is computation to your future career?” 92.4% of students said it was in some way relevant, 33% said it was extremely relevant, and 81% of students agreed that the course should remain a requirement.

The course was also well received. 90% of students agreed or strongly agreed with the statement: “Are you satisfied with your experience in Computational Methods?” and 77% said they learned more than they expected. Reading the feedback from students, we have reason to believe that we have taken an intimidating subject and made it approachable:

> "I feel that I have learned more than I could have anticipated. I was very lost and confused at first, but slowly things started to make since and I truly felt accomplished about my work. I think that the course gives a great foundation understanding about how computer designing works."

> "This course was not quite what I expected, but I was pleasantly surprised. Learning about the logic of computation is incredibly important and relevant today."

A good indicator of student engagement is whether students are motivated to keep learning about a subject after completing the course. In the post-class survey, 70% percent said they would consider taking an advanced version of Computational Methods. This is a positive outcome for an introductory course.

Another goal of the study is determining how much students understand about computation after a semester in *Computational Methods*. Are students really learning computational thinking and does this affect how they approach design? Unfortunately, we found this difficult to determine from the assignments and projects we collected. Our students can write programs, but we do not have the assessment tools yet to examine *how* they write programs. They learn to document and present their process in the course, but what they produce does not tell the whole story (or even the whole truth). The student evaluations offer more insight:

> I was skeptical about digital design when I started this course (other than using architecture-minded software like Revit, for example). However, now that I've seen how parametrics actually works [sic], learned a particular scripting software, and have seen examples in class of some inspired, digitally designed architecture, I do believe that digital design can result not just in 'blobs' but in some really beautiful, metric-based designs. I still don't quite know how and when to apply this technique to my own studio designs, but I think it's a good thing.

> I leave the class definitely thinking about new ways to approach a design. I understand that the process is not exactly as linear as it once was, as rules and decisions can be made before hand as you get to build a system before a project. Even within a design project, I already find little moments where Grasshopper would programmatically accelerate the design.

> I think that I learned a lot in this class, mainly because I can begin to apply it outside of just comp methods. This has taught me a new way of thinking about things and the design process and now I can begin to see how this can be incorporated in studio.

Judging from our evaluations, the course appears to be successful at teaching many of our students to see computation as another way of thinking about design. We are particularly encouraged by the statements about process in the comments that many of them wrote. Still, we do not know with certainty how many students think this way and how sophisticated their thinking is. For example, our students can use computation to solve the small problems we give them in class, but when they want to design something for studio, many of them have trouble breaking down their idea into steps they can turn into a program. Our students also report that it is difficult for them to come up with their original ideas for using computation or that they do not always recognize when they could use it in a project. In future versions of the course, we hope to address these problems.

While we seem to have raised their awareness of computation and made them inclined to apply it, it is also unclear whether the knowledge and skills we teach students will transfer to other subjects they study. Transfer to new contexts is one of the most important measures of learning (Thorndike and Woodworth, 1901; Singley and Anderson, 1989). We are only beginning to measure this rigorously. However, we can report some initial findings. At the end of the course, when asked whether they thought their experience would help them learn Revit or other computational tools, 98% percent of our students said they believed it would. This may turn out to be true. In our advanced computing courses such as digital fabrication and our BIM seminar, the faculty report that students who have taken Computational Methods tend to learn new material faster and perform better on assignments, because they have a firm grasp of computational fundamentals. Eventually, the instructors believe that they will be able to teach more in their courses, because they do not need to introduce so many computing concepts themselves. Granted, this is only anecdotal support. At the end of this semester, we plan to track the outcomes of our Computational Methods students in later courses to determine if there is any measurable difference.

4.0 Reflection and future plans

Our two year experiment with Computational Methods has taught us several lessons. First, it is essential to consider student attitudes and expectations of the subject. In order to change the design culture, we must respect the existing culture. It is not enough to make the course required and expose everyone to programming. Students come to the course without much exposure to computation and apprehensive about their prospects of learning it[4]. With this in mind, we designed the lessons to make the material relevant and to connect to ideas, software, and precedents that students already know. In addition, labs were made into active social experiences where students were encouraged to work and solve problems together. As a result, our surveys showed that students were motivated to learn the subject and finished the course with a different mindset about computation.

Second, we learned that architecture students can learn to write programs, but this does not necessarily mean they can apply them in a design context. While they recognize commands and can exploit programming patterns we teach them, students still have difficulty with program flow and design. This should be expected, as these are common problems even for computer science students (Soloway et al., 1982; Eckerdal et al., 2006; Linn, 1985). Still, it makes our students less effective at using computation in their studio projects. We also want them to be able to intelligently choose where to apply computation (instilling a sense of “computational ethics”, as it were), and it seems that they are still unclear about this. They do not learn these ideas implicitly, even though we show them examples of “good” uses of computation and critique their work on its merits. It might be necessary to devote more course time to explicitly teaching these ideas, or to design assignments that scaffold these kinds of choices for students.

Third, we may need to adjust our expectations regarding our students’ learning outcomes. Computation is a challenging subject. As Alan Kay reflected in his research with children learning programming, developing thinking that goes beyond the superficial characteristics of the language often takes time (Kay, 1993). Better tools and pedagogy can help, but even with the best of both, learning to design computationally will probably take more than a semester. We can introduce students to a different way of thinking and teach them the language of computation – which we believe is worthwhile, pedagogically – but their ability to express themselves in this language is low, at least initially. This makes sense, if we can analogize learning programming to the acquisition of a foreign language. Fluency is not expected in a single semester. This understanding has possible repercussions for our teaching. To help achieve the depth of thinking we want our students to possess, we may need a second required computation class that focuses more on design and process, or perhaps a studio where all of the students apply computation.

Our evaluation of the course is iterative and ongoing. We recognize that, at this time, we cannot quantifiably measure whether the course is meeting all of its goals. This is because we have not performed the some measurements at the time of this writing and also because, in hindsight, some of our assessment tools were not capturing the right data. Our plan is to perform a follow-up assessment of the course, to track how well students have retained what they studied, to study the differences in later classes between students who have taken Computational Methods and who have not, and to record how often computational design is applied in later studio work. To help answer the question of whether students are learning computational thinking, we are working with a cognitive scientist to develop a procedural assessment tool for future versions of the course.

5.0 Conclusion

The School of Architecture at UNC Charlotte believes that computational design skills will someday become a standard part of an architectural education. Computational Methods is our attempt to begin this transformation at our own institution. By learning about programming early in their education, students are exposed to computational thinking, which may help them learn software and other tools in the future. As an introduction to the subject that motivates students to continue learning, the course appears to be fulfilling its purpose.

The impact of Computational Methods extends beyond the two cohorts of students who have taken the course. The other students and faculty are seeing and hearing more about computational design, and this is strengthening the impact of our new curriculum. The school is more aware of computation, its potential, and its accessibility. They see that programming is not only for certain professions or the math-savvy, but something that anyone can do. What was once an esoteric subject is on the way to becoming normative – another way for students to think about and pursue design. It will take time and further study, but we are making progress towards creating a computational culture.

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ENDNOTES

[1] For those interested, a more detailed description this curriculum can be found in (Senske, 2011).
[2] Perlis did not coin the term computational thinking. It is not clear who did. However, in contemporary usage this is the phrase used to describe the educational ideas he proposed. See (Matteas, 2005), (Wing, 2006), and (Guzdial, 2008) for more recent discussions of the need for computational thinking in schools.
[3] For more information on our lab pedagogy, refer to (Senske, 2013).
[4] In our pre-class survey, 87.7% of students reported no previous introduction to computation. Of these, 47% expressed concern with their possible performance in the course.

Hybridized Pedagogies: Architectural Education in Motion

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ABSTRACT: Twenty-first century experiments in architectural pedagogy are beginning to increasingly take steps towards the hybridization and critical cross-communication of the sciences, arts and humanities. The blurring of these boundaries now allows us to see architecture as a body of knowledge that participates in a long-term and deeper transformation of society. This paper will examine three emergent pedagogical typologies that exemplify innovative methods of generating research, the results of which are made accessible to the larger public, which in turn expands the boundaries of architectural practice. This examination will be conducted by identifying three uniquely structured entities, each a hybridized condition where partnership, collaboration and exchange represent the core of their makeup. Each of these entities has established an innovative relationship between academia and practice, while expanding and cultivating new audiences for the research they conduct.

The current challenges that permeate the culture of architectural education are due in large part to the crisis of a quickly changing world, which is at odds with the evolutionary slowness of educational models. As a means of addressing the pace of contemporary society, new institutions are exploring models of lightness, speed and fluidity. Strategic global networks, academic research programs nested within established professional practices, and parallel practice / research endeavors are the core characteristics of these new models. The Center for Architecture Science and Ecology, OMA/AMO and GSAPP's Studio-X are the three models that will be examined. The paper will make explicit the unique research being conducted by each of these three entities and will establish how this research is changing the relationship between academia, professional practice, and the larger public's understanding of the architectural discipline.

INTRODUCTION

In the twenty-first century, unprecedented pedagogical structures are beginning to emerge in architectural education. These experimental models are moving with greater flexibility and speed, allowing for a greater inclusiveness of questions that are crucial for architects to begin to engage the world at the outset of this century. The organizations of CASE, OMA/AMO and Studio-X are beginning to provide supplemental or alternative visions of how architectural knowledge can be taught and practiced. They are conceived as ways of expanding the frame and scope of possible methods of teaching, practicing, and consequently making apparent architecture's larger role in culture and society. In *Architecture School, Three Centuries of Educating Architects in North America*, editor Joan Ockman establishes a precise framework in which to understand the current condition of architectural education and practice. In her introduction, she makes clear the historically contentious relationships between the two, and identifies some of the most pressing challenges facing contemporary architectural education.

> Architecture schools are undergoing far-reaching transformations in the early twenty-first century. Globalization, digital technology, and an increasingly market-driven education economy are among the powerful forces shaping academia. Natural and man-made disasters have also played a part over the last decade, focusing the attention of educators on environmental change, the technical performance of buildings and their representational role. (Ockman 2012, 10)

This extensive book makes explicit the challenge of contemporary education's struggle to keep pace with many new challenges that face the discipline at the outset of this millennium. The previous quote echoes the fact that we currently face great societal, environmental and economic pressures, and as such, we are now forced to rethink the way we teach the discipline of architecture. We have shifted from an era in which an architect is one who masterfully designs discrete objects, to a citizen who engages larger sets of systems and forces. The expansion of the frame of our discipline has allowed us to participate in the direction of how we choose to form not only our physical environment, but also to become an operative participant in the formation of society's larger philosophical and cultural aspirations.

This paper will proceed by exploring specific type of pedagogy, research, and the possible ways that these somewhat invisible structures can be made apparent in the world. The paper will progress by articulating three challenges facing architectural education and practice, followed by an identification of three experimental pedagogical models, which are currently addressing these challenges. In order to understand how each of these pedagogical models is structured, the paper will examine closely the hybridized and collaborative frameworks of each. Ultimately, it will be established how each model makes their research and knowledge apparent in the larger cultural arena, as a means of effectively connecting architectural knowledge to a broader and more diverse public.

1.1 Contemporary Questions of Pedagogy, Research and Visibility

In his essay "Education By Infection" (Groys 2009), art historian and cultural critic Boris Groys speaks of the delicate paradox involved in effectively educating art students. He articulates the need to simultaneously separate and immerse students into the larger flux of society. This notion of creating a highly concentrated academic environment for art students, while also exposing them to external social and cultural forces, echoes a similar conundrum within the context of contemporary architectural education and practice. This condition is reflected in the challenge of providing architecture students the proper balance between a highly concentrated environment of independence, while also exposing them to the multitude of challenges and opportunities that lay waiting outside the doors of academia.

One of the core struggles of current architectural education is how to establish precise pedagogical methods to allow for dynamic exchange. Arguably, the ideal strategy for generating knowledge is to create a precise balance between autonomy and engagement, internal desires and external resistance, unfettered exploration and definitive limits. This process is perhaps most exemplified in the context of conducting research. Within the context of architecture, research is often seen as exclusive knowledge generated within the narrow confines of academia or professional practice. This model of exclusivity and concentration can be productive and appropriate at times, but if not moved beyond its small confines, the model runs the risk of remaining separate from a larger context, and may suffer from eventual irrelevance.

As a counter to this condition, new modes of architectural research are currently evolving to create and benefit from opportunities of collaboration and exchange as a means of achieving a higher caliber of innovation and discovery. In each of the following scenarios, the experimental pedagogical models blur the lines between academia, practice and the broader cultural landscape. Each of these ongoing experiments seeks to expand and deepen the capacity for architectural thinking to have a greater impact on society.

1.2 Three Existing Problems / Three Emerging Pedagogical Responses

Three primary challenges face the integration of academic and practical architectural knowledge as it relates to the larger social fabric. These challenges are addressed with respect to the corresponding pedagogical entities that have been actively seeking ways to contribute to possible solutions.

1. The first challenge has been identified as the separation between education, practice and the industrial sciences. The Center for Architecture Science and Ecology (CASE) was formed as a partnership between an academic program (RPI) and professional practice (SOM), and is actively moving to blur the division between students, educators, practitioners and industry specialists.

2. The second challenge has been identified as the separation between architectural practice and its role in broader cultural participation. AMO, established as the research arm of OMA, has contributed directly to work that has been realized in the built environment, while also generating research for purposes beyond the conventional boundaries of architectural production.

3. The third challenge has been identified as the separation between localized academic study and global urban culture. To ameliorate this schism, Columbia University's Studio-X has evolved into a highly responsive, light and dynamic feedback system, between a fixed location of a central campus and multitude of cities around the globe.

These three pedagogical frameworks allow for the necessary speed and flexibility to both absorb new developments in the related fields of the sciences, arts and humanities, while also engaging the public in new and dynamic ways. While the make up and mission of each entity differs, they are all linked in that they each have identified a problem and have established a pedagogical structure with which to address it. Each entity has also fostered collaborative exchanges to perform experimental research with the goal of having it broadcast to a wider arena.

1.3 Center for Architecture Science and Ecology

CASE is a partnership between Rensselaer Polytechnic Institute's School of Architecture and the offices of Skidmore Owings & Merrill LLP. Simultaneously situated within the New York office of SOM and the campus of Rensselaer, CASE has emerged as a dynamic experiment where students, educators, practitioners, scientists and industrial specialists share a space of common inquiry. Founded in 2009 by architect and educator Anna Dyson, CASE has evolved to serve as a nexus between academic research, professional practice and the industrial sciences. Sensing the gap between education, practice and technological innovation, she founded a model that would create an immediate opportunity for an academic institution and professional practice to mutually benefit from direct linkage. The faculty is devised of a diverse set of individuals ranging in background and expertise. The broad base of knowledge associated with such a structure allows for effective communication between the many players that are involved in the sophisticated and complex projects in which they participate.

Motivated by the desire to address problems of intelligent energy use in the built environment, CASE has selectively contributed to the realization of built projects in the office of SOM. These projects serve as a testing ground for much of the innovative research conducted by CASE. To gain a clearer sense of the radical nature of this pedagogical model, it will serve us well to focus in upon one of the many collaborative efforts between CASE and SOM.

In late 2012, a momentous step was taken in furthering CASE's stated mission. To educate the public on the possibility of the intelligent use of energy in buildings, SOM has recently broken ground for New York City's first Net Zero Energy School Building (see Fig 1). CASE served as a consultant in tandem with various other professional specialists including environmental consulting firm In:Posse, which provided other components of expertise.

Scheduled for completion in 2015, the project specifically makes use of the extensive research that CASE has been conducting in solar thermal systems for hot water, and intelligent facade design. SOM's Education Lab was able to implement aspects of this research into the project, leading to a radically different way for the building functions to be experienced by its inhabitants. The technical intricacy of the building is beyond the scope of this paper. Instead, the emphasis here is placed upon the collaborative nature of the project. Chris McCready, AIA, Director of SOM's Education Lab and project manager of P.S. 62, has stated:

> Reaching the ambitious goal of net zero energy consumption would not be possible without the collaboration of our consultants… We'd like to recognize all the members of our project team for their contribution: In:Posse, AKF Group and Center for Architecture Science & Ecology. (McCreedy, SOM News)

Fig 1. Rendering of P.S. 62 Net Zero Energy School, Source: (Skidmore, Owings & Merrill LLP 2012)

The project is conceived as a highly collaborative endeavor between a diverse set of interests, and serves as a critical step in New York City's move towards a more sustainable and intelligently designed environment. The results that emerge from the experimental nature of this particular project could prove to have a far-reaching impact on the future of how schools, and eventually many other building typologies are realized in the city.

In CASE's three years of operation, they have received support from the NYSERDA, the DOE, the NSF and the NYSTAR. The research is being made visible in the world by its implementation in built projects. Problems of built ecologies are critically tested and explored by teams of students, educators, practitioners and industry specialists. Built in the physical landscape and put to practice, this model accelerates the speed between experimentation and realization. Perhaps the single most important aspect of this building is its program of an elementary school. As an intelligent object, the building also becomes a pedagogical tool that has firstly benefited the undergraduate, graduate and doctoral students who have collaborated on the related research applied to the building, and secondly, will benefit the future students who will inhabit the building. In each case, an opportunity is presented to understand something about a possible future of collaborative efforts and encourage fostering a more intelligent future.

In *The Three Ecologies* (Guattari, 2008) philosopher Felix Guattari articulated the three ecological threads that need to be woven together at the outset of the twenty-first century. They were defined as environmental, social and mental ecologies. The broader collaborative research of CASE, and this project in particular, manages to approach the question of integrating these three forms of ecology, by virtue of the collaborative nature of the project and the impact that it will continue to have upon its completion

1.4 OMA/AMO

If we consider the structure of research and practice as proposed by the CASE / SOM model, we can begin to see the dissolving of exclusionary boundaries between education, research and practice. Another pedagogical model which has been unfolding for over a decade with the intent of eliminating such boundaries is that of the mirrored practice/research model of OMA/AMO. Established in 1998 by OMA partners Rem Koolhaas and Reinier de Graaf, AMO emerged as a parallel think-thank of OMA with the mission of dynamically engaging both the challenges and opportunities of globalism. At the international cross-disciplinary conference *Anything*, held in 2000, Koolhaas publicly announced the ambitions of AMO (Koolhaas, "The Regime of ¥€$"). He articulated the complex network of connections between a disparate set of figures, both within and outside of the academic and professional boundaries of architecture (Fig 2). Hosted by the Guggenheim Museum in New York City, the context of his declaration was ideal as it was the last conference of the decade long experiment which consisted of an annual series of exchanges between architects, artists, educators, curators, economists, social scientists and philosophers.

Koolhaas, during his presentation at this event, articulated the conceptual underpinnings of this new experiment (Fig 2), which proposed a radical reconsideration of the relationship between academia, practice and a variety of other individuals and institutions, which reside beyond the boundaries of architecture.

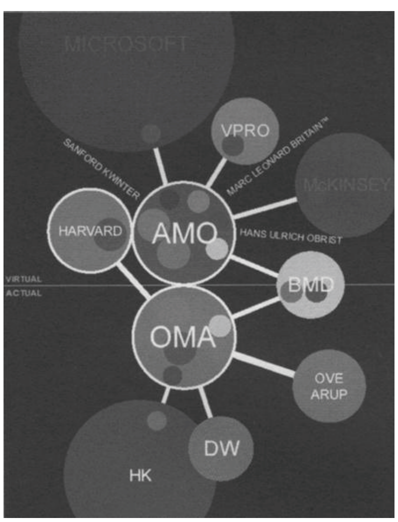

Fig 2. Diagram of OMA/AMO, Source: (*ANYTHIING* 2000*)*

Since that moment over a decade ago, much has changed within the practice of Rem Koolhaas in particular, with architecture in general, and with culture at large. Given this condition, it will prove effective to extract a single OMA/AMO project in order to better understand the specific manner in which the experiment contributed to new perceptions of architecture as an active cultural participant.

The 2006 Serpentine Gallery Pavilion in London was a collaborative effort between Koolhaas; engineer Cecil Balmond with Arup, and curator Hans Ulrich Obrist. The larger conceptual mission and impact of AMO are made manifest in the particular dynamics of this project. While small in scale - relative to many of the larger built works of OMA - the significance of this project cannot be overstated. Conceived as a lightweight, inflatable, temporary pavilion, its main agenda was to act as a space to host a series of diverse, fluid and transient events. One programmatic layer of the project of particular interest was a series of sixty-six interviews conducted over a twenty-four hour span of time in the presence of a continuously changing audience. Koolhaas and Olbrist conducted these marathon interviews with "leading politicians, architects, philosophers, writers, artists, film-makers and economists…acted as live research, exposing the hidden layers of London." (Obrist and Koolhaas 2012, 11)

The desire for an architect and his architecture to expose and make visible, the hidden or latent conditions, is the core of the project's radical composition. This serves as an important example of architecture imbedding itself within a larger social matrix. By adopting certain artistic techniques such as the surrealistic strategies of sleep deprivation, games of chance and informal staging; architecture becomes an event where lines of normality are blurred, reimagined and sometimes erased all together. Inhabitants become actors in a play of unfolding events in a game of architectural exquisite corpse.

This pavilion challenges the conventional notion of the stabile and static object, and instead presents architecture as a dynamic frame which initiates, provokes, enables and encourages new relationships It is meant to be seen, experienced and connected in unexpected ways. Due to its experimental and speculative nature, this particular project provides a model for architects to begin to understand how to remain an active participant in all phases of an architectural endeavor, from the earliest stages of conception through its realization and its dissemination into a larger cultural sphere. This model represents a dynamic loop, which has helped to establish a precedent by showing how radical architectural thought can remain visible through the lifespan of a built work. It challenges the conventional notion of the architect as a mute actor, who merely provides a service where static objects are delivered to satisfy predetermined goals and expectations.

In the post-life of the pavilion, the dynamic exchange of interviews led to a detailed documentation and related publication, *London Dialogues* (cited above). This document is the most recent in a long line of complex collaborative publications devoted to AMO's research, including the three Harvard related books, *Project On The City 1, Great Leap Forward* (Chung, Inaba, Koolhaas & Leong 2001), *Project On The City 2, Harvard Design School Guide To Shopping* (Chung, Inaba, Koolhaas & Leong 2002), *Mutations* (Koolhaas, Boeri, Kwinter, Tazi & Obrist 2004), and *Project Japan: Metabolism Talks* (Koolhaas and Obrist 2011). The pavilion, publications and a multitude of other related exchanges stand as a testament to the success of OMA/AMO's earliest mission of establishing a set of complex linkages between many individuals and institutions across geographical, institutional and disciplinary boundaries.

1.5 Studio-X

Founded in 2008, Studio-X began as an initiative by Columbia's GSAPP Dean, Mark Wigley. In contrast to the fixed nature of the main campus, Studio-X was imagined as a constellation of mini think-thanks, which are strategically situated to form a global network of knowledge. The ultimate mission and goal is to contribute to the erasure of boundaries separating localized education and global knowledge.

In the context of Studio-X, it may be more fruitful to look not at a single project, but to its overall mission and organizational structure. Similar to Koolhaas's observation about the speed of globalism and the relative slowness of architectural practice, Wigley observed a similar phenomenon as it relates to globalism and architectural education. In the mission statement of the project, he defines the program as "a dynamic space that evolves at the same speed as the urban environment itself" (Wigley, *About Studio-X*). The objective is to grapple with some of the challenges and opportunities afforded by the complexity of globalization. The lightness of these programs allow for a smaller footprint and greater absorption of new knowledge and new modes of practicing and disseminating knowledge.

The radical nature of the program allows for an expansion of the boundaries of education, and also allows a much wider audience of participants and players. The mobile structure opens itself to many forms of intelligence held by figures both within and outside of the architectural discipline. Much like AMO, the mission of Studio-X is based on a model of complex and unlikely cross-pollination, with the desired outcome of newly emerging mutations.

Studio-X is constructed of nebulous relationships and shifting contexts which challenge the conventional balance between a centrally fixed base of power and peripheral obedience. They are essentially working to level and expand the field of play. With locations in seven cities around the world, including New York, Mumbai and most recently Tokyo, the program ensures that it has the ability to both see and hear, while being heard and seen in every part of the globe (Fig 3).

Fig 3. Diagram of Studio-X, Source: (Columbia GSAPP)

CONCLUSION

In her essay "*The Thing Seen",* writer and educator Ann Lauterberg states that art education is "more critical to the vision and fabric of democratic social space than ever before" (Lauterberg 2009, 97). The implication of this statement for the discipline of architecture is vast and speaks to the current goals and aspirations of countless students, educators and practitioners alike. Given the vast challenges facing us all, it seem only appropriate that the diversity of research and the related knowledge of architecture, be more intricately woven into a world of ever-increasing speed, immediacy and complexity.

By attempting to understand three uniquely structured experimental entities, a number of directions and models have been established that may prove instrumental in understanding a possible future of education, practice and the larger public's understanding of architectural knowledge. Each of these three institutions has sought to make new connections between the speculative knowledge that unfolds within the walls of academia and practice, by bringing this knowledge into a larger cultural and social domain.

The means and methods of each entity are diverse, as is exemplified by OMA/AMO's complex networking of academia, practice, media and the many ways of implicating a larger audience of participants; by CASE's strategy of weaving expertise and knowledge between, students, educators, practitioners, scientists and industrialists with the single aim of improving the relationship between architecture and the inhabitants of cities around the globe; and finally by Studio-X's innovative vision of projecting architectural education into the global landscape. Despite the differences, all three share a common desire to see architecture expand and to deepen its societal role in the early twenty-first century.

The unique expertise that architects possess has been brought into to the realm of partnership, collaboration and exchange. As a result, the territory of architectural inquiry is vastly expanding. There now exists in pedagogy a provocative notion of hybridization, of merging, blurring, or eliminating traditional distinctions between academic knowledge, professional practice, architectural production and architectural research. This necessarily establishes architecture simultaneously as a specialized discipline and a cooperative participant in a larger cultural terrain.

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POLICY

Educating Policymakers, Practitioners, and the Public

Linking Programming, Design and Post Occupancy Evaluation: A Primary Care Clinic Case Study

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ABSTRACT: The architecture design process typically encompasses separated phases or steps leading to a completed building project. Steps may include programming, conceptual design, design development, construction and sometimes post occupancy evaluation. As a result of these distinct steps, it is usually difficult to trace the linear thinking from the beginning of a project to the end of a project. Consequently, the findings produced from each step are not carried forward throughout the process and it is difficult to conduct an assessment of the building in use that is tied to front-end thinking. If these steps are linked in a project, then it would allow for capturing project goals and design attributes (input measures) in relation to desirable outcomes (outcome measures). Various life-cycle process models for architecture were explored in a literature review. While useful, these process models offer limited practical recommendations on how to create a performance-based framework that connects design to measurable outcomes. In response, the objective of this study is to explore an integrated, multi-step process that links programming, research and design with a goal of understanding how design decisions impact building performance. While the use and acceptance of Evidence-Based Design (EBD) research and Post Occupancy Evaluations (POEs) have increased over recent years, most studies don't encompass all steps and are focused on inpatient care facilities. Since outpatient clinics represent the fastest growing segment of healthcare spending and there is limited empirical research on the architectural performance of these healthcare settings (Preiser, Verderber, & Battisto, 2009), a primary care clinic was chosen to explore this integrated process.

KEYWORDS: life-cycle model, performance-based framework, post-occupancy evaluation, primary care

INTRODUCTION

According to a 2011 National Center of Health Statistics (NCHS) report, there were 1.2 billion ambulatory care visits in the United States in 2007, with 48.1 percent of these visits being to primary care physicians in office-based practices (Schappert & Rechtsteiner, 2011). The rising demand for primary care services is influenced by demographic changes, including an aging population expected to increase from 12.7 percent of the total U.S. population in 2008 to over 20 percent of the total U.S. population by 2050 and a rise of chronic conditions prevalent in this population (Mann, Schuetz, & Johnston, 2010). The crisis primary care confronts "is a result of the confluence of a rising demand for primary care services and a decreasing supply of professionals providing these services" (Mann, Schuetz, & Johnston, 2010, p. 9). This crisis is further heightened by a lack of standardized facilities, technologies, and equipment across practices that would improve coordination and collaboration. While these challenges are clear, the availability of planning and design guidance tools are limited for this healthcare setting type.

Feeling the pressures of improving their primary care clinics, a local health system wanted to explore a new prototypical design for their family practice clinics and reached out to a nearby university that specialized in healthcare architecture. After discussions, it was decided that the development of a new prototype was an ideal project to work toward linking pre-design activities (such as programming and conceptual design), with design development and construction and finally to a post-occupancy facility assessment.

Literature Review

A literature review was conducted focusing on two relevant areas: lifecycle process models in architecture, and post-occupancy evaluation. Below are the findings from the review. First, an overview of three theoretical process models for architecture is presented - they recognize the facility lifespan from the pre-design phase to the post-occupancy evaluation phase. Second, Post Occupancy Evaluation is reviewed proving insight on how a building in use may be assessed according to the upfront planning decisions, design attributes and measurable outcomes.

Life-cycle Process Models: From Pre-Design to Building Occupancy:
Three theoretical process models for architecture that recognize the facility's lifespan from pre-design to post occupancy considered for this study include: the *Design Development Spiral Model* by John Zeisel (1981), *Building Performance Evaluation (BPE) Process Model* (Preiser & Vischer, 2005), and the *Center for Health Design's (CHD) Evidence-Based Design Process Model* (Center for Health Design, n.d.). First, in his book, *Inquiry by Design: Tools for Environment-Behavior Research*, John Zeisel (1981) sets out basic concepts regarding the relationship of research and design. He claims that the researcher learns by making hypothetical predictions, testing ideas, evaluating outcomes, and modifying hypotheses. This spiral model includes: design programming (research particular object's design); design review (using the knowledge from existing environmental behavior research to assess a design's conformance); and post-occupancy evaluation (a comparison of the actual completed in-use project with the original goals and hypotheses of a design) (Hourihan, 2011). Second, The BPE Process Model is a life cycle model based on expanding the post-occupancy evaluation model developed by Preiser, Rabinowitz, and White (1988). The phases included in the BPE model are programming, planning, design, construction, occupancy, and recycling. This cyclical model spans from pre-design to post occupancy, with each building cycle looping forward to and informing the next project cycle. Finally, the Center for Health Design's Evidence-Based Design (EBD) Process Model includes five phases: organizational readiness, pre-design, design, construction, and occupancy. The steps that inform each phase of the project include: definition of EBD goals and objectives, finding sources of relevant evidence, critical interpretation of relevant evidence, creating and innovating EBD concepts, developing a hypothesis, collecting baseline performance measures, monitoring implementation and design construction, and measuring post-occupancy evaluation results (Center for Health Design, n.d.).

While these theoretical models have individual strengths, they offer limited recommendations towards practical solutions that link programming, design and research activities throughout the architectural process. Additionally, they offer limited practical recommendations to translate findings into planning and design recommendations for future projects. There are some resources available to guide decision making for outpatient care but they focus on minimum room-type areas and technical requirements. Following is a summary of the resources considered for this study (Table 1). Overall, these resources, lack information that is critical for effective planning and design of outpatient clinics.

Table 1: Healthcare facilities guidance tools analysis

Sources	Information Provided in Tools	Limitations
FGI Guidelines for the Design and Construction of Healthcare Facilities (2010)	Provides minimum recommendations for: ▪ Room area sizes ▪ Lighting, Acoustics, Mechanical and Electrical requirements	Limited to minimum values No recommendation of the overall clinical modules and room layouts
Whole Building Design Guide (WBDG)	Provides general recommendations including the implementation of: ▪ Modular concepts ▪ Room area standards ▪ Adjacencies ▪ Design features to reduce environmental stressors	Limited to general recommendations No recommendations of room area sizes and layout, and the overall clinical modules
SpaceMed (Hayward, 2006)	Provides specific information regarding: ▪ Space program requirements ▪ Area calculation methods ▪ Room area sizes	No recommendations of the overall clinical modules and room layouts
Department of Defense (DoD) Space Planning Criteria and Templates	Provides specific information regarding: ▪ Space program requirements ▪ Area calculation methods ▪ Room area sizes ▪ Room layouts ▪ Technical requirements	Limited to room requirements excluding the overall clinical modules

Post-Occupancy Evaluation:
"Post-occupancy evaluation is the process of systematically comparing actual building performance, i.e., performance measures, with explicitly stated performance criteria" (Preiser, 1995). The concept of Post-Occupancy Evaluation (POE) was introduced in the 1960s and has evolved into a discrete process of building performance review (Mallory-Hill, Preiser, & Watson, 2012). In 1988, Preiser, Rabinowitz and White published the first book on Post-Occupancy Evaluation, entitled *Post Occupancy Evaluation*, which became the primary reference for POE. Initially as an assessment tool, POE aimed at receiving user feedback to ascertain how well the designed settings satisfy and support human needs and values of the building occupants. POE includes "any and all activities that originate out of an interest in learning how a building performs once it is built, including if and how well it has met expectations." (Preiser, Rabinowitz, & White, 1988; Preiser & Vischer, 2005; Vischer, 2001, p.23). Following are the various levels of POE that have been introduced by Preiser, Rabinowitz, & White (1988) ranging from a very high level review to a detailed, in-depth study (Table 2).

Table 2: Post-occupancy evaluation levels of effort

Post-Occupancy Evaluation Levels of Effort	Purpose	Methods
Indicative	Provides an indication of major strengths and challenges of a building's performance	Archival and document evaluation Walk-through evaluation Interviews
Investigative	Provides a thorough understanding of the causes and effects associated with behavioral, functional and technical building performance using explicitly stated evaluation criteria	Literature assessment Walk-through Survey Interviews Focus group
Diagnostic	Provides a correlation of physical, environmental and behavioral performance measures with subjective occupant response measures	Walk-through Survey Interviews Focus group Technical readings Observation

POEs for general building types have targeted different performance measures classified in three areas: functional, behavioral, and technical (Preiser, 2003). Applied to the context of healthcare and to the particulars of primary care clinics, four outcome categories of performance measures were identified for this project including positive experience (similar to behavioral), operational efficiency (similar to functionality), clinical effectiveness (new), and healthy environment and sustainability (similar to technical). Based on the literature reviewed, a combination of these four different performance areas may provide the most balanced assessment. As a result, a performance-based framework that incorporates the initial design goals and the critical issues that influence primary care facilities was developed to inform the post-occupancy evaluation effort of this pilot study.

Methodology:
Project Team, Scope, and Timeline:
A partnership was formed between Clemson University's School of Architecture, NXT Health, and a health system. A multidisciplinary approach to plan, program and evaluate a prototypical design for a family practice clinic was initiated. The intent was to expand upon the traditional view of health and redefine patient expectations by providing efficient, high quality care that leverages the latest technologies within the context of healthy and sustainable spaces.

The programming and conceptual design phase was completed in the spring of 2009 as a service learning project with Clemson University's Architecture + Health programming and pre-design seminar. Based on a series of collaborative work session, planning goals and objectives were established as well as the space needs and other operational requirements. Following the programming phase, a final conceptual design was developed during the summer of 2009 with faculty and students. Once the schematic design was completed, an architectural design firm was selected to further develop the conceptual design and prepare the contract documents. The facility was built in 2010 and the planning for a Post Occupancy Evaluation began by a different team at Clemson. A POE study protocol for Institutional Review Board approval was submitted in January 2012 and received in February 2012. A team from Clemson University conducted a post-occupancy evaluation in the summer of 2012. Lessons learned from the post-occupancy evaluation are currently being translated into design guidelines for the next family practice clinic project.

Overview of steps:

Three critical steps have been delineated in the project's multi-step process: 1) Programming and Conceptual Design, 2) Professional Design and Construction, and 3) Post-occupancy Evaluation. Table 3 summarizes the steps including the purpose, the groups involved, and the goals and deliverables, followed by a brief discussion of each step.

Table 3: Overview of steps

Architectural Process Steps	Groups Involved	Goal	Deliverables
1. Programming and Conceptual Design *Purpose: Develop the project scope, guidance criteria and conceptual design*	Clemson University and NXT Health in collaboration with the Health System	*Guiding:* ▪ Develop project scope ▪ Translate findings from interactive work sessions ▪ Use research to identify planning and design recommendations ▪ Develop conceptual design that captures project goals	*Guidance Criteria:* ▪ Project mission and vision ▪ Project goals and objectives ▪ Spatial, functional and operational needs *Conceptual Design:* ▪ Facility and key rooms ▪ Design strategies and concepts ▪ Conceptual design
2. Professional Design *Purpose: Develop the professional design informed by the guidance criteria and conceptual design*	McMillan Pazdan Smith Architects with Clemson University as a consultant	*Implementing:* ▪ Translate guidance criteria and conceptual design to achieve project goals and objectives	*Professional Design:* ▪ Existing building retrofit to move conceptual design forward into design development and produce a set of construction documents
3. Post-occupancy Evaluation *Purpose: Assess the quality of the physical environment*	Clemson University in collaboration with the Health System	*Measuring:* ▪ Learn how the built environment achieves the client's established goals and objectives by connecting design attributes and measurable outcomes	*Final POE Report:* ▪ Analysis of the facility in-use to identify strengths of the facility design and areas of improvement.

Step 1: Programming and Conceptual Design Development:

The process and outcomes for this step are described in detail in Battisto, Thomas, Whitman, & Weeks (2009). Simply put, this research included a literature review, case study and observation research in three family practice clinics, and four collaborative work sessions with client stakeholders. During this phase, the project team developed qualitative guidance criteria including the project mission, vision, goals and objectives. Additionally, quantitative data was produced including the functional program, a space list and key room area sizes. These data were translated into design strategies and concepts informing a conceptual design for three different scenarios including a two, three and four physician clinical pod module.

Figure 1: Conceptual design developed by Clemson University

Step 2: Professional Design and Construction:
In order to develop the facility professional design, collaborative work sessions were conducted with the selected architectural design firm to advance the conceptual design proposal developed in the programming phase into the final schematic design and construction drawings. The implementation of the planning criteria resulted from a dialogue with all team members allowing a seamless and direct transfer of the concepts into the final design. It is also important to note, that the professional architecture firm was involved in some of the initial programming and planning work sessions. In the end, the selected project site was to be a retrofit of an existing new facility therefore the proposed design was finally developed for a two- physician clinic.

a. Waiting Concourse b. Reception Area c. Assessment Room

Figure 2: McMillan Pazdan Smith Architecture professional design, Photography by Kris Decker/Firewater Photography

Step 3: Post-Occupancy Evaluation:
The health system had an overarching goal to improve operational efficiency in their family practice offices. Given the assets of the team (expertise in clinical operations, architecture, research), it was envisioned that this initial prototype could be used to study if and how the facility design impacted the client's two top goals: to operational efficiency and the patient experience. In pursuit of this goal, the POE developed for this project incorporates features of the indicative and investigative approaches noted by Preiser (1988), and provided a focused assessment of a single family practice office. This research project was an exploratory study to assess the efficacy of the built environment. A case study research design process was employed, utilizing mixed methods inclusive of both quantitative and qualitative approaches. The post-occupancy evaluation was organized in two main phases: 1) Facility Documentation, and 2) Facility Performance Evaluation. Informed by the literature in healthcare design and research, a performance-based framework was developed to link design attributes to measurable outcomes. Below is an example of one outcome category within the overall performance framework (Figure 3). A more expanded framework was developed to include four outcome categories: Positive Experience, Operational Efficiency, Clinical Effectiveness, and Healthy Environments and Sustainability.

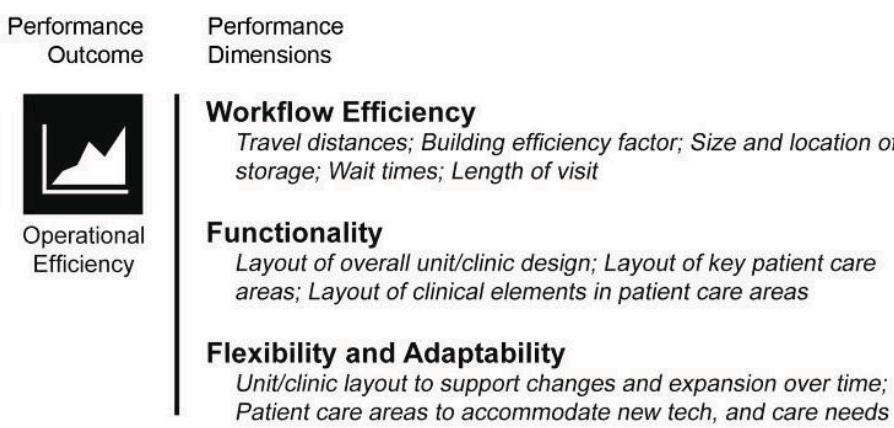

Figure 3: Performance dimensions and key metrics to assess operational efficiency

To conclude the authors have summarized the research activities conducted during each step of the multi-step process.

Table 4: Architectural process model

Architectural Process Steps	Activity	Methods
"Guiding" 1. Programming, and Conceptual Design	Identify the critical issues that influence primary care clinics	Literature Review
	Study "best design practices" in primary care clinics	Case Study Research
	Identify key issues linked to outcomes in three primary care clinics	Observation Research
	Define spatial, functional and operational needs. Finalize project goals, objectives, design strategies and concepts	Collaborative Work Sessions
"Implementing" 2. Professional Design and Construction	Collaborative work sessions to refine the space list, and the space and operational planning criteria	Professional Design Services and Construction
	Refine and apply design concepts and strategies into a schematic design	
	Develop professional design, construction drawings and specifications	
	Execute project bidding and negotiation	
	Complete project construction	
"Measuring" 3. Post-occupancy Evaluation	Seek approvals and request facility data and planning documents	Archival Research
	Capture the physical environment using measured drawings	Floor plan take-off
	Generate diagrams to capture the design concepts across the performance dimensions	Facility Diagramming
	Verify on-site facility information and answer questions from take-off analysis	Facility Verification
	Document facility environmental features using a visual format	Photographic Profile
	Review the design intent of the facility	Architect Fact-Finding Interview
	Familiarize the POE team with the overall facility	Guided Facility Walkthrough
	Understand patients, family and staff perceptions of the facility design with respect to the performance dimensions	Survey
	Gain insight on how the facility performs in practice with respect to lighting, temperature and acoustics	Technical Readings
	Gain insight on the care delivery process by documenting patient and staff steps and flow patterns	Observation Research

Findings:

Integration of the Three Steps:

The purpose of the multi-step approach is to establish a relationship between decisions surrounding physical environment (identified during the programming phase and design phase) and the desired outcomes (studied in the POE). Understanding associations between the physical environment and outcomes can yield insight that may be used to inform our future design decisions. In this pilot study, three critical steps were connected: 1) Programming and Conceptual Design, 2) Professional Design and Construction, and 3) Post-Occupancy Evaluation. To connect these three steps, a table was developed to outline the linear thinking using the performance framework as a structure. The table linked project goals and design concepts with the outcomes areas, and was later used to assess the facility performance during the post-occupancy evaluation. Table 5 shows one example of how goals are aligned to performance outcomes, dimensions and design concepts including objective and subjective metrics to assess workflow efficiency.

Table 5: Linking design to outcomes for workflow efficiency

Project Goals	Performance Outcome	Performance Dimension	Key Design Concepts	Metrics *Objective*	Metrics *Subjective*
The design of the facility should assure a high quality of care through the adoption of efficient work processes	Operational Efficiency	Workflow Efficiency	1. Clear organization of office, clinical, and provider zone 2. Separate patient and staff circulation flow patterns 3. Direct access to patient care areas for patients and family 4. Direct access from staff work areas to patient care areas	▪ Area calculations ▪ Travel distances ▪ Time	Staff satisfaction with workflow efficiency

Following is an example of the conducted POE analysis for workflow efficiency (Figure 4).

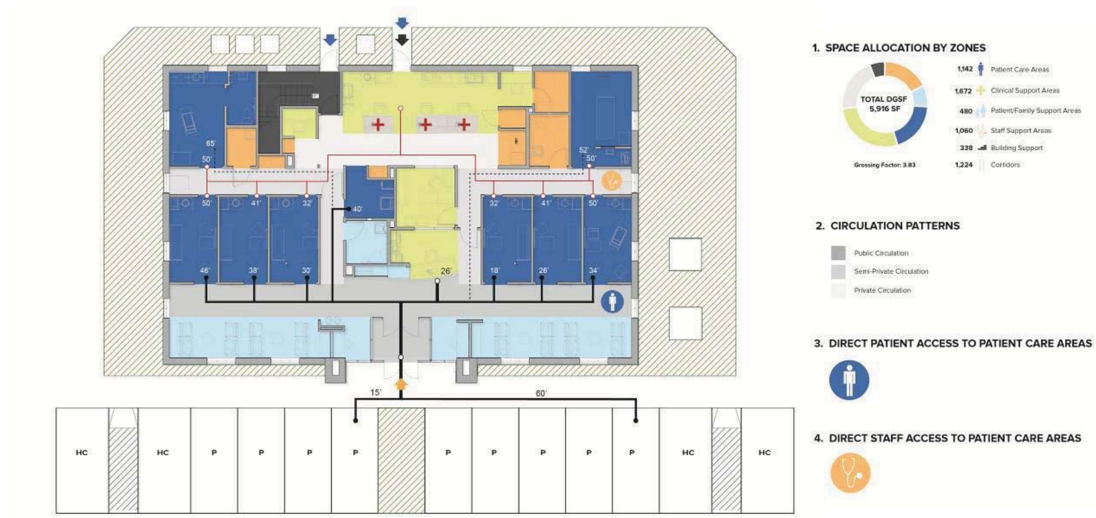

Figure 4: Post-occupancy evaluation analysis for workflow efficiency: clinical modules, circulation hierarchies and patient and staff travel distance

Based on lessons learned from conducting this project, the authors defined three steps: 1 *Guiding* the project scope, goals and conceptual design; 2 *Implementing* the ideas into practical design solutions and 3. *Measuring* if and how the design concepts are linked to desirable outcomes. These three steps should be linked throughout the architectural process and have been delineated in Table 4. The authors argue that the proposed multi-step model should be anchored by a performance-based framework determined during the programming and conceptual design phase of the project. The performance-based framework can be used for “guiding” the decision-making process throughout the project cycle. Clearly established “guiding” criteria developed at the programming and conceptual design phase of the project allows for “implementing” seamlessly the design concepts and design strategies leading to the final project design. The post-occupancy evaluation focused on “measuring” how the facility performs when studied after the building is in use. In summary, this multi-step process model encourages an integrated and transparent approach to programming, design, and evaluation anchored by identified performance outcomes and dimensions.

CONCLUSION

The development of a multi-step process anchored by a unified framework advanced knowledge by linking research and design. The results of the post-occupancy evaluation demonstrated the value of conducting research in a systematic and rigorous manner during the programming phase of the project. The development of a framework to document the project goals and the associated design concepts and performance metrics allowed the researchers to establish a relationship between the key environmental factors and performance outcomes that lead to excellence in design with the purpose of improving building performance. As a result, the development of a performance-based framework to guide the architectural process advances knowledge by exploring pathways to inform the architects' design decision-making process. Additionally, it assists the facility documentation process conducted as the initial phase of a post-occupancy evaluation by accurately documenting the hypothesized project goals and the key performance indicators considered in the programming and design process.

To summarize, the main contribution of this study is the development of a multi-step process that linked systematically research and design leading to an informed design decision-making process. Additionally, this study explored the initial development of a performance-based framework to guide the architectural process. The implementation of the multi-step process anchored in a unified framework allowed for an integrated and seamless translation of the project goals and objectives throughout the architectural process. This unified framework becomes relevant when the project steps are conducted by multiple companies. Additionally, it will inform the architects from the initial programming phase the evaluation criteria that will be employed during the post-occupancy evaluation to assess compliance with the hypothesized project goals. However, to explore the full potential of post-occupancy evaluations, which includes the translation of lessons learned into useful guidance tools to inform design decisions, future studies should focus on further developing a performance-based framework informed by the critical issues that influence primary care facilities. The development of such a framework will allow replication of the proposed multi-step process across multiple primary care facilities leading to the development of a data repository and guidance tools that can help inform future primary care design decisions.

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Health and the Environment: Shaping Policy and Place through Community Academic Partnerships

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Figure 1: Three nested watersheds, Paradise Creek Nature Park plan, and views of educational pavilions

ABSTRACT: Innovative pedagogical models in architectural education can educate practitioners, policymakers, and the public about the crucial relationship between public health and the built environment. This paper describes an interdisciplinary design research methodology that works with community partners to identify opportunities, design sustainable projects that inspire environmental stewardship, and develop implementation strategies. Civic engagement to influence public policy is an essential aspect of this approach to academic research. In collaboration with the City of Portsmouth, non-profit environmental groups, Portsmouth public schools and community partners, University of Virginia faculty and students from architecture, art and medicine investigated the complex relationship between human health, environmental restoration, and sustainability education through the design of a forty-acre wetland park. The Paradise Creek Nature Park will co-exist with contaminated industrial sites and an economically challenged and racially diverse neighborhood. Students designed the Park and its Wetland Learning Lab and Rainwater Filtration Pavilion to engage urban kids in hands-on learning. There were several research goals: create a place that increases the sense of well-being, economic vitality and opportunity for outdoor exploration for all ages; design green pavilions that educate visitors about sustainability; make a place where citizens may rediscover the healing respite of a healthy river; and create strategies for industry and natural ecosystem to co-exist in harmony. The research considered complex social, economic, ecological and architectural issues across scales. The design manifests an inventive educational agenda that teaches about sustainable dwelling, environmental restoration and human health. This design research project establishes a model for university and community collaboration that is capable of changing public policies, while fostering a commitment to environmental ethics and sustainable practices by connecting academic learning with the students' desire to make a positive difference in the world.

KEYWORDS: public park, health, community partnerships, restoration, education

INTRODUCTION

A civically engaged design process that influences public policy is central to this academic research. In collaboration with the City of Portsmouth, Portsmouth Public Schools, the Elizabeth River Project (ERP) and other community partners, University of Virginia (UVA) faculty and students investigated the complex relationship between human health, environmental restoration, and sustainability education through the design of a forty-acre public wetland park. The Paradise Creek Nature Park research project provides the opportunity to assist a community in need, while designing, implementing and testing strategies for creating healthy places and shaping public policy in the community. The Hampton Roads region and immediate park vicinity possess a challenging mix of conditions, including industrial, economic, emotional and spiritual stresses that contribute to environmental degradation, gang violence and other ills. The investigation raises several questions: How might a particular design encourage individual and community reflection, spiritual connection and environmental stewardship? Can the design physically manifest an educational agenda that teaches about sustainable dwelling at several scales? Does experiencing a restored urban nature park amidst industry affect the visitor's well-being and resilience?

1.0 RESEARCH OBJECTIVES AND METHODOLOGY

1.1 Methodology

This study utilizes a design research methodology that generates architectural knowledge through the design process, physical realization of the project, critical reflection, and dissemination. Several related theoretical frameworks support this methodology, including Donald Schön's concept of the *reflective practitioner,* Brad Haseman's *performative research* paradigm, Nigel Cross' *designerly way of knowing,* Alain Findeli's *project-grounded research,* and the *design fiction* approach of Simon Grand and Martin Wiedmer. (Schön 1983; Haseman 2006; Cross 2007, 2011; Findeli 2008; Grand and Wiedmer, 2010) Wolfgang Jonas' essay, "Exploring the Swampy Ground: An Inquiry into the Logic of Design Research," effectively argues for the validity of design research supported by theories from the 1960's to the present. (Grand 2012) In the Journal of Architectural Education's theme issue, *Architectural Design as Research, Scholarship, and Inquiry,* my essay "Working on the Elizabeth River" advanced the design research method that is utilized in the Paradise Creek Nature Park study. (Crisman 2007) This paradigm rejects the simplistic and non-productive framing of a duality between qualitative and quantitative research.

1.2 Phased Research Goals and Objectives

This research is part of a multi-year study starting in 2006 that involves several studios and implemented projects. The overall goal is to establish a model for university and community collaboration that is capable of changing public policies about the value of environmental restoration and sustainability education. Connecting academic learning with the students' desire to make a positive difference in the world fosters a commitment to environmental ethics and sustainable practices. The first goal of the Paradise Creek Nature Park research is to create a public place that increases the sense of well-being, economic vitality and opportunity for outdoor exploration for all ages. Several objectives were established for the ongoing research that will extend through construction completion. These objectives include completing a literature review of environmental and evolutionary psychology research that studies the measurable impacts of nature and public parks in urban settings on user health and well-being; structuring a design research process to maximize the potential for the built Park to increase human health and well-being; designing green pavilions, a children's playground and other places that educate visitors about sustainability by revealing the relationship between natural and built systems;[1] creating strategies for industry and natural ecosystem to co-exist in harmony; and constructing a public place where citizens may rediscover the healing respite of a healthy, living river. When Park construction is completed in 2015, the research team will focus on the second goal of understanding how urban environmental restoration through the creation of public parks contributes to improved human health and well-being. This will be achieved by completing a post-occupancy analysis that surveys park visitors and by publishing evidence-based best practices for the creation of public parks in industrialized urban settings. The third goal is to create a powerful model for how university researchers may collaborate with diverse community partners to effectively create green spaces that can change public policy about the value of the environment to human health and well-being.

Figure 2: Rainwater Filtration Pavilion at Park entrance

2.0 HUMAN HEALTH AND THE ENVIRONMENT

Currently the public health sector is intensely interested in how both *natural* and *synthetic* environments affect human health and well-being. A growing body of research attempts to measure and compare the benefits of short-term human activity in these two types of places. Use of the term *natural* in these studies is misguided, since it suggests these places are not the result of human design. In fact, a park and a college campus are designed artifacts. All of these *natural* environments have been constructed through human agency. Those reservations aside, this quantitative research can support the claim of designers for the significance of the built environment and perhaps more effectively shape policy by appealing to the quantitative bias of politicians. A recent review of twenty-five such studies concluded that "natural environments may have direct and positive impacts on well-being," yet the authors acknowledged the difficulty of this place-based research outside the lab.

> Cross-sectional studies have suggested positive relationships between green space and health; however, identifying the causal pathway can be complex. In order to objectively assess whether or not there is an 'added benefit' from green space, research studies need to investigate if there is a difference in the health benefits of an activity in a natural environment (e.g. a park) compared with the same activity in a more synthetic environment (e.g. a gym). If it is found that the natural environment does bring added benefits to health and well-being over and above those arising from the activity being undertaken, it is important to understand what benefits are realised, by whom, and in which environments. (Bowler 2010)

Environmental Psychology Professors Rachel and Stephen Kaplan's 1989 book, *The Experience of Nature: A Psychological Perspective*, developed the Attention Restoration Theory that humans concentrate more effectively after spending time in nature. (Kaplan 1989) In a later paper, *The Restorative Benefits of Nature: Toward an Integrative Framework,* goes further to state: "Natural environments turn out to be particularly rich in the characteristics necessary for restorative experiences." (Kaplan 1995) Of course, there are many types of natural spaces and those located within cities must be understood in relation to the surrounding physical context. Studies such as *Green Space, Urbanity, and Health: How Strong is the Relation?* examine how the health of different socioeconomic groups is affected by parks and other green spaces specifically located within urban environments.

> "The percentage of green space inside a one kilometre and a three kilometre radius had a significant relation to perceived general health. The relation was generally present at all degrees of urbanity. The overall relation is somewhat stronger for lower socioeconomic groups. Elderly, youth, and secondary educated people in large cities seem to benefit more from presence of green areas in their living environment than other groups in large cities. This research shows that the percentage of green space in

> people's living environment has a positive association with the perceived general health of residents. Green space seems to be more than just a luxury and consequently the development of green space should be allocated a more central position in spatial planning policy." (Maas 2006)

Based on these findings, the immediate population served by the Paradise Creek Nature Park may experience greater benefits. Also underlying this design research is the *Biophilia Hypothesis* that an instinctive or evolutionary biological bond exists between humans and other living things. (Wilson 1984) Related theories of evolutionary psychology support the human need and often preference for natural settings, trees, animals and the like. While valuing both evolutionary and environmental psychology studies linking human well-being to spending time in natural environments, this design research does not seek to quantitatively measure such outcomes in the Park. Just as important as these social science studies, however, is the scholarly research that investigates the relationship between ethics and aesthetics in place design. Several essays in *The Hand and the Soul: Essays on Aesthetics and Ethics in Architecture and Art* connect issues of beauty, form and sensory pleasure with ethical obligations to the human community and natural world. (Iliescu 2009) Though the subject of another paper, but it is important to note that qualitative aspects that are undervalued in psychological or medical research that relies solely on the scientific method.

3.0 PARADISE CREEK NATURE PARK

3.1 Overview

The Paradise Creek Nature Park is located along a tributary of the Elizabeth River in Southeastern Virginia. One of the most industrialized and polluted tributaries of the Chesapeake Bay, the river is also known as Norfolk harbor and supports the world's largest naval base. There is limited public waterfront access and area residents are largely disconnected from the river at the physical and psychological levels. The site offers challenging constraints and rich opportunities. A mature forest coexists with dredge spoils, invasive plant species, toxic industrial sites and an economically challenged urban neighborhood. In this area of exquisite beauty and horrific environmental degradation, citizen-led efforts are making wildlife meadows and rain gardens, storm water improvements, back yard habitats and a constructed oyster reef. The US Navy has converted seventy acres of waste landfill into wildlife habitat across the creek. In collaboration with residents, environmentalists and nearby industries, UVA's cross-disciplinary team has created a design that invites visitors into a deeper relationship with their community and River. The Park will be the first public landscape in the region with the primary purpose of engaging 20,000 citizens a year in environmental stewardship of the Chesapeake Bay by providing public river access and conservation education.

Figure 3: Children's Playground

Figure 4: UVA students with Portsmouth Mayor

3.2 Community Engagement and Research Partners

The Elizabeth River Project, lead NGO partner, worked with the community on more than twenty projects to restore the Paradise Creek tributary. When a stakeholder committee identified the need for public park access to inspire long-term river stewardship, ERP purchased the forty-acre park site and met over a two-year period with nearly fifty diverse stakeholders to develop consensus on a park plan. UVA research involvement began at that point in 2006 and in 2012 we completed design of the Phase II park plan and several architectural elements that will engage urban kids in hands-on learning. Specific outreach methods are currently being used to connect with key stakeholders and build public support. For instance, twenty at-risk youth have become *Park Ambassadors.* They are growing native plants, removing invasive species, educating the community, providing input on the UVA park design, and will eventually help UVA students to build the park pavilions. Multifaceted community engagement is a crucial aspect of the research approach. The research team includes UVA faculty and students from several disciplines and multiple external partners, including Portsmouth Public School science teachers, Portsmouth city officials and Cradock Neighborhood Association members. Several state and federal agencies are involved as well: the National

Oceanic and Atmospheric Administration and Virginia Departments of Environmental Quality, Forestry, Conservation & Recreation, and Game & Inland Fisheries. The US Environmental Protection Agency provided habitat recommendations and project funding. Paradise Creek Nature Park is one of only five urban sites selected by the federal government to participate in the *America's Great Outdoors* partnership. This diverse array of partners is working together to restore living resources, conserve land, increase public access, and expand citizen stewardship of the Park and ultimately the Chesapeake Bay.

3.3 Park Visitors and their Needs

Paradise Creek Nature Park will meet the needs of diverse stakeholders in one of the most populated regions of Virginia. The Park is predicted to attract over 20,000 park visitors a year from the Hampton Roads metropolitan area, whose population totals 1.7 million and includes the cities of Norfolk, Portsmouth, Chesapeake and Virginia Beach. Audiences include inner-city students, at-risk youth, and families lacking access to meaningful outdoor experiences and missing out on the well-being that comes with green space. Foremost, the park will connect residents with their home river at the physical and psychological levels. This reconnection to the Elizabeth as a living river is essential to sustain public support for environmental restoration. Surrounded on three sides by heavy industry, the Park has the potential to become a place of reconciliation between industry and environment. Already neighboring industries have participated in wildlife habitat and pollution reduction projects. Finally, the Park will increase green space in the distressed and aging port city. Portsmouth, the poorest of four cities in the Elizabeth River watershed, has only a third of the park space that is recommended for its size.

3.4 Design Research Studio Pedagogy

The studio pedagogy is structured around scholarship on community engagement (Boyer 1996; Wood 2003) and theories of agency.[2] (Giddens 1984; Latour 1987; Schneider and Till 2009) During a Spring 2012 design research studio, undergraduate architecture students completed a multi-faceted investigation. They created case studies of innovative nature parks and outdoor classrooms, studied environmental education programs, and researched the water, wetland and wildlife habitat ecosystems and human culture and settlement history of the park site. After completing a detailed site analysis, they designed a Phase II Park plan, two pavilions for classroom activities and social gatherings, green play areas and canoe launch to promote physical activity, and benches and moveable furniture for individual reflection and relaxation. Throughout the process the UVA students worked closely with ERP and teachers from Portsmouth Public Schools and Starbase Victory—a hands-on science enrichment program focused on science, technology, engineering and math skills for middle-school students. Ultimately, the studio pedagogy was structured to teach students create designs that enrich the physical and mental wellbeing of individuals and the larger community. Numerous sustainable strategies based on *SITES Guidelines and Performance Benchmarks,* such as easy orientation, accessibility, safety and showing signs of human care, were employed to create places for mental restoration, social interaction and physical activity**.** Educational and interactive elements, including paths, portals and pavilions, were designed to welcome people into the park and teach them about its history and culture. The park was designed for greater environmental awareness by creating restorative natural views of the river using visual and sound screening to focus inhabitants. (Stoner 2008) The restored and healthy ecosystem of Paradise Creek Nature Park may be the source of many real and measurable benefits that humans derive from a relationship with nature.

CONCLUSION

The primary indicator of success will be an increased sense of well-being and health for Paradise Creek Nature Park visitors and nearby residents. Several planned outcomes will contribute to this overall goal. Exhibits will be visitor-centered, inquiry-based, and promote engagement. Utilizes the elements of portal, path, destination and sense of surround, the overall design will educate park visitors about the importance of green infrastructure, the value of riparian buffer conservation, native plants, tidal wetlands, and the role of the citizen steward. The Elizabeth River Project will provide guided Park tours and public education workshops, as well as evaluate public engagement based on numbers of visitors to the park. They will also monitor and measure green infrastructure performance by calculating nutrient reductions using the Virginia Stormwater Management Nutrient Design System. UVA will disseminate research through publications and exhibitions. In these ways, the project intends to become a national model for how a public park may promote health and well-being in the midst of industrial uses and a stressed urban community.

The research has particular pedagogical outcomes as well. By working with diverse community partners and real world constraints, the project empowered University students to enrich and focus their research, design and communication skills, while learning about intertwined issues of human health and sustainable design, environmental education, and community engagement. The students connected sustainability education with their lives as citizens making a positive difference in the world. Their work will contribute to the city of

Portsmouth and the entire Hampton Roads region—establishing a translatable model for sustainable land use, while creating a public place that physically and spiritually connects the urban community of the Elizabeth River watershed with its home river.

Figure 5: Wetland Learning Lab

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ENDNOTES

[1] For instance, the Water Filtration Pavilion collects and filters rainwater, a native plant rain garden filters gray water, solar panels supply required electricity, natural ventilation cools the structure, and recycled industrial materials are used in the building construction. The Park and its architecture physically manifest an inventive educational agenda that teaches about sustainable dwelling and human health, as well as the inextricable links between water and land, the tidal river ecology and wetland restoration.

[2] [Agency] means being able to intervene in the world, or to refrain from such intervention, with the effect of influencing a specific process or state of affairs. This presumes that to be an agent is to be able to deploy a range of causal powers, including that of influencing those deployed by others. Action depends on the capability of the individual to “make a difference” to a pre-existing state of affairs or course of events. An agent ceases to be such if he or she loses the capability to “make a difference”, that is to exercise some sort of power.” (Giddens 1984, 14)

Selective Visibility: Governmental Policy and the Changing Cultural Landscape of Rwanda

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ABSTRACT: In a developing country like Rwanda, the pursuit of modernity is related to visibility through the cultivation of a particular image. Since the 1994 genocide, Rwanda has concentrated its efforts on recovering from widespread devastation and becoming a middle-income nation with a modernized economy. In the last twenty years, the Rwandan government has employed a strategy of selective visibility to produce significant impact on the built environment, through both specific policies and campaigns as well as through the allocation of funding to certain prioritized projects.

An examination of specific examples of change in Rwanda's built environment, with photographic documentation of conditions before and after an implementation of policy, reveals how architectural research can help to make the invisible more visible and provide a basis for critical reflection on a cultural landscape. These observations are based on immersive research undertaken in Rwanda in 2011 and 2012 including participant observation, interviews, and existing condition documentation, as well as a review of documents produced by the Rwandan government.

KEYWORDS: Policy, Rwanda, colonialism, demolition, beautification

INTRODUCTION

Over time, buildings, neighborhoods, roads and infrastructure appear and disappear, correlating to parallel changes in economic conditions, political affairs, and popular tastes. One of the most critical functions of architectural research is to document and analyze the history of our built environment to ensure that future changes are made with thoughtful reflection on our cultural past.

The study of these changes is particularly important in developing countries where an ongoing pursuit of modernity is frequently prioritized by government and also vertically integrated throughout a whole society. Located in the heart of Africa, Rwanda is a small nation that still depends largely on subsistence agriculture, but greatly aspires to become modernized and middle-income, and it is trying to achieve this goal in large part by controlling visibility in the built environment.

This paper presents a series of case studies that are based on immersive research undertaken in Rwanda including participant observation, interviews, visual documentation and analysis, and document research. A number of documents consulted were primary sources produced by the Rwandan government, including speeches, master plans, and other strategic papers.

1.0 BACKGROUND

1.1. Rwandan history

Rwanda has existed as a kingdom with a common language and culture since roughly the 15th century. The earliest inhabitants of the region, forest-dwelling hunters and gatherers known as the Twa, are thought to have settled the area as early as the Neolithic period. A group of agricultural immigrants, the ancestors of the modern-day Hutu, arrived between the 5th and 11th centuries, while the pastoralist, cattle-raising Tutsi arrived around the 14th century, and gained control of the area due to their more advanced combat skills. The Tutsi established a feudal-like system called *ubuhake* where the Hutu gave agricultural products and personal or military service to the Tutsi in exchange for the use of land and cattle (University of Pennsylvania 2010).

Tutsi kings ruled over the kingdom for several centuries, expanding its borders to roughly what they are today by the end of the 19th century. By this time, European exploration was encroaching on the kingdom. In the 1885 Conference of Berlin, the European powers declared the region to be under German control, a full nine years before the first European set foot within the kingdom. The Germans ruled Rwanda until World War I, when Belgium gained Rwanda and Burundi as territories. The Belgian colonial administration favored the minority Tutsi for administrative positions, believing they were a more intelligent and "civilized" race. The Hutu resented this inequity, and civil unrest and violent uprisings led the UN to terminate Belgian control, with Rwanda gaining independence in 1962.

Tensions between the Tutsi and the Hutu, which had been stoked by colonial prejudices, were at an all-time high in the second half of the 20th century, and a civil war erupted in 1990 after a rebel Tutsi group (the Rwandan Patriotic Front, or RPF) invaded from Uganda. A cease-fire agreement was reached when the government agreed to a power-sharing arrangement with opposition parties, but Hutu dissatisfaction with this agreement led to continued random acts of violence, and the Rwandan president was shot down in his plane in April 1994. This sparked a genocide in which nearly a million Tutsi (and Hutu moderates) were killed, decimating the population and leading to mass exodus. After three months of mayhem, the RPF gained control and established a new government. After a transitional period that saw the establishment of a new constitution, democratic elections were held in 2003, 2008, and 2010.

Rwanda's contemporary ethnic distribution is 84% Hutu, 15% Tutsi, and 1% Twa.

1.2. Motives

Since the 1994 genocide, Rwanda has concentrated its efforts on recovering from widespread devastation and becoming a middle-income nation with a modernized economy and a strong identity. A plan called "Vision 2020" was developed by the national government based on a consultative process that took place in 1998-99. The plan addresses everything from economic and technological development to gender equality, education, and healthcare. Calling itself "an ambitious plan to raise the people of Rwanda out of poverty and transform the country into a middle-income economy," it asserts that it represents the bond of all Rwandans in sharing a common wish for a better future (*Rwanda Vision 2020,* 2000).

The Rwandan government has implemented a range of strategies in order to achieve the goals outlined in this document. Some are purely socio-economic in nature, but others affect the built environment and have had or will have an indisputably visual impact. In essence, these policies create a strategy of selective visibility for image control. This is closely tied to national pride, to a desire to move on from a painful past, and to the reality that Rwanda still depends heavily on foreign economic aid or investment. In the last two decades, Rwanda's government has had significant impact on the built environment, both through specific policies and campaigns as well as through the allocation of funding to prioritized projects.

2.0. THE PAST

Rwanda conversely has both pride in its strong historical traditions and a willingness to downplay or lose some of them in the pursuit of modernity. Certain historical aspects of Rwandan culture, such as the traditional *Intore* dance where males dress as warriors, are eagerly displayed to tourists and performed at public ceremonies. However, neither the government nor private citizens have demonstrated great interest in the conservation of built heritage. Some aspects of vernacular building, like traditional thatched roofs, are viewed as primitive, while the majority of buildings from the colonial era are seen as valueless except for the potential to recover scrap building materials. Furthermore, through exposure to other cultures due to both diaspora or exile and the increased presence of Western media in Rwanda, Western styles and ideas have slowly encroached on and replaced traditional facets of Rwandan culture.

2.1. Thatched roofing

As recently as three years ago, the hills of Rwanda were covered with thatched roof homes, but after a government campaign was launched in 2010, thatched roofing has nearly been eradicated (Fig. 1). Now the green hillsides glitter with shiny metal roofs (Fig. 2), changing the look of the entire landscape. The government has cited valid health and safety reasons such as mildew or the potential hazard of fire as justifications for the campaign, but it can also be surmised that the traditional way of roofing, which could potentially be viewed as primitive, would not fit in to the Vision 2020 image of a modern middle-income nation.

It is significant that this campaign was not in fact initially conceived by the government, but by members of the Rwandan diaspora. The campaign is rooted in the 4th Diaspora Global Convention hosted in Kigali from December 13-15, 2009 by the Diaspora General Directorate, a division of the Ministry of Foreign Affairs and Cooperation. Rwandans traveled from abroad to return to their motherland and find out how they could assist in the sectors of health, education, and culture. They visited the southeastern province of Bugesera and observed people living there in *nyakatsi,* or thatched houses. Dr. Ismail Buchanon, the executive director of the Rwanda Diaspora Global Network (RDGN), explained:

> We could tell from the first sight that they were not happy with their lives. So as the Rwandan Diaspora, we asked ourselves the question, 'What can we do to help our fellow countrymen living in such hard conditions?' Not conditions that they created but those caused by our past…. So we thought about this project called 'Bye Bye Nyakatsi' so we can get rid of those houses made from leaves. We also did this so we can fall in line with the Government's policy and vision because, as you know, our government aims at getting rid of leave houses by 2010. (*Bye Bye Nyakatsi* 2011)

Robert Masozera, the general director of RDGN, stated that the Rwandan diaspora "saw at firsthand how those houses are similar to bird nests" (*Bye Bye Nyakatsi* 2011). In fact, a common tagline for the campaign was "Nests are for birds, not people." After explaining how the small *nyakatsi* would shelter a family of five or six and their domestic animals without proper sanitation or access to clean water, Masozera asserted that as a result of the campaign to replace these houses with better houses, "certainly, this will be a modern community" (*Bye Bye Nyakatsi* 2011).

Figure 1: Traditional thatched hut circa 2001. Source: (Wikimedia Commons)

Figure 2: Contemporary metal roof on a typical rural dwelling today (2012).

In fact, an alternative to thatch has been developed in Rwanda since the 1930s. With the introduction of European styles of house construction during the colonial era, the traditional circular thatched hut was gradually replaced by rectangular houses with pitched roofs of locally-made clay tiles. These tiles are more waterproof than thatch, and as they are locally produced from an abundant material, they are fairly affordable. Some maintenance is required but spot repairs can be made as needed without replacing the whole roof. The use of clay tile also supports a local industry and provides jobs. However, the Rwandan government has virtually ignored the potential of clay tile roofing in favor of the promotion of corrugated metal roofs. As conservationist and architect Robin Kent has noted,

> In recent years, corrugated iron has become a common roof covering. Despite it being cold and noisy in the rainy season and rusting quickly in the tropical climate, the government is offering it free to replace thatch. Import duty has also been removed from steel and concrete to encourage development. (Kent 2011, 25)

Metal is the one element of many rural vernacular houses that cannot be made by hand. The most durable metal sheets must be imported from Europe, Uganda, or Kenya, while the ones that are made locally last only about fifteen years (Hatzfeld 2006). But metal is perceived as the most modern roofing material because it is synthetic, it is industrial, it is not hand-made, and it doesn't look like a bird's nest. And the visual impact of metal shining in the sunlight against the green hills is certainly more pronounced than clay tile would be. Visitors to the region remark that they perceive a visual contrast between rural Rwanda and adjacent areas of Uganda, right on the other side of the border, where thatch and clay tile are more common. The "Bye-Bye Nyakatsi" campaign has created a visual signifier of Rwanda's pursuit of modernity.

2.2 Colonial buildings

From direct observation, it can be inferred that Rwanda seeks to diminish and in some cases erase the memory of its colonial period. Many colonial Belgian buildings are being torn down, with the bricks reused in construction elsewhere. Many of these buildings were perfectly sound and it would be more economically practical to adaptively re-use them, but they are reminders of an era in Rwandan history that Rwanda is trying to forget.

For the better part of a year, I worked on a construction project in the rural district of Burera in northern Rwanda. We were building houses for doctors near a new district hospital. Our site had previously been a military post, but before that, it was a colonial farmstead. There was an old Belgian house on the top of the hill (Fig. 3). One day we came to site, and the house had been torn down into a large pile of bricks. Only the foundation of the building still remained in place (Fig. 4). We were quite surprised because, as the architects in charge of the site, we had thought the house was under our control. While it had sustained some damage from shelling during the war, it was a well-built structure made of quality bricks, and could potentially have been reused in some way. We suspected that the local district government had ordered the demolition of the structure, and the military had carried it out, without consulting us.

Furthermore, when we tried to use some of the bricks as flooring in a block production yard that we built elsewhere on site, the district ordered us to cease, as these bricks were still "district property." There clearly remained a desire for full control over this colonial building, even in its dismantled state. The demolition of it was an important symbol of power to the district government.

Figure 3: Colonial Belgian house (2011).

Figure 4: Only foundations remain (2012).

It is clear that colonial buildings, for most Rwandans, are a distasteful reminder of a period of history when colonial rulers subjugated indigenous groups and contributed to horrific ethnic conflict. President Paul Kagame noted in a 2010 speech in London that even after decades of post-colonial independence, nation-building in most African countries remained an “up-hill task” due to the “disruption and fragmentation of our societies caused by our former colonialists” (Kagame 2010). The desire to be rid of physical reminders of their colonial past may seem extreme, but it must be considered in the context of the long history of Rwanda. As literary theorist Aijiz Ahmad has observed,

> …in periodising our history in the triadic terms of pre-colonial, colonial, and post-colonial, the conceptual apparatus of ‘postcolonial criticism’ privileges as primary the role of colonialism as the principle of structuration in that history, so that all that came before colonialism becomes its own prehistory and whatever comes after can only be lived as infinite aftermath. (Childs and Williams 1997, 8)

Although Western scholars tend to study post-colonial African nations largely in terms of how they were affected by colonialism, Rwandans do not want to be defined by this limited view of their own history. They seek to demolish colonial-era buildings because Rwandans do not view this built heritage as “their” heritage.

In the official national policy on cultural heritage as outlined by the Ministry of Sports and Culture, there is no mention of colonial heritage (Ministry of Sports and Culture 2008). Currently there are no formal policies in place in Rwanda for the protection of historical colonial-era sites.

3.0. POVERTY

In addition to the selective disappearance of elements of built heritage, Rwanda’s government has also implemented a strategy of selective visibility in dealing with poverty. Without question, real efforts have been made by the government to lift Rwandans out of poverty, and many have been effective. The exemplary *Mutuelle de Santé* health insurance system is one such example. However, there are also shortcuts that have been taken in order to give Rwanda the appearance that it is leaving poverty behind faster than it really is. The Rwandan government understands the critical importance of image, of the way Rwanda is presented to outsiders, to its ability to receive these funds and move forward toward its goals. To stay involved, foreign governments and NGOs want to feel like they are assisting a country that is stable, uncorrupt, and demonstratively able to make good use of their funds for improvement. Thus Rwanda feels motivated to decrease the visibility of slums and increase strategic urban beautification.

3.1. Demolition

The high visibility of the urban poor is a difficult problem for the Rwandan government: the existence of poor neighborhoods in the capital of Kigali cannot be fully denied due to the hilly nature of the city, as the blighted areas can always be seen across a valley. However, urban design measures are taken to ensure they cannot be seen up close, as story-tall concrete walls painted with brightly-colored ads distract visitors and hide the slums from the eyes of drivers and passengers on the street. However, this is not the most drastic measure taken by the government to ensure the poor are not visible. On certain main boulevards in Kigali, entire neighborhoods have recently been razed, seemingly overnight. One way to make the poor invisible is to make them simply disappear.

The city government estimates that 70% of Kigali is presently ‘unplanned’ (City of Kigali, *Urban planning and land management use* 2008). There was no official property registry in Kigali until 2002 and no building code in Rwanda until 2007, and even after these were established, most residents were unable to register property because their plots did not qualify (being too far from a road and basic infrastructure, or too small) and/or were unable to build to code because the code-required materials were too expensive (traditional materials like adobe or wattle-and-daub were not acceptable). Furthermore, city regulations currently require Kigali residents to buy a house in a subdivision, so they cannot build their own house in a location of their choice (Ilberg 2008). These restrictions led to the existence of many informal settlements.

This community in the Kacyiru neighbourhood is a typical example of the informal settlements that are common in Kigali (Fig. 5). However, this one is actually visible from a major road, and located right near the American Embassy and several government ministry buildings. It should not have been a surprise, therefore, when it disappeared one day. Children used to run and play in the narrow spaces between houses, while chickens ran around and squawked. Then one day there was only dirt (Fig. 6).

Figure 5: Informal settlement in Kacyiru, Kigali (2011).

Figure 6: Same neighborhood, after demolition (2012).

The Vision 2020 plan calls for “Pro-Poor” growth and development, which seems important in a country that is 60% below the poverty line. Neighborhood clearance is discouraged by the Kigali City Master Plan of 2007. However, in my year in Rwanda, I observed no less than three major neighborhoods within the city proper demolished. This would seem out of line with official policy, but because land management and urban renewal are a lower level administrative duty, national policies are often violated (or interpreted creatively) to support particular agendas. Furthermore, there is an unexpected complacency of the Rwandan people toward expropriation. Its necessity is not widely questioned, and residents seem happy to receive any small compensation (Ilberg 2008). The long-term informality of their living conditions seems to resign them to their fate. While alternative housing on the fringe of the city is offered to the displaced residents, it is usually too expensive for them to afford, and most people end up going elsewhere, with some small sum of extra money in their pocket.

A major problem facing the Rwandan government is the conflict between land shortage (and the resulting need for centralization/decongestation) versus traditional settlement patterns. Rwanda has an ancient pattern of single dwellings scattered throughout the landscape on small farmsteads. Local identity was traditionally derived from one’s district and hill; the rise of *imudugudu*, or rural villages, is a fairly recent phenomenon that resulted from a national program to cluster rural dwellings (Ilberg 2008). Thus, the government is trying to convince people against their cultural instinct to cluster together in order to relieve pressure on the land and develop economic bases other than agriculture; however, it doesn’t want them to do so informally in the city where they could blight the vision for Kigali as a modern economic and political hub. By displacing people from dense urban neighborhoods, the government forces them to resettle on the margins of the city or the surrounding rural land, compounding the problem of too much density on the already saturated landscape. The demolition of urban settlements is obviously not a workable solution, and the government should aim to develop a plan to support urban density in a more acceptable configuration.

3.2 Beautification

Rwanda prides itself on the cleanliness and attractiveness of its capital city. Indeed, upon first arrival to Kigali, a visitor who has experienced other nearby capitals in Africa might be amazed at the litter-free streets, the well-manicured medians, and the roundabouts with their decorative fountains. However, Kigali and several other large towns and cities in Rwanda implement a selective beautification that is focused on the places and elements with the greatest visibility.

This discrepancy can be viewed easily by traversing the main boulevards of Kigali and then venturing one or two streets off the main road. A great amount of effort is put into the beautification of the main boulevards, with painted curbs, evenly spaced palm trees, and street lighting (Fig. 8). One could travel from the Kigali airport to a meeting at a large NGO or ministry, to a restaurant downtown and then to a hotel, and think that the whole of the city is paved like this. In reality, however, the side streets, which lead to the neighborhoods where most city residents actually live, are most often still dirt, with no street lights or sidewalks (Fig. 7). Riding down these streets in a car or on a moto-bike can be quite a bumpy ride. In the better cases, the dirt has recently been smoothed and compacted, and the road is wide enough to fit a vehicle. In the worst, the road is more like a ravine, and there is no access to some houses except on foot.

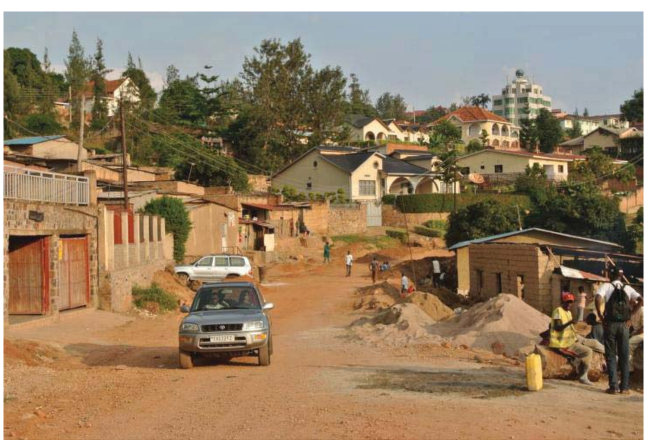

Figure 7: Typical dirt side street, Kigali (2012).

Figure 8: Main boulevard, Kacyiru neighborhood, Kigali (2012).

This selective beautification again ties to the government's need to encourage continued external aid and investment. Thus, the greatest effort is made in the places that will be seen and experienced by the typical NGO director, philanthropic donor, or political ambassador. This desire to sequester and dazzle the international visitor is evident in the master plan, which describes particular projects to be undertaken within several developmental zones within the city. The plan for Rebero, a neighborhood "on top of one of Kigali's hills with an exquisite view," is for it to undergo a "beautification process" to become an "alternative resort area" that will support "5-6 star exclusive hotels":

> With the growing influx of tourists and investors attending a variety of meetings, this will not only provide a peaceful environment away from home, but also a secluded area for key meetings that call upon a large delegation of participants. (City of Kigali, *Kigali Master Plan implementation projects* 2008)

The word "secluded" is particularly telling in this context. It is important for these visitors to perceive that Rwanda is succeeding with its funding, and that it is a stable and economically promising sink for aid money; thus they cannot see the slums or the poor, lest that image be dispelled.

However, there are also deep-seated cultural factors that affect this beautification strategy. Cleanliness and presentability are ingrained in the Rwandan consciousness, and personal image is greatly valued. This can be observed in the cultural tendency to dress fastidiously, and the pride with which formal dress is worn at ceremonies. The desire to present Kigali and Rwanda impeccably to outsiders is more than just an economic strategy; it also reflects the Rwandan culture.

CONCLUSION

It is important to reflect on the difference between official policy and practical action. Rwanda's formal visioning and master planning documents contain undeniably positive intentions, but they are not always carried out to the letter. This is due to many reasons including a complex administrative structure, but one of the main reasons is that as human beings, we tend to prioritize and understand best what we can see with our eyes. After the collapse of their country in the mid-90s, Rwandans now look to put the past behind them and seek pride in their current status as one of the most stable and progressive nations in this region of Africa. They want this progress to be visually reflected in the built environment. Although previously torn apart by ethnic divisions, the priority now is to develop a feeling of Rwandan heritage and pride that supersedes ethnic differences. Furthermore, while there is a goal to become self-sufficient, Rwanda still relies heavily on foreign aid and investment, which is dependent on image. With these considerations in mind, it is easy to see how these factors have led to an unwritten policy of selective visibility.

To reconcile both its long cultural history and recent turmoil, Rwanda seeks to simultaneously retain and re-define its identity, which is no easy task. Luckily, there is hope that in attempting to do so, it will continue to do so thoughtfully and critically. Alphonse Nizeyimana, the vice mayor in charge of finance and economic development of Kigali, recently told a room full of architects and engineers,

> If the ‘urban excellence’ vision is to be achieved, architects and engineers have an important role to play. Policy makers conceive plans, but you are the ones to realize their implementation. That’s why your support is highly needed. (Karinganire 2013)

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Transitional Space and Preschool Children's Play & Learning Behavior in Childcare Environment

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ABSTRACT: Research shows that the built environment influences children's behavior. A number of previous studies indicate that the indoor environment, as well as the outdoors, motivates children's activities. However, very few, if not any, empirical studies exist on the relationship between *in between* transitional space and children's behavior. Transitional space is defined by the interrelation between the indoors and the outdoors and is often described as an important space for children by researchers, educators and designers. This paper describes the methodology of a research design which aims at examining the claim of the importance of transitional space in children's lives with empirical evidence.

Case study research will be conducted in childcare settings on preschool age (3-5 years) children. The study will employ Behavioral Mapping as its primary data collection method and compare behavioral variances between indoor, outdoor and the transitional environment. Behavioral mapping provides the unique opportunity of measuring actual use of a site and capable of providing data for understanding the usage pattern of a space. It is, in fact, the only instrument which can make behavior *visible* in the context of a physical environment. *Play* and *learning* are the two observable behaviors of children in this study which are taken into account as dependent/measured variables. Visual analysis and statistical analysis of data gathered by behavioral mapping will be corroborated by qualitative questionnaire data analysis.

It is expected that findings of this research will demonstrate the value of transitional space for influencing certain play and learning behavior among children, which are restricted to or limited in indoor or outdoor environments. It is also assumed that the methodology described in this research will depict the ways of defining and measuring transitional space variables which are crucial from the perspectives of children's usage. Aim of this research is to influence design awareness and design policy for childcare environment.

KEYWORDS: transitional space, behavioral mapping, preschool age children, play and learning behavior.

1. INTRODUCTION

Throughout history, architecture has both accommodated and constrained behavior, and it is not surprising that there has been a considerable amount of discussion on behavioral research for architectural design (Lang, 1974). Schools, including care environments are among the four most influential environmental settings in the lives of the children alongside natural environment, home environments and neighborhood landscapes (Irwin & Joachim, 1978). How the architectural design of a school may influence the play and learning behavior of children is an emerging issue; both in the fields of design and environmental behavior studies. However, very few studies have provided empirical evidences on the relationship between architectural variables and children's behavior in childcare/preschool settings. Children have a decidedly different perception of architecture. Where adults perceive space more on form, function and aesthetic, children see the space more on its functions rather than aesthetic (Christensen, 2008). Research addressing the relationship between architecture and children's behavior, therefore, demands a different methodological approach. Early childhood institutes are much more than just institutes for education and care. Children spend most of their waking hours in such environments, and that should in itself prompt investigation into the impact the physical environment has on them (Martin, 2006). Educational research has focused on what is taught, and how it is taught, however, what has received too little attention is the physical environment in which education occurs (Sanoff, 2009). There seems to be a lack of research in educational settings that look into the school environment and children's behavior (Martin, 2006). Very few research studies have examined the role of transitional space on play and learning behavior of preschool children.

1.1. Why Transitional Space?

In this study, transitional space refers to any space which cannot be defined as an indoor or outdoor. An indoor space is formally defined by architectural enclosure like walls and roof and contains controlled environment. The outdoor on the other hand refers to the surrounding site area of the building which defines and contains the indoor environment. Transitional space lies between the indoor and the outdoor. There are few fragmented clues in thoughts and writings of researchers, reformists, designers and philosophers which impose importance of research on the relationship between transitional space and children's behavior. Revisiting those clues is of prior significance for this research. Perhaps the boldest statement on the importance of the transitional space in an early childhood institution is given by Olds in her famous book 'Child Care Design Guide' (2001). She has given specific instruction for providing a strong relationship between indoor/outdoor space in a childcare center and emphasized on making the most of a transitional outdoor space. She described transitional space as the suitable area for *messy* activities encouraging experimentation. Her ideas are incorporated in *Child Care Center Design Guide* by the U. S. General Service Administration (GSA) and they also provided guidelines for creating a stronger bond between indoor-outdoor space in a childcare center by providing well designed transitional space (GSA, 2003). Moore and Cosco emphasized on the importance of good transitional space in the school environment in their design approach (Moore & Cosco, 2007) undertaken for naturalizing the Montessori school grounds. They mentioned about the visionary interest in transitional space of Maria Montessori, the legendary physician and educator, best known for the philosophy of education which bears her name (Montessori system). Design of early examples of Montessori schools bears signs of her vision for using transition spaces for specific activities connecting classrooms to the outdoors. This is perhaps the earliest attempt to incorporate transitional space as an important aspect of design for motivating play and learning among young children. Moore and Cosco (Moore & Cosco, 2007) has further elaborated on the value of indoor – outdoor transitions of space and mentioned that where classrooms meet the outdoors are crucial areas, which demand designers intervention. Frost and colleagues in their work (Frost, Wortham, & Reifel, 2001) has also given importance to transition space for play behavior and mentioned that the best play and learning places for children flow between the indoor and the outdoor settings. The authors also emphasized on the need for more studies that would explore the relationship between transitional space and children's activities.

1.2. Why Play and Learning?

Play and learning are perhaps the two most influential observable behavioral outcomes of children that can be heavily attributed to the physical/environmental variables. In early childhood and preschool age, play and learning are often inseparable and closely knit to each other. Play is central to the process of socialization, and during these years children assimilate environmental experience and information through play which enhances their cognitive abilities. Play, is the central essence of childhood; one of the most essential criteria for healthy physical, social, emotional, and intellectual development of the child. Literature emphasizing the importance of play in lives of children seems to be an infinitive source over time. Beginning from the time of eminent psychologist Parten and Piaget, to the present day era of behavioral studies; researchers were univocal about the numerous developmental roles of play. Play contains all developmental tendencies and is itself a significant source of development. Children are at the highest level of development when they are at play (Vyogotski, 1978). Play contributes not only to the health and wellbeing of a child, but it is equally beneficial for his/her cognitive development, brain development, social communication skills, creativity and imagination. Many organizations have advocated for the important role of play in children's development. For example, the NAEYC, the leading organization of early childhood educators developed a position statement on principles of child development and learning that inform developmentally appropriate practice. The statement includes the item play as a powerful vehicle for children's social, emotional, and cognitive development (NAEYC, 2009).

1.3. Why Preschool Children and Childcare Environment?

Preschool age is defined as the age range from 3 years to 5 years (GSA, 2003). Between the ages of 3 and 5, children are still in their *play years*. Play is central to the process of socialization, and during these years children assimilate environmental experience and information through play (Narayan, 2010). In the perspective of child development, McDevitt and Ormrod (2002) posited that early childhood is a period of incredible fantasy, wonder, and play. They perceive the world as a forum for imagination and drama. That is they reinvent the world, try on new roles, and struggle to play their parts in harmony. Through sensorial and motor activities with peers and adults the children rapidly develop their language and communication skills. During these years, children assimilate environmental experience and information which enhances their cognitive abilities. Childcare has become an accepted aspect of childhood. Early care environments should be subjected to research, particularly as the child may spend the majority of his/her waking hours in a childcare setting (Goelman & Jacobs, 1994). Also, childcare environment is suitable from the observational methodology stance of the study because It is not as regularized as formal schools, therefore, provides researchers the opportunity of observing untaught and spontaneous responses of children to their surrounding environment. Childcare and preschools predominantly house children of 3-5 years of age.

2.

2. BACKGROUND LITERATURE

2.1. Defining Transitional Space

This study is particularly interested in transitional space in architecture which demarks the relationship between the indoor space and the outdoor space. Surprisingly, an elaborated search was unsuccessful in finding studies that have actually discusses the architectural aspects of such a relationship. Harle has emphasized on the uniqueness of transitional spaces which demarked the relationship between indoor/outdoor (1993). He has also said that these (transitional) spaces are more necessary for children and old people than for working adults.

More clearly stated definition of transitional space and indoor outdoor relationship has come from a design guideline for childcare center (GSA, 2003). They described transitions as to be the link between interior and exterior spaces such as a deck or open vestibule. From a childcare design point of view, transitional areas allow for a blend of interior and exterior environments and can function as a point of departure or staging area for play yard excursions. This definition is given prior importance because it directly addresses the need of such transitional spaces from children's point of view. This study tries to generate its own definition of transitional space consistent with the research perspective. Figure 2 shows how transitional spaces can be formed by removing defining elements (wall/s, roofing) of an interior and illustrates few of the possibilities of transitional spaces that may occur between the complete indoor and outdoor. The definition that will be used for *transitional space* is as followed

If one or more wall elements and/or the roof are entirely or partially removed to expose an enclosed environment to the outdoors, then such partially enclosed space becomes a transitional space. Examples of such transitional space are verandah, open vestibule, covered walkway, garden pergola etc.

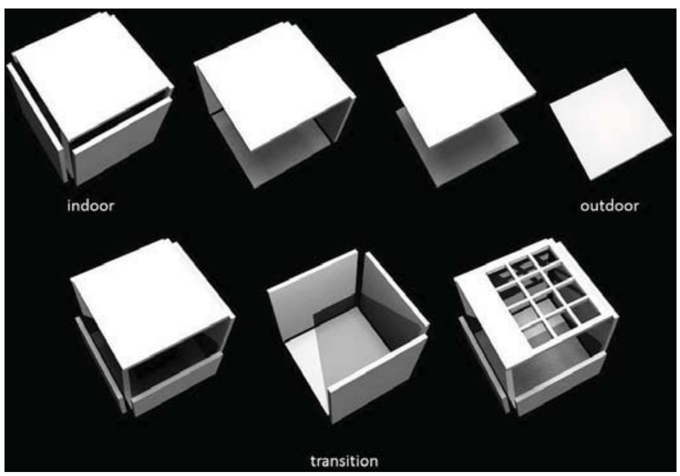

Figure 1: Transitional space can be any combination that lies between complete indoors to complete outdoors (author)

2.2. Extent Research and Their Findings

No research study was found which tried to establish the relationship between transitional space and children's behavior. This subsection tries to summarize similar research findings which have examined the role of certain built-environment variables on specific behavior of children (see Table 1). There are few studies which have examined the role of indoor or outdoor space on children's behavior. Sandra Home Martins review literature titled *The Classroom Environment and Children's Performance – Is There a Relationship* (Martin, 2006) was a good starting point which summarized findings of many previous studies exploring the relationship between various classroom (indoor) variables and the performance of children. The author in her discussion provided a classification of such variables based on the empirical findings and discussed them under four broad categories namely function, room organization, the ambient environment and other environmental factors. Indoor – outdoor relationship of space was absent from the list of the author. There is a good amount of studies which have established the importance of outdoor environment in lives of young children. The outdoor is the place where the diversity of the natural world is presented in all its sensory glory, and if the outdoor environment is sufficiently diverse, children and teachers can together ride the wave of motivation (Moore, 1996). In a study of 41 programs, it was found that in lower quality outdoor environments children engaged themselves in more functional and repetitive play while in higher quality outdoor environments, children showed a tendency to display more constructive play. As the quality of the outdoor environment decreased, the frequency of negative behavior increased (Debord, Moore, Cosco, Hestenes, & Mcginnis, 2005). One research showed that preschool children were more likely to engage in more complex forms of peer play (i.e., interactive and dramatic play) outdoors than indoors (Shim, Herwig, & Shelley, 2001).

Table 1: Literature list indicates a lack of previous research on transitional space for children

Indoor(classroom) environment & children's behavior	**Outdoor environment & children's behavior**
The Classroom Environment and Children's Performance – Is There a Relationship' (Martin, 2006)	The Preschool Outdoor Environment Measurement Scale Debord, K., Moore, R., Cosco, N., Hestenes, L., & Mcginnis, J. (2005)
Preschool Science Environment: What Is Available in a Preschool Classroom? (Tu 2006)	Childhood's Domain: Play and Place in Child Development Moore, R. (1986)
The Classroom Environment and Its Effects on the Practice of Teachers (Martin, 2002)	Preschoolers' Play Behaviors with Peers in Classroom and Playground Settings (Shim, Herwig, & Shelley, 2001)

2.3. Variables of Play and Learning

The research heavily referred the introduction of the book titled *Children's Play in Child Care Settings* by Goelman and Jacobs (1994) for understanding the complex range of variables of play and learning of children. A list of possible play variables in childcare settings is generated based on the discussion provided by this book (see Table 2). Some of these variables were considered for coding as other relevant variables of the study.

Table 2: List of other independent variables of play and learning

CATEGORY	**VARIABLES**	**MEASUREMENT**
Child Data	Gender, age, socioeconomic, familiarity with child care setting, average hours in child care	Observation + mapping/coding questionnaire
Environmental Data	Amount, novelty, types and realism of available play material	Systematic observation
	Crowding/density	Systematic observation
	Amount of open space	Systematic observation
	Space organization	Systematic observation
	Climate condition	Recorded data
Miscellaneous Data	Daily/weekly schedule	Questionnaire
	Caregivers' education	Questionnaire

(Based on *Children's Play in Child Care Settings* by Goelman and Jacobs)

3. THEORETICAL PERSPECTIVES AND RESEARCH QUESTION

At its conceptual level, the study will examine a relationship between the child's behavior and its environment. This relationship is mentioned as to be a reciprocal one in many studies (Björklid 1982, Moore 1986). For its conceptual base, this study revisits a fundamental concept in the field of Environment and Behavior of Children commonly termed as Ecological Psychology. Behavioral Setting by the eminent social psychologist Roger G. Barker emphasizes the reciprocity of the environment-behavior relationship and is considered to be a good fit for the study in hand. Behavior setting has been applied for decades as a useful construct in environment-behavior research. Behavior settings are ecological units where the physical environment and behavior are indissolubly connected. These eco-behavioral units were first described by Barker (1976). Behavior settings have a clear structure: they are located in time and space, they are composed of entities and events (people, objects, and behavior) and other processes (sound, shade, etc.), their spatial and temporal boundaries are identifiable.

3.1. Research Questions

The background literature leads the study towards its primary research questions. The study asks -*Why is transitional space in preschool/childcare architecture crucial for children's play and learning behavior?*
The study would try to investigate whether the transitional space accommodates certain level or type of play and learning activities among children which is not afforded in the other environmental settings (indoor or outdoor). The second research question would try to investigate the mechanism of the relationship between transitional space and children's behavior. The question is stated as - *How does a transitional space impact preschool age children's play and learning behavior?*
The study is also interested in learning about the qualitative values of transitional space and asks - *What is the value of a transitional space in the school/childcare environment of preschool age children*? It is expected that finding the answers of these three research questions would identify empirical evidence of the importance of well-designed transitional space.

4. METHODOLOGY

4.1. Research Design

The research will be conducted in two distinct phases. The first phase of the study adopts a single case study research design (Yin, 2003; Groat & Wang, 2002). The main theme of the study is to compare play and learning activities of preschool children between transitional space and other environments (indoor and outdoor). The research intends to learn from the differences of level and diversity of play/learning between transitional, indoor and outdoor environment in a child care setting. The case should be carefully selected so that the variation between outdoor, indoor and transitional environment is prominent and well defined. The second phase will be a multiple case study design. Behavior and activity data will be collected from different schools/childcare with varying degree of transitional spaces. Besides observational data from behavior mapping, this phase will also incorporate questionnaire analysis of teachers to understand how transitional space can become a crucial determinant for play and learning activities in early learning environment of children. Conclusions drawn from the 1st and 2nd phase of the research will be used to answer the 3rd question.

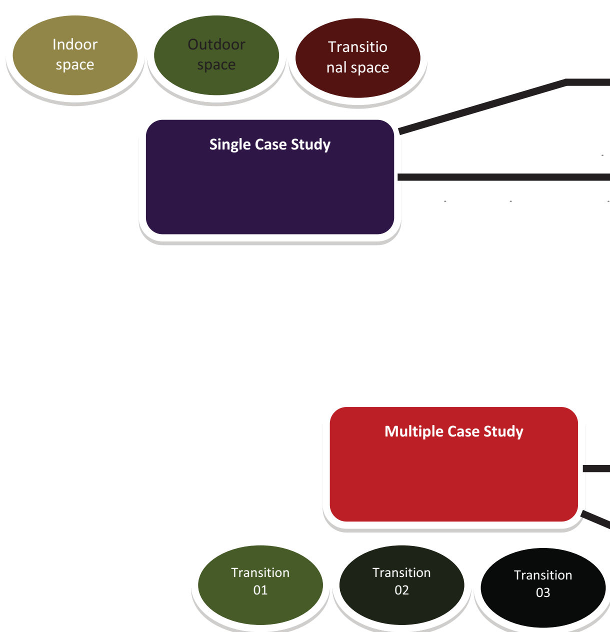

Figure 2: Methodology flow diagram

4.2. Dependent and Independent Variables

The two main dependent variables of the study are *Play* and *Learning*. Play will be measured in two sub categories – Play Activity Level of the child and Play Variance. Play activity will be measured by a modified CARS (Children's Activity Rating Scale) scale (Durant et al. 1993). The scale allows trained observers to record children's activity on a scale of 1 to 5 representing different levels of energy expenditure. Play variation will be measured by POS (Play Observation Scale) scale (Rubin 2001) which uses Parten (1932) and Piaget's (1968) classification of play. The POS proposes a comprehensive tool for observing play behavior of children. The tool provides a matrix of total 28 observable behaviors. Learning of a child will be coded as 4 distinct science learning activities – reading-writing, observing, exploring, and cause-effects. The key independent variable of the study is space type. It is a categorical variable with three possible values: indoor space, outdoor space and transitional space. The idea is to compare the measurements of the dependent variables among these three kinds of spaces in a childcare setting. For the second phase, the research will incorporate *transitional space* variables elaborated later in 4.3.2. This study will also incorporate the other important variables of play and learning as discussed in 2.3.

4.3. Data Collection

4.3.1. Behavioral Mapping

The method that is most comprehensively aligned with the concept of behavioral setting is known as Behavioral Mapping (BM). BM can be used to compare the use across sites (Cosco, Moore and Islam 2010) or within sites (Moore and Cosco 2007). It allows a researcher to measure or evaluate a physical environment in terms of activities and behavior. The philosophy highly matches with the purpose of the intended research. This research is interested in knowing the behavioral dimensions of a transitional space, not only the architectural ones. This is why behavioral setting as a conceptual ground carries immense importance for this particular study because it offers methods for defining an environment in terms of activity of children. Typical question being asked - *What dimensions are imposed to the environment by the behavior of its inhabitants? or what is the measurement of an environment in terms of behavior?* This question reflects a lot of similarities with the research questions of the intended study.

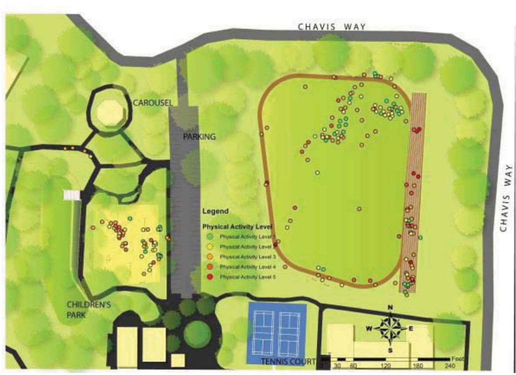

Figure 3: BM provides a researcher data about distribution of use by type of setting/site zone (author's own work)

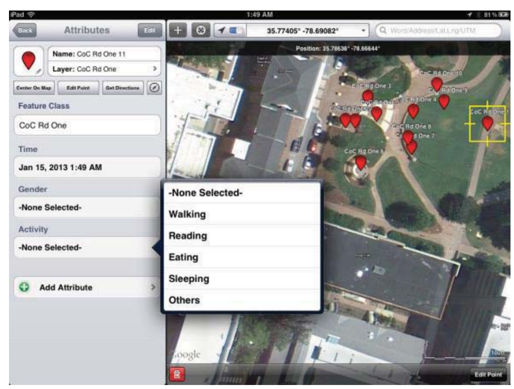

Figure 4: Latest advent of behavioral mapping by GIS Pro (by Garafa Inc.) allows simultaneous coding and mapping

Traditionally, behavioral mapping has two distinct parts – *mapping* allows a researcher to map the point location of the subject on a base map and *coding* records all the attributes of the subject. The *coding* part is flexible and designed as per the direction of the research question.

4.3.2. Transitional Space Measurement

Due to lack previous similar study, it was difficult to establish the measurement variables of a transitional space. Olds' (2001) famous book *Child Care Design Guide* gives a faint clue when it claims that a maximally effective transitional space should not be less than 6 feet deep and ideally should be around 15 feet deep. This research would use this clue, and a list of all possible architectural dimensions is listed in Table 3.

Table 3: List of transitional space variables

Indicators	Measurement
Total area of the transitional space	Direct measurement
Length-width proportion of the transitional space	Direct measurement
Amount of interlocking between indoor and outdoor space in the transition	Direct measurement
Height of the transitional space	Direct measurement
Enclosure type	Systematic observation
Roofing type (open/pergola/enclosed)	Systematic observation
Shading condition of transitional space	Systematic observation
Lighting condition of transitional space	Systematic observation
Color of enclosure/roof	Systematic observation
Materiality of the transitional space	Systematic observation
Vegetation	Systematic observation
Seating provision	Systematic observation
Availability of play equipment (novelty, type, amount)	Systematic observation

4.4. Data Analysis

Three types of unique quantitative data analyses are possible from data gathered by the overarching frame work of BM. They are Map Analysis, Map Overlay and Spatial Statistics. Qualitative Analysis will be conducted on data gathered by questionnaire survey.

CONCLUSION

Promoting play and learning by developing a childcare environment for preschool children requires empirical understanding on the relationship between childcare environment and children's behavior. The purpose of this research is to examine particular elements of architecture that are responsible for motivating play/learning behavior among children in a child care/preschool setting. It is expected that BM data will demonstrate behavioral variation of children in indoor, outdoor and transitional space of a childcare environment. BM data will also identify which design aspects of transitional space are most influential for behavioral outcomes. The researcher is aware of the constraints like tight schedule of a childcare institute which may hinder observation of spontaneous behavior in environmental variation; which is the key to the methodological innovation of the research. However, an early childhood institution provides more flexibility than formal schools and possibility of observing/coding spontaneous behavior is higher. It is assumed that this research will demonstrate empirical evidences for the importance of transitional space in motivating certain play and learning behavior among children which is not possible in indoor classrooms or outdoor playgrounds. It will corroborate the speculation of educators, designers and reformists (discussed in 1.1) with research evidences from the real world observation.

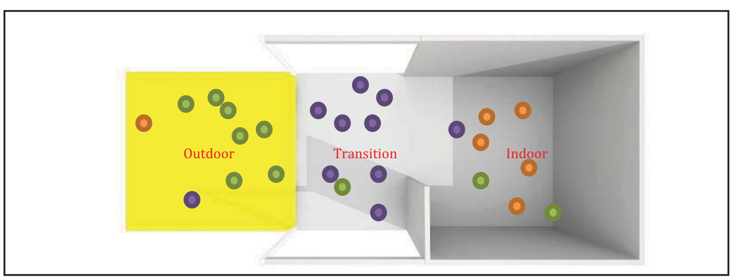

Figure 5: Hypothesis of the research expects behavioral variation in BM data among indoor, outdoor and transitional space (author)

Findings of this research may become a useful guide for designers, educators and policy makers because it has the potential of explaining the importance of certain architectural characteristics of early childhood institutions. The findings of this research should be able to contributing in design directives for childcare centers and preschools. The innovative methodology itself may become immensely useful for future research intended to unfold relationship between architecture and behavior because it applies direct observational techniques (BM) for delineating relationship between environment and behavior.

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SUSTAINABILITY

Visualizing Sustainability and Performance

Comparative Performance Evaluation of a Multi-story Double Skin Façade Building in Humid Continental Climate

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ABSTRACT: This paper focuses on investigation of a multi-story double skin façade system in the humid continental climate of Michigan. The double-skin façade is an architectural phenomenon driven by the aesthetic desire for an all-glass façade which aslo reduce building energy consumption. In this paper building envelope performance is investigated by modeling energy performance of different design scenarios of a commercial building with double skin façade and compare it with the actual energy consumption. The primary goal of this research is to clarify the state-of-the-art performance of DSFs in hot continental climate, so that designers can assess the value of these building concepts in meeting the design goals for thermal comfort, ventilation, energy efficiency and sustainability. This investigation adopts an analytical approach using dynamic simulation software (Energy Plus/Designbuilder), to understand the performance of single skin façade in comparison with a double skin façade. The results proved that the multi-story façade in humid continental climate had a major impact on enhancing performance and as a result, a reduction in energy usage.

KEYWORDS: multi-story double skin façade, energy performance, building envelope,

INTRODUCTION

The building facade plays an important role in achieving energy conservation. Due to technological advances, transparency and the use of glass has become an attractive envelope option in architectural design. Designing buildings with all glass facades provide external views and potential for an excellent level of natural light as well and natural ventilation.

However, with the use of glass, heat loss during the winter and solar gain during the summer will increase energy loads. In central Europe, which has moderate-to-cold climates, new concepts were tested that used outdoor conditions in creating climatic-responsive buildings (Givoni, 1998; Szokolay, 1980; Wigginton, 1996). Advanced facade technologies were developed for the high-end office building sector, in particular (Wigginton, 2002), and designers tried to integrate more building services into the facade system.

Transparency and the use of glass has also become an attractive envelope option primarily in buildings. The challenge is to improve building performance while providing a more comfortable and healthier place for users. Fortunately, there are numerous methods and techniques that can be employed to achieve these goals.

The concept of DSF is not new and dates back to many years ago where in central Europe; many houses utilized box-type windows to increase thermal insulation (Oesterle, 2000). Many authors claim that the double skin façade system can improve energy performance of the building due to the greater insulation provided by the outer skin. Design strategies need to consider the climatic conditions and local characteristics such as temperature, solar radiation, wind velocity and temperature in order to results in energy consumption reduction. The potential of using a double façade of the building in climates other than Europe has not been fully studied though. A number of interesting investigations and findings are reported in the literature pertaining to passive ventilation in buildings with double skin facades.

New enclosures that can substantially reduce energy usage by allowing natural ventilation is a promising development. Aesthetics aside, a double-skin facade (DSF) is believed to reduce cooling loads, allow for more or better natural ventilation, and provide natural ventilation in high-rise buildings. The aim of this study is to propose an effective way to reduce energy consumption in a building during cold and hot seasons in humid continental climate-of Michigan. Therefore, it will focus on how DSF works in such climates. The primary goal of this study is to clarify the state-of-the-art performance of DSFs, so that designers can assess the value of these building concepts in meeting design goals for energy efficiency, ventilation, productivity, and sustainability.

1.0 METHODOLOGY

One major goal of this study is to do a Building Performance Verification to compare the simulation result with the actual building energy consumption data provided in the unversity of Michigan webstie; and in doing that also checking the simulation tool capabilities. As suggested by Ternoey et al. (1985), the easiest way to evaluate energy improvements in building design is to appraise energy use patterns with a base case. For this purpose, the building has been simulated with single skin as a base case.

Then a parametric study was carried out focusing on energy use. The base-case scenario with double low-E pane windows was simulated to calculate the energy demand during the occupation stage. Then the same building with the DSF was simulated. Moreover, parameters such as different types of glazing, and cavity depth were varied to study the impact of energy use. This study is divided into three main parts:

- Development and simulation of the reference single-skin building
- Simulations of the DSF in terms of energy performance
- Simulation and analysis of the alternatives.

1.1. Base Case- model description

The five-story, 593,727 square foot, Biomedical laboratory of University of Michigan Ann Arbor integrates sustainable design features with innovative mechanical systems to reduce the building's energy consumption. Although the initial construction cost for the double skin façade buildings are higher than conventional, energy efficiency measures allow for lower operating costs and a greater long-term rate of return.

Nestled in the University of Michigan main campus in Ann Arbor, the Biomedical laboratory have 2 laboratory Blocks, Office ribbon towards south double-skin facade, Separated from the laboratory spaces by the Atrium, 300-seat Auditorium, and Vivarium.

Figure 1. Double Skin Façade Biomedical laboratory (image: Mona Azarbayjani)

The specifications of the project are:

-Double glass façade for full length of office ribbon. This passive façade includes a three ft wide space that provides a seasonal heating and cooling benefit to the building. During winter, dampers at the top of the double wall are closed. Heat from sunlight hitting the double wall is captured within this void, effectively reducing the heat load on the south face of the building. During summer, dampers at the top of the double wall are opened. Heat from sunlight hitting the double wall is flushed out via the stack effect, effectively reducing the cooling load on the south face of the building. And while the double glass façade is a cost-effective environmental design feature, it also produces a striking visual statement about the use of technology in a highly technical building.

-Multi-story thermal flux: the greater height improves natural convection and makes the heat capture and exhaust more efficient.

-Exhaust air energy recovery,
-Use of specialized fan-coils in linear equipment corridors where equipment that generates a great deal of heat is located,

-Use of special sensors that automatically increase the volume of supply air when higher-than-desired levels of carbon dioxide are measured in returned air (non-lab areas only, since all lab air is exhausted

-Extensive use of sensors and remotely-monitored control systems

Some of the building features are as follows:

- A Unique High-Performance Facade:

• The double-skin facade (two surfaces of glass, creating an insulated airspace) is a multi-story (full height), full depth (3'), thermal flue. The facade allows for complete transparency while ensuring protection from excessive heat gain, heat loss, and glare:

- Natural Light:

• The facade brings a significant amount of balanced natural light into the library, carefully controlled by fixed and movable sunshades.

- Natural Ventilation:

• Operable windows in the facade allow for fresh air throughout the year (even in winter). In the winter, spring and fall, the windows allow heat from the cavity to be brought into the building. During the summer month the cavity is ventilated to the outside as a external air curtain.

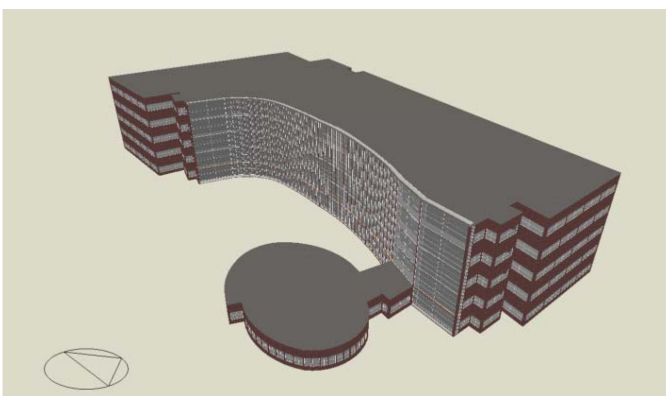
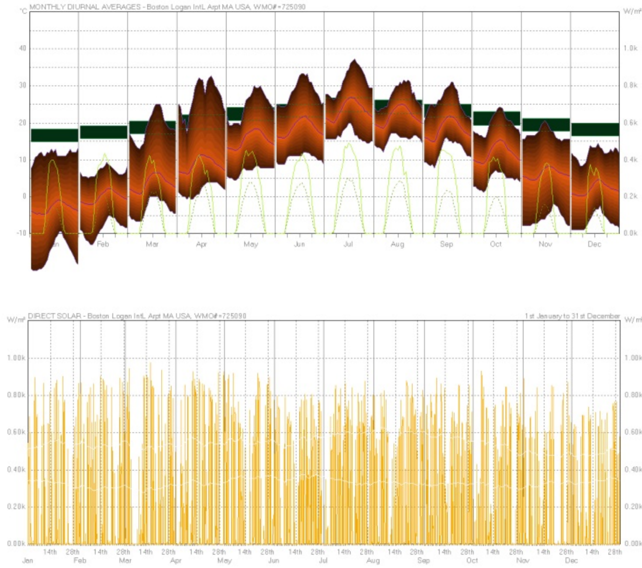


Figure 2. Model of the double skin façade building created in DesignBuilder

After obtaining basic building and weather data, a simulation of the building's energy performance was undertaken. This was the base case simulation for a single skin facade system. The simulation software used for this research was Design Builder with EnergyPlus as an engine.
Since the behavior of double skin facades is highly dependent on the type of climate, following sections outline a process for selecting the type, analyzing characteristics and properties and selecting strategies preferable for a specific context.

Components of the studied double skin included internal layer, composed of 6 mm clear glass pane, 20 mm argon filled gap and 6 mm internal low-e glass and aluminum frame with thermal breaks. External layer consisted of 6 mm clear glass. Components of the single skin were similar, with double glazing composed of 6 mm external clear glass, 20 mm argon filled gap, internal 6 mm low-e glass and aluminum thermal brake frame. Both cases included shading blinds, where in the case of double skin they were placed in the cavity, and for double glazing on the interior of the building.



The building will not only conserve significant amounts of energy, but it will also create a highly conducive environment for study and research while ushering in a new era of campus architecture focused on resource conservation.

Figure 3. Climate analysis, average temperature and solar insolation

The Michigan, Ann Arbor climate is classified as a humid continental climate (Koppen Dfb with areas of Dfa). Summers are typically warm, rainy, and humid, while winters are cold, windy, and snowy. Spring and fall are usually mild, but conditions are widely varied, depending on wind direction and jet stream positioning. The hottest month is July, with a mean temperature of 73.9 °F (23.3 °C). The coldest month is January, with a mean of 29.3 °F (−1.5 °C). The city averages 42.5 inches (1,080 mm) of precipitation a year, with 41.8 inches (106 cm) of snowfall a year. Most snowfall occurs from December through March. There is usually little or no snow in April and November, and snow is rare in May and October. Prevailing wind directions throughout the year are South-West and North-West.

1.2. Zoning

The plan was divided into multiple zones according to geometry, proximity, and use. Each zone was then assigned an activity template (indicated by color in images) which associate that zone with different energy profiles and schedules. As shown in figure 4, the zoning and schedules are often repeated floor to floor. The atrium is treated as one single zone inside DesignBuilder, with openings in the floor and ceiling of the corresponding floors connecting them. The building has 3 floors and a basement, and the zones are divided by the use of each one. We have 8 different zones, hall/lecture/assembly area, circulation area, display and public area, generic office area, reception, toilet, workshop-small scale, light plant room.

1.3. Model parameters and inputs for DSF

Please note the R-Value unit is h·ft²·°F/Btu and the U-value unit is BTU/(h °F ft²)

Equipment Gain: Open Labs = 10 W/sqft
[Diagonestic Imaging]
- Typical Alcoves = 20 W/sqft
- Tissue Culture Alcoves (65 total) = 30 W/sqft
- Entrance Alcoves = 10 W/sqft
- Procedure Rooms = 20 W/sqft

Linear Equipment Corridor = 30 W/sqft [zone 12, 19]
Office areas: 6 W/sqft
Lighting Energy: 0.050 W/sf/foot-candle
Display and Task Lighting: 2 W/sf

Widow area: 100% on the South facade, 30% over all

Glazing Type:
Exterior: Double Clear 3mm/6mm Air [U-Value: 0.568]
Interior: Double Clear 6mm/13mm Arg [U-Value: 0.449]

Construction Template: Medium Weight

External Walls: R-16
Roof: R-22
Ground Floor: R-16
Infiltration: 0.5 ac/h

HVAC Template:
VAV with fan-assisted terminal reheat, Ventilation: 6 ac/h
Heating CoP: 0.60
Cooling CoP: 1.30
Fuel: Electricity for Heating and Cooling

The default schedules for the laboratory activity templates were based on a 9 hr/day, 6 days/week operational schedule. Outside this time plug, lighting, heating, cooling and DHW loads would shut off.
However, being a collegiate facility, the Center maintains significantly longer hours. For this model the schedule was simplified to 14hr/day (8 am – 10 p.m.) 7 days/weeks. While this schedule does not reflect daily variation in office hours, it averages to the same number of operational hours per week. Modified schedules were implemented for public spaces, office spaces, and assembly spaces.

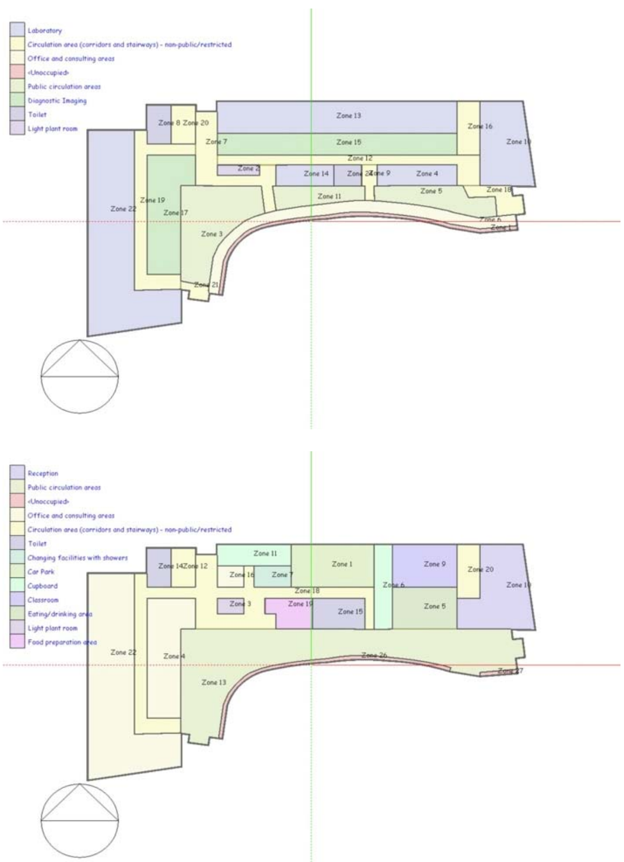


Figure 4. Zoning, model created in DesignBuilder

The hourly energy simulation shows the daily variation in system loads since insolation, air temperature and internal gains vary throughout the day. The cavity has been considered as a separate zone and it can be seen that the building systems are performing reasonably. The cavity, which is not heated or cooled, shows large temperature swings, high solar gains (up to ~1,500Kbtu/ hr) and high natural ventilation rates (up to 70 ac/hr) when the temperature rises above the set point. The interior zones, which are heated and cooled, have more stable temperature profiles, lower solar gains (~300 Kbtu/hr) and moderate ventilation rates (~ 2ac/hr). It can also be seen that internal gains follow the 8:00am – 10:00pm occupation schedule.

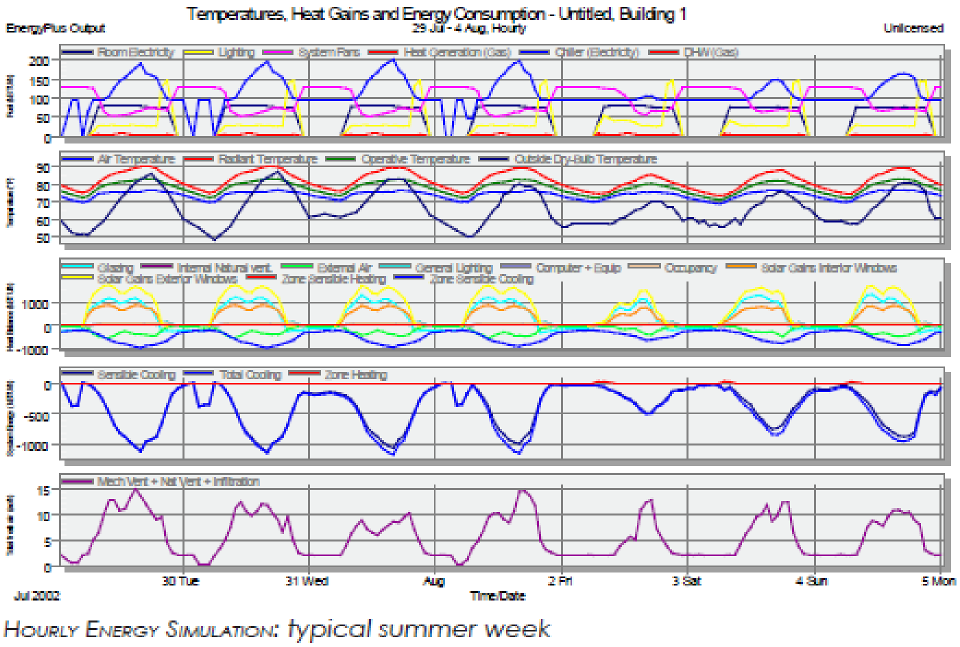


Figure 5. Hourly data on a typical summer week

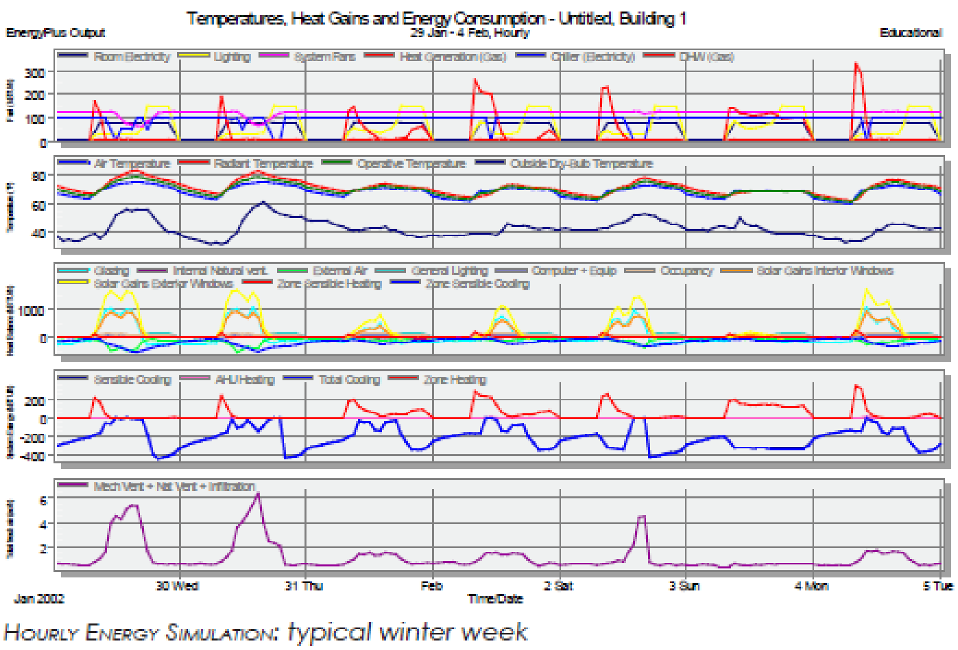


Figure 6. Hourly simulate data on a typical winter week

1.4. Results: Building performance and its consumption

Monthly energy results average the daily variation and shows how energy loads respond to season variations. It can be seen that lighting loads are reduced during the summer, as the days are longer and day lighting can meet a larger portion of the lighting need. There is also a reduced fan load during the summer month. However these savings are offset by a roughly 40% increase in cooling loads during the summer months and total electric load remain fairly constant throughout the year.

Figure 7. Double skin façade energy simulation results (Left side) Single skin façade energy simulation results (Right side)

The benefit of the double façade becomes apparent comparing heating loads.
The annual energy consumption of the double skin has been compared with single skin as illustrated above. It was discovered that in total double skin façade consumes 5 percent less energy than single skin façade.

One major goal of this study is to do a Building Performance Verification to compare the simulation result with the actual building energy consumption data. As illustrated below the modeled energy consumption and actual energy performance are within 10 percent range which is pretty accurate.

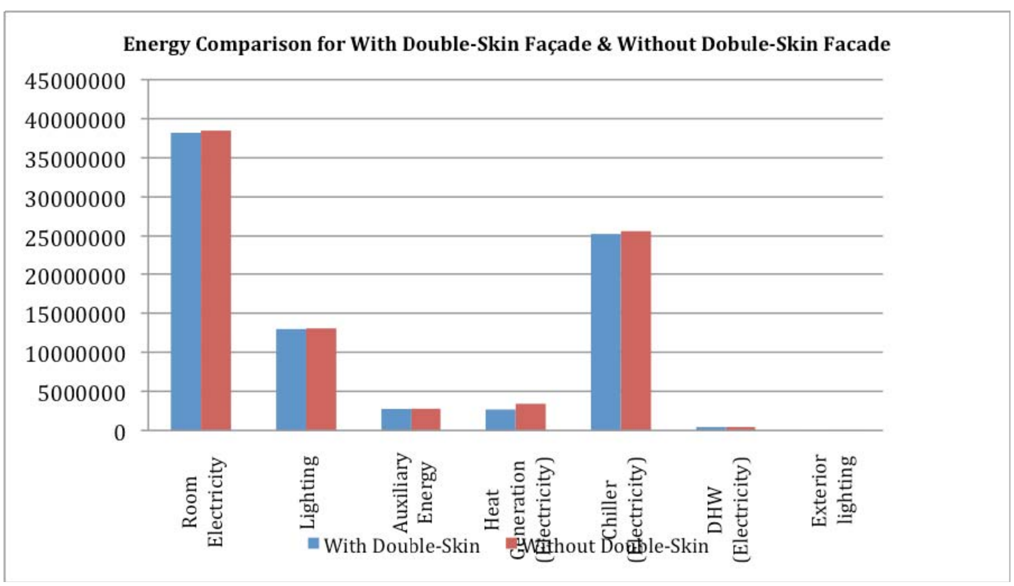


Figure 9. Total energy consumption comparison

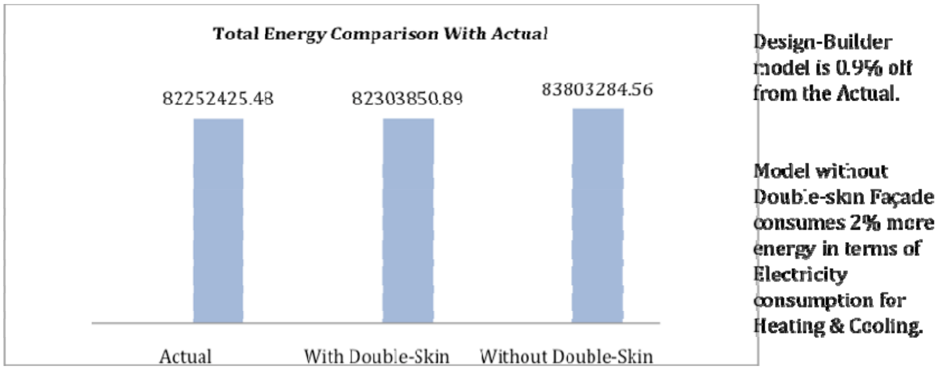


Figure 10. Annual energy breakdown comparisons [KBtus]

As illustrated in figure 10, Energy consumption can be reduced by about 5.4 percent after implementing double skin façade system.

CONCLUSION

In general, energy consumption in buildings is determined by function, climate, building components, construction, control, and settings. The climate and the ambiance are considered as-boundary conditions in energy simulation. Building function also has an important impact on energy use. Building components and construction both provide great potential for improvement of energy demand in such areas as adequate thermal insulation, a key component of energy consumption. A careful choice of windows and shading devices should help to avoid additional solar gains. Incorporating efficient HVAC equipment and heat recovery techniques may also reduce the energy use. Designing a high-performance facade system will make a tremendous impact in minimizing energy consumption and optimizing the thermal condition.

One major goal of this study is to do a Building Performance Verification to compare the simulation result with the actual building energy consumption data. Second, is to change building envelope properties in the simulation tool with keeping all the other input parameters as it is and check the effect of that for control of microclimates within this type of environment. These strategies include preferential glazing to admit or block insulation, appropriate location and orientation of spaces to introduce air currents within inhabited spaces, employment of passive strategies (ducts, wind towers and shafts) to promote circulation as well as heat extraction.
Energy savings are not so much but other aspects can justify the recourse to the double skin facade other than energy efficiency and that is thermal comfort in all glass façade building which is not in the scope of this paper.

For this climate, the main advantage is improved thermal insulation. During the winter months, exterior skin increases external heat transfer resistance, therefore utilizing interior air for preheating air cavity is advantageous. During the summer, air must be extracted in order not to cause overheating, by natural, hybrid or mechanical modes.

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A Standardized Case Study Framework and Methodology to Identify "Best Practices"

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ABSTRACT: A review of the literature reveals limited information on how to conduct a facility-based case study yielding useful information for architectural practice. In the wake of an "evidence-based design" movement, it is imperative for architects to think about case study research within a performance-based framework that links design decisions to measurable outcomes. Building on this premise, the objective of this paper is to argue for a standardized approach for case studies, present a framework and methodology providing guidance on how to conduct case studies, and conclude with an example. A six-step case study research process is presented including the purpose and activities for each step as well as possible deliverables. The authors claim that a standardized case study approach would allow for cross-case comparisons using a set of performance indicators. A desired end goal of case study research is to develop a facility database that could be used to inform the development of design guidelines, rules of thumb and "best practices."

KEYWORDS: case study, best practices, facility, methodology, primary care

INTRODUCTION

Clients are looking to architects for information, knowledge and the best possible design solutions when planning healthcare facilities. While architects are notorious for using case studies to capture building precedents and "best design practices", there is currently no publicly available resource in the architectural literature that captures facility case studies using a standardized framework and methodology. Therefore, it is not possible to systematically compare facilities across multiple cases. While architects may archive facility information from past projects, this historically has been proprietary information and not shared publicly. As a result, a client is limited by the expertise of one architectural firm. To address this knowledge gap, this paper proposes a standardized case study framework and methodology for facility investigations that allow for cross-case comparisons based on a set of performance criteria. Utilizing a consistent methodology and format will allow for the development of a facility database that could inform design guidelines. This paper is organized into three sections. The first section argues for the importance of a structured, performance-based approach to conducting facility case studies in architecture. The second presents a framework and methodology for conducting case study research including the approach, process and methods. In the third section, the proposed case study model is applied to a common healthcare building typology, primary care clinics.

A review of the literature on case study research in general provides useful guidance on how a facility-based case study might be conducted. Case study research has been defined as a strategy of inquiry, a methodology or a comprehensive research strategy (Yin 2009). Yin (2009: 21) suggests that case study as a research method, "offers a way of investigating an empirical topic by following a set of prescribed procedures." In comparison, Creswell (2007: 73) writes that case study research can be "a methodology, a type of design in qualitative research, or an object of study as well as a product of the inquiry. He continues to say that case study research is a qualitative inquiry where an investigator explores a clearly defined system (a within case analysis) or multiple defined systems (a cross-case analysis) using multiple sources of information such as interviews, observations, documents and artifacts. In addition, Punch (2003: 144) claims that case study research "aims to understand a case in depth in its natural setting, and recognize its complexity in the context." He continues to say it has a "holistic focus that aims to preserve and understand the wholeness of the case" (p. 144).

Depending upon the objective of the case study, the researcher often will conduct "purposeful maximal sampling" (Creswell 2005) leading to a "holisitic analysis" of an entire case or an "embedded analysis" of a specific aspect of a case (Yin 2009). Table 1 provides a brief summary of three types of case studies noted in the literature.

Table 1: Types of case studies

PURPOSE	CASE STUDY TYPES		
	Intrinsic	Instrumental	Collective
	Focuses on the case itself because the case is unusual or unique	Focuses on an issue or concern then selects one bouded case to illustrate a case description	Uses the logic of replication by using multiple bounded cases to discover case-based themes

Source: Adapted from Creswell (2007) and Yin (2003).

A PERFORMANCE-BASED APPROACH TO FACILITY CASE STUDY RESEARCH

The position the authors take in this paper is that case study research is an essential component to support client expectations toward evidence-based design (Ulrich, 2006), a widely accepted practice in healthcare. Case study research can include two levels of effort including a facility documentation phase only or it can also include a follow up Post Occupancy Evaluation phase as shown in Figure 1. It is argued that including both phases is a pre-requisite to understanding how the design attributes are linked to outcomes. This means that the primary thrust of a case study research effort is two-fold: 1). to *accurately capture and document facility information* (front-end thinking such as design goals and the physical environment); and 2) *identify the performance indicators* that can be used to assess the success or failure of the design decisions within a particular facility using Post Occupancy Evaluation (POE) approach (Preiser and Vischer, 2005). POE can be viewed as *a* follow up step to assess achievement toward the desired outcomes defined in a performance-based framework.

To develop this performance-based framework, performance indicators need to be identified from the research literature and include two types: *design attributes* (input indicators) and *outcomes* (output indicators) as shown in Figure 1. The first type of design attributes, *objective facility elements*, includes indicators such as size and type of space which are often captured using planning documents (i.e. space list) or from floor plan take-off calculations. The second type of design attributes, *design concepts*, includes how an architect translated ideas into a design solution with an objective of achieving a desired outcome (the output indicator). Design concepts are best identified from an interview with the professional architect of record or using an expert evaluation from a review of the facility drawings.

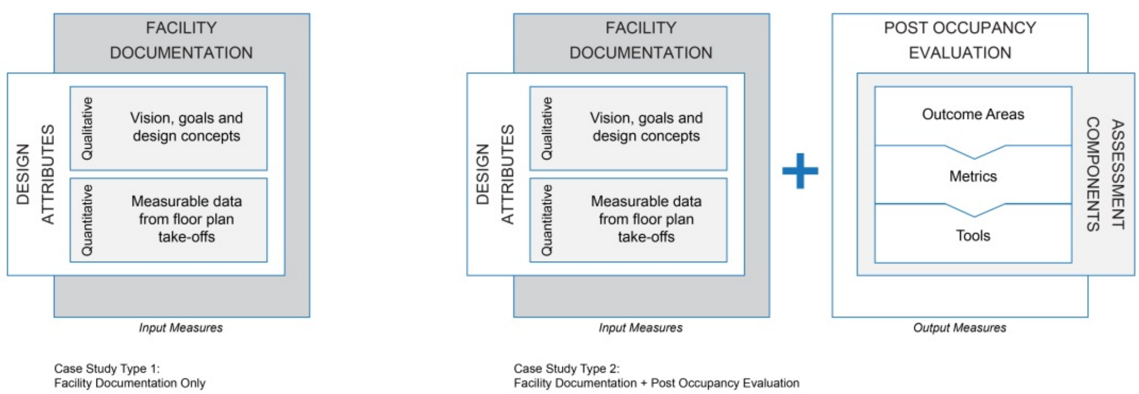

Figure 1: Two levels of effort for case studies: 1. Facility Documentation and 2. Facility Documentation plus POE

Facility case studies can be used for a variety of purposes including:

1. To understand current trends and eventually “best practices” in a specific department or facility typology whereby educating clients and project teams on current practices in the field.
2. To generate a modest performance-oriented data base from cross-case comparisons using a standardized approach.
3. To inform design guidelines and planning decisions for a facility type from the knowledge gained from the collective cases
4. To aid in conducting follow up facility assessments or POEs in two ways: 1. accurately document facility information in a standardized format, and 2. A collection of cases offers a peer group to compare findings from one case to other comparable cases.

One of the reasons that case study research is situated within a performance-based approach to facility design is to arrive at a more systematic way to determine “best practices” in facility design. “Best practices” in facility excellence cannot be objectively identified without conducting case study research using a standardized format (so each facility is evaluated based on the same criteria). Currently best practices are defined by “experts” recommending particular examples or cases to look at based on anecdotes, or suggested from findings from a research study or studies. In order to be deemed a “best practice,” there should be performance-based indicators based on established criteria packaged within a framework.

A collection of case studies can help answer the question, *What is Design Excellence?* If a client is seeking “Excellence” then it is important to define the performance indicators of success or what excellent is (the criteria, the metrics and the targets/benchmark). Then after the assessment or evaluation it is possible to determine if the facility achieved the established grade or score. The facilities that score high in the areas of interest (for example operational efficiency) would then be the facility “exemplars” that should set the bar for creating “Excellence” in operational efficiency. The criteria for categorizing “exemplars” might be organized into three distinct levels, for example: 1. *Good ideas*, peer review recommended facilities based on connections between design attributes and outcomes. The connections between design attributes and outcomes are not yet rigorously tested, but show indications of initial success; 2. *Promising practices*, have been systematically evaluated using limited indicators of success; and 3. *Best practices*, are evidence-based design practices that have proven outcome and process indicators of success, practices have been replicated and proven to be effective in multiple site examples.

The identification of facility benchmarks, i.e. the "Best of the Best" should emerge from case study research. These facilities should set the standard for their category and proven based on standardized indicators of success (and measured in the follow up POE). In case study research, considerable information can be collected off-site yet, the best ones that warrant additional study may undergo a site visit investigation to learn more about their design, developmental processes, policies and procedures, and organizational structure that have contributed to their success. Case study research can lead to the collection of "best practice" facilities and the factors that make them successful. The authors argue that a standardized performance based framework is a pre-requisite to determining “empirical-based best practices.” Best practices are high performing facilities that employ "evidence-based" design and operational approaches that can be replicated with the expectation that they will achieve similar results. The results from case study research can also inform the POE process by setting benchmarks for comparison value. The information collected for case studies can be considered a subset of the larger body of information collected for a POE.

There are many decisions that need to be made prior to conducting case study research. Below are three key decisions that need to be made: 1. *What resources are available to support the investigation?* Will it be a limited effort (involves off-site investigations only) or expanded effort (includes off site investigation and an on-site investigation). 2. *What is the scope of effort*? Will the entire facility be studied or a particular area or room within a facility? 3. *What is the level of the effort?* Will the case study research include one facility or multiple facilities (this allows for the case study comparisons).

In summary, the essence of case study as a research strategy is to “illuminate a decision or set of decisions: why they were taken, how were they implemented, and with what result” (Yin, 2003, p. 12; Schramm, 1971). This definition identifies “decisions” as the major focus of case studies (Yin, 2003). As a result, the objective of facility case study research is to catalog one or multiple facility sites within a building typology using a standardized format, methodology and pre-determined set of indicators. Accurately documenting and analyzing facility information is the focus of this effort. It should include quantitative objective information that can be pulled from existing floor plans, technical facility information and other documents as well as qualitative data such as themes and patterns (for example design concepts) that emerged from interviews, observations and other sources. Within the next section, the authors will present a proposed model for conducting case study research.

PROPOSED APPROACH, PROCESS AND COMPONENTS TO CASE STUDY RESEARCH

Within this section, the authors propose a model for conducting facility-based case study research informed by case study research design and methods literature (Yin 2009). The case study approach for systematically documenting a facility includes a six-step process as shown in Figure 2 below. For each step, why the step is important, the activities involved in the step as well as potential deliverables are presented. In the last section of the paper, the model is applied to an example of primary care clinics.

STEP 1 IDENTIFY CASE	STEP 2 DEVELOP STANDARDIZED FRAMEWORK	STEP 3 DEVELOP FACILITY DOCUMENTATION METHODOLOGY	STEP 4 COLLECT DATA	STEP 5 ANALYZE DATA	STEP 6 INTERPRET DATA AND WRITE UP RESULTS
Define Case Boundaries Select Case Site(s) Seek Approvals for Participation Request Site Specific Archival Data (Facility and Operational)	Conduct Literature Review Identify Design Attributes Identify Expected Outcomes (To Be Studied in Follow Up POE - If Applicable)	Identify Process and Logistics for Data Collection Efforts Develop Off-Site Data Collection Tools *Interview for Architect* *Floor Plan Take-Off* *Facility Diagramming* Develop On-Site Data Collection Tools (If Needed) *Walk Through Checklist* *Onsite Facility Verification* *Photographs* *Observations*	Conduct Off-Site Data Collection From Step 3 Conduct On-Site Data Collection From Step 3 (If Needed) Organize Data	Analyze Data From Single Case Base On Standardized Framework Analyze Data From Multiple Cases Using Standardized Framework to Discover Patterns or Themes Develop Diagrams to Visually Study Design Concepts Develop Data Tables For Quantitative Data Comparison	Compare Findings To The Benchmarks Or Standards In The Literature (If Available) Compare Findings To Other Case Studies That Used Same Methodology Develop Facility Guidelines If Multiple Cases Were Studied (Minimum Three) Write Up Lessons Learned

Figure 2: Six step case study process overview for facility documentation phase

Step 1: Identify Case. The end goal of this step is to identify a case and define the bounded system (or the specific boundaries of what will be investigated). For an architectural inquiry, a case often involves a setting and its phenomena and can range from a large scale community to a building type to a specific room or room element. In this step it is important to define the boundaries of the case and determine if a single case will be studied (within case study) or multiple cases (cross-case comparison). The boundaries of the case may be determined by a client request, a researcher or firm's interest or a funded research opportunity. If the researcher is unfamiliar with the case selected (such as a building typology), this step should include a preliminary review of the literature to gain a better understanding of the system, programmatic elements, and context. Another activity in this step is to identify eligible cases (and then *select a case or group of cases*) for the analysis. Once approval is granted by a site administrator, it is important to develop an archival data request with a list of facility and operational data needed to conduct the research.

Step 2: Develop a Standardize Framework. The end goal of this step is two-fold: First, identify the performance indicators linked to the case chosen from the research literature including design attributes and desired outcomes; and second, develop a standardized case study framework. A time consuming step in the case study project is to review the published literature to finalize the performance indicators. Published literature may be reviewed including design and research databases from various online and print sources (research articles, design articles, codebooks and planning books, organizational websites). Project specific information provided by the client should be requested and reviewed as well. The organizing framework used to study the cases should include key design attributes, outcome areas and corresponding metrics.

To help understand the terminology, definitions have been developed for these major case study components. First, *Design Attributes* are the elements that define the physical environment and can range from quantitative, objective attributes such as size of rooms and qualitative design attributes can range from design strategies (what should be done in the design as suggested in the literature) and concepts (how the architect solved the particular problem; a solution). Second, *outcomes* are the end results or consequence of an input measure (in this case the design decisions related to the physical environment). Desired outcomes are often voiced by a client or documented in the published literature. Outcome areas are an expansion of the outcomes to provide a filter that translates outcomes to architecturally significant areas of inquiry. Examples of design concepts are the separate circulation zone (concept) to optimize workflow efficiency (outcome area); clustering care pods (concept) to reduce travel distances (outcome metric); hierarchical circulation pathways (concept) to encourage access and wayfinding (outcome area). *Metrics* are ways to measure design attributes and outcome areas.

Step 3: Develop Facility Documentation Methodology. Facility documentation includes capturing up-front decision making, the architectural design and the key design attributes for a selected case. To document this information in a consistent manner (and allow cross-case comparisons), it is important to develop a methodology of *what to collect and how to collect necessary information for the case study analysis*. Therefore, the tools need to be developed and a logistic plan for data collection needs to be established.
Yin's (2009: 101-114) provides an overview of six sources of evidence commonly used in case study research including: "documentation, archival records, interviews, direct observations, participant-observation, and artifacts." These sources are often complementary and case studies often use multiple sources. Following his discussion of these sources of evidence, Yin suggests following three principles to help deal with problems concerning "construct validity and reliability of the case study evidence." (114). The

principles are: 1. Use multiple sources of evidence, 2. Crease a case study data base, and 3. Maintain a chain of evidence.
The authors suggest that case studies should include the development of a questionnaire and the completion of an interview with the architect and planning team of the project. The purpose of the interview is to solicit information from the architects on the design goals, drivers and solutions. A questionnaire should focus on identifying design concepts and related outcomes. The types of questions to be asked could be organized into two thematic sections: 1. Background facility information (such as project size, cost, timeline, challenges, and design process); 2. Design drivers and concepts related to the outcome areas for the facility overall and for the key areas studied. Finally, this step should include the development of a final report template that will eventually be populated with data collected from step 5 which will come from three primary sources: 1. information gathered from literature review; 2 take-off information from facility drawings and other archival information provided by architect or client, and 3. interview with architect. If a site visit is possible, it will provide opportunities to verify facility information, as well as collect new information from a photographic protocol or onsite observation.

Step 4: Collect Data. The purpose of this step is to implement the facility documentation methodology and tools developed during step 3. Thus this activity includes off-site and possibly on-site data collection efforts. The use of diagramming is a useful visual approach to capture qualitative data such as design concepts. In contrast, quantitative data is best represented using data tables and displays. Measurements such as area sizes, net to gross factors and travel distances collected from floor plan take-offs are examples of the types of data that are quantitative in nature and lend themselves for objective data tabulations and comparisons.

Step 5: Analyze Data. This step involves taking all of the data collected and organizing the data for an effective analysis strategy. The analysis strategy is dependent upon whether a single case is studied or multiple cases are studied. Likewise, whether the entire case is studied or a partial aspect of the case is studied. The type of data collected (i.e. quantitative data versus qualitative data) will determine the best way to analyze the data. To organize data, Miles and Huberman (1994) offer some helpful suggestions including collecting data, displaying data in different formats, and reducing the data down into manageable chunks in an effort to draw and verify conclusions. The strategy of coding data allows for establishing relationships and patterns that emerged from the data. Throughout the analysis, is important for the researcher to ask the following questions: What patterns and themes emerged from the data and how do these themes relate to the study questions? Are there any deviations from these patterns and if so how they are explained?
Qualitative modes of data analysis provide ways of discerning, comparing, understanding and discovering themes and patterns from the data collected. In quantitative analysis, there is an emphasis on comparing numbers and tabulating results. It is best to understand the complexity of the situation by using both qualitative and quantitative sources of data to triangulating conclusions. Finally, Yin (2009:136-160) offers five analytical techniques that are helpful during the data analysis step and include: 1. Pattern Matching, 2. Explanation Building, 3. Time Series Analysis, 4. Logic Models, and 5. Cross-Case Synthesis.

Step 6: Interpret Data and Write-up Results. The end goal of the final step is to synthesize all data collected and draw conclusions based on the evidence available. Findings from the analysis include case description for a single case and case-based themes for multiple cases to understand the complexity of the defined case. Once conclusions are presented it is important to support conclusions or claims with evidence collected from the case study investigation (and ideally use multiple sources of evidence to support conclusions). Themes and patterns that emerged from interviews or observations can be supplemented with quantitative data from floor plan take-off calculations, surveys, or technical readings to strengthen the argument. Developing a standardized report template is ideal particularly if additional case studies may be studied using the same methodology and framework. Data collected is used to populate the case study template and it should be organized around the performance-based framework.
Once the case study research is completed, it is possible to compare the case to determine how it performs among peers based on the established indicators as shown in Table 2. The data collected from the aforementioned steps can lead to the start of a modest data table that allows for comparisons with similar facility types or with recommendations from the literature. Once the POE is conducted, or there is evidence to support a positive relationship between the design attributes and outcome area, then best practices can be concluded.

Table 2: Deliverables from facility documentation and facility performance evaluations case studies

CASE STUDY TYPE	TYPE OF DATA	FACILITY DOCUMENTATION	FACILITY PERFORMANCE EVALUATION
Single Case	*Quantitative*	Unique Space Allocation and Use	Impact of Space Allocation and Use On Expected Outcomes Within Case Studied
	Qualitative	Unique Design Concepts	Impact of Design Concepts On Expected Outcomes Within Case Studied
Multiple Cases	*Quantitative*	Common themes and Patterns in Space Allocation and Use Across All Cases Studied	Patterns Demonstrating How Space Allocation and Use Influenced Expected Outcomes Across Cases Studied
	Qualitative	Common themes and Patterns in Design Concepts Across All Cases Studied	Patterns Demonstrating How Design Concepts Influ-enced Expected Outcomes Across Cases Studied

APPLYING THE CASE STUDY RESEARCH MODEL TO PRIMARY CARE CLINICS

The example selected to apply the case study research model is a primary care clinic. This building typology was selected for two key reasons: outpatient clinics are the fastest growing segment of healthcare spending and second the authors have conducted numerous case studies on this building type. In this final section of the paper, the authors illustrate the steps with examples. Due to length restrictions of this paper, these steps have been abbreviated.

Step 1: Identify Case. An outpatient healthcare clinic was chosen to study since it is the fastest growing segment of healthcare spending. According to a 2011 National Center of Health Statistics (NCHS) report, there were 1.2 billion ambulatory care visits in the United States in 2007, with 48.1 percent of these visits being to primary care physicians in office-based practices (Schappert & Rechtsteiner, 2011). The rising demand for primary care services is influenced by demographic changes, including an aging population expected to increase from 12.7 percent of the total U.S. population in 2008 to over 20 percent of the total U.S. population by 2050 and a rise of chronic conditions prevalent in this population (Mann, Schuetz, & Johnston, 2010). Despite this growth, there remains a paucity of empirical research on the architectural performance of these healthcare settings (Preiser, Verderber, & Battisto, 2009). Furthermore, there is limited availability of guidance tools that can help inform future healthcare design decisions.

Once the case type was selected, the authors reviewed the research literature and other published sources to identify: outcomes and design attributes. Additionally, the authors sought out ideal facilities that would be a good fit to study the relationships between the outcomes and design attributes. These example facilities may be identified from experts, published literature or client testimonials. Once a facility was selected (or groups of facilities selected), the authors contacted the project designers and client (in this case the healthcare systems) to request digital floor plans and operational facility data. It is important to note that, facilities that would provide electronic floor plans and pledged cooperation with the research team were considered for this study. Digital floor plans are required for accurately documenting facility information.

Step 2: Develop a Standardized Framework. After the research literature was reviewed and interpreted, the authors decided upon four main outcomes and ten outcome areas for the case study research on outpatient clinics. Additionally, a broad set of design attributes were generated and then short-listed based on literature findings. Following the synthesis of the research and design literature, the authors worked toward operationalizing a case study research framework for primary care that included key design strategies that have been positively linked to the identified outcome areas. Utilizing these key components, a standardized case study evaluation framework was developed. The key design attributes aimed at documenting the physical characteristics of the facility and connections to outcome metrics allowed for comparing multiple cases across a standardized set of evaluation criteria. Table 2 illustrates the proposed case study framework for outpatient clinics.

Table 2: Performance-based case study framework for primary care clinic

OUTCOMES *Measuring Performance*		KEY DESIGN ATTRIBUTES *Facility Documentation*	
Outcomes	**Outcome Areas**	**Design Strategies:** *Qualitative data*	**Objective Design data:** *Quantitative data*
Positive Experience: *The overall patient, family and staff experience within the facility.*	• Aesthetics and amenities • Access and way-finding • Patient and family privacy, comfort and control	• Access to daylight and views in public and patient care areas • Patient and family amenities throughout the facility • Access to patient care areas • Privacy accommodations in patient care areas • Comfort of family accommodations	• Percent of rooms with access to daylight • Waiting and Patient Care Areas space allocation • Pathways and Travel Distance
Operational Efficiency: *The extent to which time and effort is well used.*	• Workflow Efficiency • Functionality • Flexibility and growth	• Clear organization of office, clinical and provider zones • Separate patient and staff circulation patterns • Direct access from staff work areas to patient care areas • Functional layout of the clinic for efficient work processes • Functional layout of the patient care areas for delivering effective care • Flexible and adaptable spaces to accommodate new technologies and changes in care delivery practices	• Net-to gross factors • Department zones space allocation • Room zones space allocation • Movement and travel distance
Clinical Effectiveness: *The quality of care rendered within the healthcare setting.*	• Effective communication, collaboration and connectivity • Staff Support Areas • Safety and Infection Control	• Layout of patient care areas to promote communication between patients, family and staff • Spaces available to coordinate care among staff • Spaces available for staff training and education • Clear visibility lines • Compatibility of electronic systems and medical devices	• Percent of total clinic area for staff collaboration, training and education • Visibility lines from staff work areas • Travel distance from staff work areas to patient care areas
Healthy Environments and Sustainability: *The relationship between the physical environment and environmental impact.*	• Environmental Stewardship	• Implementation of green design initiatives to encourage a therapeutic and sustainable environment	• Technical details of the facility related to energy, water, air quality, etc.

Step 3: Develop Facility Documentation Methodology. The facility documentation protocol developed by the authors for primary care included a standard methodology to capture and diagram the key facility attributes across the four outcome clusters and the ten outcome dimensions. For example, the measurement protocol included a standard methodology and specifications for conducting floor plan take-offs in a systematic manner informed by the metrics. For example, when measuring travel distances, a departure and destination point needs to be articulated; when measuring room area sizes consistency in the room boundaries are established. This will ensure the measurements are conducted consistently across cases to allow comparison based on similar parameters.

Additionally, in order to package the cases in a consistent manner a template was developed that was later populated with project specific information generated from the completing step 4. The proposed template is organized by performance outcome and dimension category. It includes the facility documentation diagrams, the measurements guided by the performance metrics, metrics for comparison and a description of the key design attributes identified through floor plan analysis. The diagrams allow for comparison of design concepts across cases. As a result, the use and implementation of a template will allow capturing the same level of information for each case used for cross comparison. This step included the development and execution of the following tools noted in Figure 4.

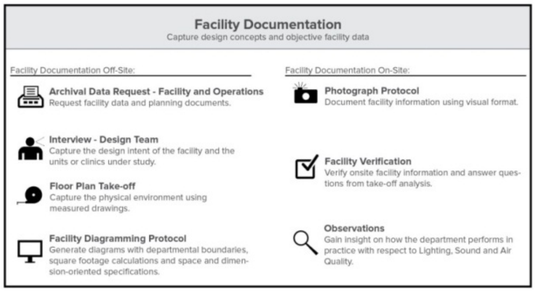

Figure 4: Facility documentation methodology

Step 4: Collect Data. After the research team completed all of the tools, methodology and logistics for collecting the data, they executed the case study research. Data was collected from the various sources including floor plan take-off calculations from drawings, photographs taken onsite, interviews with the design team. Each case study included background information such as facility location, setting, size, types of services and overall operational data such as daily patient encounters. In addition, the case study research report included an analysis of the facility by the ten outcome areas identified in Table 2. After each case was completed, all cases were compiled into a single format to allow comparison across cases based on the standard set of evaluation criteria.

Step 5: Analyze Data. The data collected from the various case studies are often displayed in different formats in an effort to establish patterns across the cases studied. Figure 6 illustrates a pattern that emerged concerning circulation hierarchies across four clinics when studying access and wayfinding as well as workflow efficiency.

Figure 5: Circulation Hierarchy Design Concept

Step 6: Interpret Data and Write-Up Results. To conclude the case study research, the authors conducted a comparative analysis of the two design attribute types organized around each outcome area. First a data table was generated that compared the objective, quantitative metrics across all cases and then compared findings to recommendations from the literature particularly national standards of leading authoritative guideline sources e.g. *FGI Guidelines*, *Whole Building Design Guide*, *SpaceMed*, etc. A rule of thumb was then produced that was the result of an interpretation from the case study findings in relation to the recommendations from the literature review. *Trends may include things such as programmatic areas and elements, space allocation, space adjacencies, travel distances, net to grossing factors and design concepts*. The authors identified various data elements for comparison across cases including overall space planning criteria such as DGSF per provider, DGSF per exam room and net to gross factors; room area sizes for exam and treatment rooms; and operational planning criteria such as number of exam room per providers and daily visits per provider. An example of a simple data table example is shown in Figure 6.

CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	Comparable FGI	Rule of Thumb
Number of Exam Rooms: 6	Number of Exam Rooms: 16	Number of Exam Rooms: 37	Number of Exam Rooms: 80	Number of Exam Rooms: 36	Number of Exam Rooms: N/A	Number of Exam Rooms: N/A
DGSF per Exam Room: 645 DGSF	DGSF per Exam Room: 375 DGSF	DGSF per Exam Room: 305 DGSF	DGSF per Exam Room: 600 DGSF	DGSF per Exam Room: 575 DGSF	DGSF per Exam Room: Not Avail.	DGSF per Exam Room: 450-600 DGSF
Exam Room Size: 120 NSF	Exam Room Size: 105 NSF	Exam Room Size: 106 NSF	Exam Room Size: 110 NSF	Exam Room Size: 120 NSF	Exam Room Size: 80 NSF	Exam Room Size: 110-120 NSF
Treatment Room Size: 150 NSF	Treatment Room Size: 180 NSF	Treatment Room Size: 169 NSF	Treatment Room Size: 138 NSF	Treatment Room Size: 195 NSF	Treatment Room Size: 120 NSF	Treatment Room Size: 140-160 NSF

Full Time Primary Care
Rotating Surgical Specialty Care
Rotating Diagnostic and Treatment Modalities
Full Time Medical Specialty Care

Figure 6: Cross-case comparisons and related standards

Second, a set of the common design concepts that were employed within the cases studied were presented and compared within each outcome area. Any empirical evidence that demonstrated a relationship between the design attribute and outcome area provides justification for best practices in architectural design. The end goal of this step is to work toward translating findings into useful design guidelines or “rules of thumb” to aid with new projects outpatient care. Below is an example of the cross case analysis conducted for the five selected clinics.

CONCLUSIONS

The authors argue in this paper for a standardized case study research approach for the discipline and practice of architecture. The standardized approach should be anchored within a performance-based framework. Building upon the literature on the case study research design and methods, the authors propose a case study approach that involves two levels of effort: 1. Facility documentation case study research only and, 2. A follow up Post Occupancy Evaluation of the facility if time and resources permit to measure the efficacy of the design concepts in relation to desired outcomes. A six-step facility-based case study research process is presented in this paper building upon the premise that a standardized case study methodology and framework are needed. These are needed to encourage the replication and comparison of facilities using a set of shared performance indicators (facility design attributes and measurable outcomes). Utilizing a standardized framework and methodology would enable similar facilities to be compared to each other. Likewise, it would help architects to identify “best practices” in facility design that are informed from a systematic process and comparable criteria. Finally, the authors claim that case study research could produce a facility data base that could be used to help inform evidence-based planning and design guidelines.

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Improving Energy Retrofit Decisions by Including Uncertainty in the Energy Modelling Process

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ABSTRACT: Currently, many investment decisions concerning energy retrofits are made directly based on the outcomes of energy simulations. However, there are various uncertainties inherent in the energy retrofit assessment process, both at the energy simulation and life cycle cost analysis (LCCA) levels, which can result in inaccuracy of energy performance forecasts and therefore, inappropriate investment decisions.
Through a case study, this paper presents a procedure for deriving and including the uncertainty associated with various factors in energy retrofit option assessment and clearly demonstrates how to generate probability distributions for final financial outcomes required for investment decision-making such as Net Present Value (NPV) and Internal Rate of Return (IRR). These distributions provide decision makers with more insight into the risks associated with achieving the expected outcomes. The simulation process proposed in this paper could be used by modelers to improve the level of confidence associated with simulation outcomes and enhance the quality of investment decisions concerning energy retrofit.
An existing office building is selected and multiple calibrated energy base models are developed to evaluate a combination of lighting controls as a new energy retrofit option. The paper demonstrates the calibration process of the base models and a LCCA of the lighting controls package. Analysis was conducted to examine how evaluating retrofit options with multiple base models could impact the financial outcomes and improve the final investment decisions. The financial metrics are compared with the results of modeling using a single base model. The results show that this approach could have the potential to and may alter a retrofit decision from ‘no go’ to ‘go’.

KEYWORDS: Energy Retrofits, Energy Simulation, Investment Decision-making, Risk and Uncertainty

INTRODUCTION

As summarized by Bozorgi and Jones (2010), evidence suggests that there is inaccuracy/error associated with energy modeling forecasts and in some cases the models are not a good predictor of project energy performance (pp. 3/15-13/16). The accuracy of model prediction is greatly dependable on the accuracy of inputs. In the context of existing buildings, the level of uncertainty associated with simulation inputs is typically higher, because the systems may not performed as they specified or designed. Therefore, there is always some uncertainty associated with projecting the energy use based on design assumptions. It is critical for decision makers to consider the inaccuracy/error of modeling forecasts to avoid overestimating or underestimating the building energy performance (Bozorgi & Jones, 2010).

In this analysis, ranges and probability distributions are suggested to be used instead of single-point estimates in order to introduce various sources of uncertainty and articulate the risks associated with achieving the expected energy performance outcomes. By providing more insight into risk, the proposed process will improve the reliability of energy modeling outcomes and also the confidence level of decision-makers in their decision-making process. As a result, the quality of investment decisions concerning energy retrofit options will increase (Bozorgi & Jones, 2010).

Calibration of a base model is a critical part of the simulation process of existing buildings for the purpose of evaluating energy retrofit options. Existing buildings are typically modeled based on the necessary data and information obtained from available plans and construction details, specification books, and operating schedules. The results of initial simulations usually indicate that despite the careful attention in creating the models, the actual measured energy use is different from what was projected by models. This discrepancy is primarily due to the significant uncertainty or error associated with the simulation inputs (Pan, Huang, & Wu, 2007, Westphal & Lamberts, 2005).

Accordingly, through conducting a case study on an existing office building, this paper aims to derive the various sources of uncertainty inherent in the energy retrofit analysis and numerically demonstrate a procedure for including those uncertainty factors into the modeling process in order to communicate more reliable outcomes to the decision-makers. The analysis shows how various potential risk and uncertainty might impact the final financial outcomes, and therefore, the investment decisions. The paper present a calibration process and explains how to create a reliable model to serve as a base case for evaluating the energy performance and generating distributions of energy performance indicators, resulting from selecting a new retrofit option. It also describes a LCCA process of the selected retrofit option and demonstrates how to generate distributions of financial performance indicators such as NPV and IRR.

Unlike the common practice of calibration, this study developed multiple acceptable base models for evaluating the selected energy retrofit option to account for inaccuracy of base models in generating the distribution of outcomes. Energy retrofit options are typically evaluated based on a calibrated energy base model. The acceptability of these base models are determined based on their forecasts error indicators. However, there might be several base models within the acceptable ranges that have different inputs, outputs, and error indicators. These base models could produce different outcomes when evaluating the performance of new retrofit options due to interactive modeling effects of retrofit options inputs. Thus, a sub-analysis was conducted to compare the estimated financial outcomes with the results of modeling using a single base model. The hypothesis here is that considering the inaccuracy of a base model could improve the level of confidence associated with simulation outcomes and enhance the quality of investment decisions regarding green retrofits. This analysis tests this hypothesis towards the broader goal of assisting decision-makers to make more informed decisions about investing in green retrofits. The results explain whether or not the impacts of modeling new retrofit options using different base models are significant enough to encourage modelers to put extra time and effort into running additional simulations.
It is important to note that this paper is mainly concerned with demonstrating the process of calibration and generation of distributions of outcomes and not the accuracy of final numeric results. The accuracy of outcomes is limited to the quality of assumptions and information that was obtained through literature, researcher's professional judgments, expert interview, and questionnaires.

1.0. ENERGY SIMULATION AND CALIBRATION PROCESS

As mentioned earlier, a thorough calibration process requires on-site measurements, surveys and interviews with occupants, etc. However, in this case study, the model was made as reliable as possible based on the available drawings and interviews with the owner representative and the property manager. No measurement or experimental study was performed for collecting the actual data other than actual utility records. The subsequent steps were followed in order to arrive at a reliable model:

1) The initial model was set up in eQuest (QUick Energy Simulation Tool) based on the data collected from the architectural and mechanical drawings, construction details, researcher's visit, pictures, and interview with the owner representative who was also an occupant in the building. The annual and monthly electricity consumptions were calculated based on the initial model. The building is all electric and there is no gas usage. A Typical Meteorological Year (TMY) file was used in the simulation process and not the actual weather file of 2009 for which the modeled consumptions was compared with. This could be one of the sources of inaccuracy associated with modeling outputs.

2) The actual annual and monthly electricity usage (KWh) was gathered by looking at 12 months of electricity bills in 2009. Adjustments were then made to those estimates in order to correspond to the calendar months. Utility records are not normally first of the month to last of the month, the simulation outcomes from energy modeling, however, are first of the month to last of the month. Two possible procedures for dealing with this include: if available, sum the daily simulation values to correspond to the measured records; or normalize the measured records to correspond to the simulated monthly values (weighted average approaches). This could be another potential source of inaccuracy associated with the modeling outputs. In this case, the weighted averages of actual electricity records were estimated to correspond to the calendar months.

3) The actual weighted average electricity usages were compared with those predicted by the simulation model, and the annual and monthly Mean Bias Error (EER) % and Coefficient of Variation of the Root-Mean-Squared Error (CV RMSE)—error indicators—were calculated by formulas presented in Equation 1:

$$\text{ERR}_{\text{month}}\,(\%) = \left[\frac{(M - S)_{\text{month}}}{M_{\text{month}}}\right] \times 100\% \qquad (1)$$

$$\text{ERR}_{\text{year}}\,(\%) = \sum\nolimits_{\text{year}} \left[\frac{\text{ERR}_{\text{month}}}{N_{\text{month}}}\right] \qquad (2)$$

where M: measured electricity (kWh) or fuel consumption; S: simulated electricity (kWh) or fuel consumption; N_{month}: number of utility bills in the year.

$$\text{CV}\,(\text{RSME}_{\text{month}})\,(\%) = \left[\frac{\text{RSME}_{\text{month}}}{A_{\text{month}}}\right] \times 100\%$$

$$\text{RSME}_{\text{month}} = \left\{\frac{\left[\sum_{\text{month}} (M - S)^2_{\text{month}}\right]}{N_{\text{month}}}\right\}^{1/2}$$

$$A_{\text{month}} = \left[\frac{\sum (M_{\text{month}})}{N_{\text{month}}}\right]$$

where RMSE: root-mean-squared monthly error; A_{month}: mean of the monthly utility bills.

Equation 1: EER and RSME formulas (Pan, et al., 2007)

The calculated EER% and CV RMSE% were checked to see if they fall in any of the three accepted tolerances for data calibration suggested by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) 14, International Performance Measurement and Verification Protocol (IPMVP), and Federal Energy Management Program (FEMP) (presented in Table 1):

Table 1: Acceptable tolerance for monthly data calibration. Source: (Pan, et al., 2007)

Index	*ASHRAE 14 (%)*	*IPMVP (%)*	*FEMP (%)*
ERR month	±5	±20	±15
ERR year	-	-	±10
CV (RMSE month)	±15	±5	±10

The error percentages of the initial model did not agree well with the above acceptable ranges, and therefore, the initial model was not appropriate for evaluating the new retrofit options.

4) Further investigation was performed to collect more updated information about the inputs that might have higher impacts on the energy consumption and/or were not clear from the drawings—Information about current Heating, Ventilation, and Air-Conditioning (HVAC) and lighting systems including: types of cooling source; Roof Top Units (RTUs) zoning, etc. Through a survey and a follow up interview with the property manager, most of the needed information was obtained and possible input changes were identified. For example, for thermostat set points which have significant impacts on energy consumption, the property manager could not provide exacts values. She indicated that this has varied significantly in the past.

5) The initial model was calibrated and updated based on the new information from the property manager. The new modeling outputs (KWh) were compared with the actual usages by calculating error indicators—monthly and yearly EER as well as CV (RMSE). The new estimates were much closer to the acceptable ranges suggested by the aforementioned guidelines; however, they were still not within acceptable ranges.

6) The calibration process continued by varying the inputs, which were more uncertain based on our interviews and on-site visits, over reasonable ranges. The input changes included thermostat set points, lighting power density, task lighting and equipment power density, cold deck reset temperature, energy efficiency ratio (EER), minimum air flow, etc. More than 80 models were created and their calculated error indicators were compared with those suggested in Table 1. A model with error indicators that complied with the ranges suggested by FEMP and were very close to those suggested by ASHRAE 14 and IPMVP was selected as the best model. This calibrated model was thought to be sufficiently accurate to serve as a reliable base case for evaluating the new retrofit options.

Figure 1 shows the monthly electricity use as predicted by both the initial and final models. Through an iterative calibration process (creating and testing more than 80 models) the model was improved until they closely matched the actual consumptions. The EER_{year} of the best model was zero.

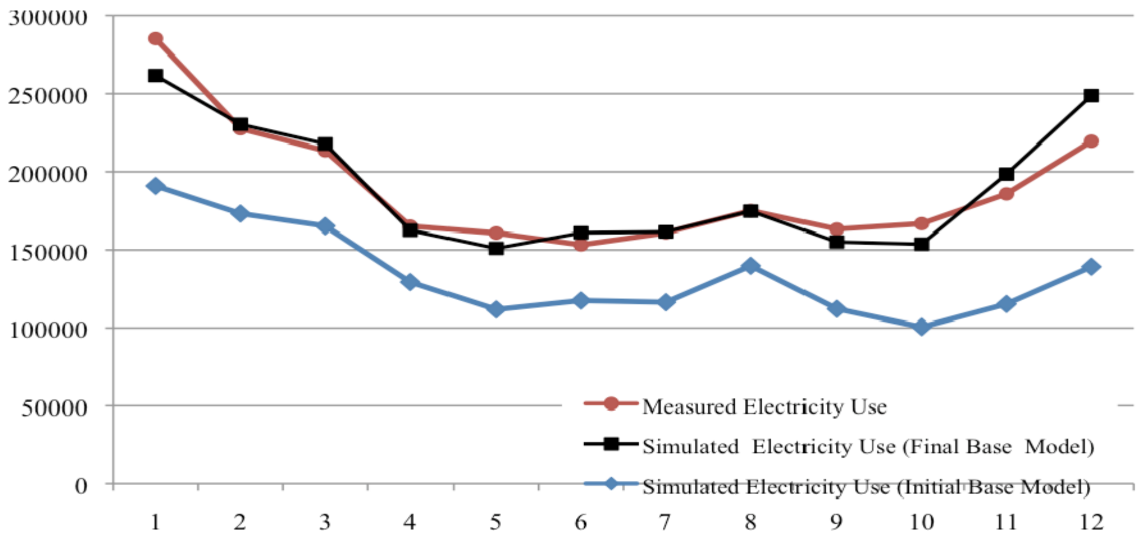

Figure 1: The eQuest Model prediction vs. actual consumption. Source: (Author 2012)

7) The next step of the process was to model the retrofit option—lighting control systems—using the calibrated base model. The lighting control systems modeling, LCCA, and a procedure for generating the distribution of final financial outcomes are discussed in the following sections:

2.0. FINAL DISTRIBUTION OF ENERGY SAVINGS AND INTERACTION OF BASE MODELS

In current practice and literature, typically, a model that falls in any of the three accepted tolerances for data calibration stated in Table 1 and matches more closely with actual consumption—overall lowest monthly and yearly EER as well as CV $_{RMSE}$—will be used as a base model for existing buildings. New retrofit options will then be entered to this base model to be assessed and compared. However, base models themselves often involve a certain level of inaccuracy as they are typically calibrated based on the final modeling outputs, *which could be results of different inputs*. For example, the predicted energy consumption (KWh) of an energy model with certain assumptions about air conditioner Energy Efficiency Ratio (EER) and lighting power density could be very close to the one with a lower EER but a higher lighting power density assumptions. And both base models might be qualified as acceptable models, based on the aforementioned guidelines, due to their close predicted energy consumptions. In fact, this is very common in the calibration process as selecting a certain/accurate value for some inputs can be difficult in existing buildings.

Therefore, there might be several base models within the acceptable ranges that have different inputs, outputs, and error indicators. *A model with lowest error indicators is not necessarily the one that replicates the actual performance most accurately*, due to the uncertainty associated with inputs. Furthermore, selecting the lowest error indicators sometimes is not very straightforward, because a model might have a lower EER $_{month}$ for most of the months, but have a higher EER $_{year}$ or CV $_{RMSE}$. It is very important to note that while the final outputs (KWh) of acceptable models might be very close, they could produce different outcomes when evaluating the performance of new retrofit options. This is primarily due to interactive modeling effects of new retrofit options inputs with the base models. Therefore, ignoring the impacts of the variability of inputs for the base models on the outcomes might result in different investment decisions when comparing different retrofit options.

In summary, there are two factors that could influence the distribution/variance of savings associated with new retrofit options in the simulation of existing buildings: 1) ranges of assumptions for new retrofit options and 2) the inaccuracy of base models. In other word, as shown in Figure 2, the final simulation output distribution is the result of interaction between these two factors. In current practice and literature, the second factor, the inaccuracy of base models, is often ignored.

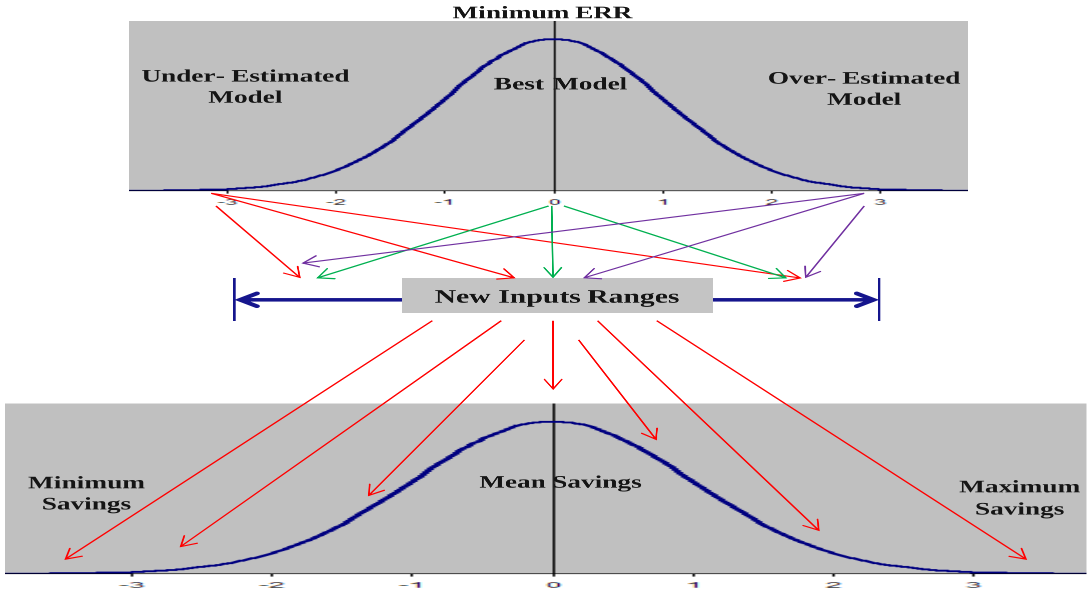

Figure 2: Interaction of base model inaccuracy in generating the final simulation outcomes. Source: (Author 2012)

In this paper, lighting control systems were modeled with multiple base models to generate the distribution of energy savings and assess the potential impacts of different base models on simulation outcomes. The objective of this analysis was to understand how this approach could improve the final decisions about retrofit options investment and if the results were worth the effort of running additional scenarios. Might this approach alter the final investment decisions? This is one of the questions that this paper aims to address.

2.1 Creating Multiple Base Cases for Evaluating a New Retrofit Option

In order to create a more acceptable model, the seven inputs were selected to be varied over reasonable ranges. These inputs include: four thermostat set points (occupied cooling, occupied heating, unoccupied cooling, and unoccupied heating), cold deck reset temperature, EER of HVAC systems, and Variable Air Volume (VAV) minimum flow. These factors were selected because, based on the interview with the property manager and researchers' professional judgments, they might involve a higher level of uncertainty.
Several base models were created in addition to those built previously and their error indicators were calculated to ensure that they meet the acceptability conditions by the aforementioned guidelines. 22 models were within the acceptable tolerances. Figure 3 shows the distribution of the predicted yearly energy usages of the 22 base models:

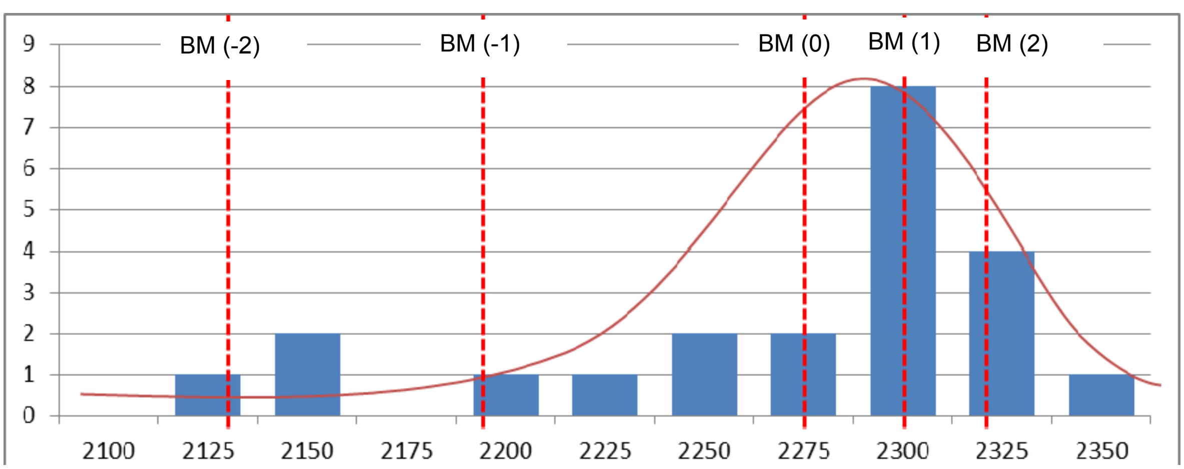

Figure 3: The Distribution of Predicted Energy Use (MWh) of 22 Base Models. Source: (Author 2012)

As the distribution of energy consumptions shows, there are some base models (towards the left side) that under-predicted the energy consumption, compared to 2,276.5 MWh consumption of the best base model, and there are others (towards the right side) that over-predicted the consumption. The best model with EER_{year} of 0%, which is presented in Table 2, is close to the mean of the above distribution. Five base models (BM) were then selected from 22 models to be used for evaluating the lighting control option and generating the savings distributions. The five base models, BM (-2), BM (-1), BM (0), BM (+1), and BM (+2), are shown in Figure 3 by dash lines. BM (-2) denotes the base model with lowest predicted energy use, BM (0) the medium, and BM (2) the highest energy use. Their related assumptions, savings, and error indicators are presented in Table 2:

Table 2: Five base models assumptions, savings and error indicators. Source: (Author 2012)

	BM (-2)	*BM (-1)*	*BM (0)*	*BM (+1)*	*BM (+2)*
Yearly energy use prediction (MWh)	2,130.90	2,181.60	2,276.50	2,291.50	2,315.60
EER month	-4.1% to +14.3%	-8.7% to +11.6%	-13.3% to +8.2%	-14.3% to +6.9%	-13.8% to +7.7%
EER year	6.24%	4.06%	0.00%	-0.62%	-1.70%
CV (RMSE m)	9.03%	8.09%	6.79%	6.84%	7.14%

2.2 Accounting for Risks Associated with the Systems Performance - Five Cases for Lighting Control Systems Option

According to a principal at CQI Associate, energy models do not replicate the real world situation, "because those models do not take into account the true investment and cost issues and as well as experience-related issues about them. We have never seen the savings that high [as predicted by model]." There is a certain level of uncertainty associated with each technology which depends on the current level of knowledge of designers or contractors. How innovative is the technology? What is the proven and what is not proven?"

The result of the analysis shows how various potential risk and uncertainty might impact the final financial outcomes, and therefore, the investment decisions. There are several risks associated with the actual performance of lighting control systems. Daylight sensors need to be well calibrated to perform as they are designed, otherwise there might be no savings and low satisfaction by occupants. Occupancy sensors may not be as effective as they are expected to be, if not located properly to cover the area under their control. There is always a risk of poor quality of installation or workmanship—the contractors' risk. Therefore, in order to demonstrate a process of accounting for the potential risks associated with the performance of the lighting retrofit option in the modeling process, five different cases were developed. Seven factors/variables related to lighting controls performance were identified and their values were varied over defined ranges for creating the five lighting retrofit cases. Case 1 was the best case, case 3 was the most-likely, and case 5 was the worst case. Defining a range for each variable would help to account for some of the risks associated with the option's performance. If a retrofit option is an innovative technology that the market does not have much experience with, the wider ranges might be defined for its uncertain variables. If it is a proven technology, like the lighting retrofit option in this case, the ranges could be narrower accordingly.

For example, studies by Lutron Electronics showed a 15% lighting energy savings when personal dimming controls were employed. A saving range of 13%-17% was considered for personal dimming controls to account for uncertainty associated with its related savings. Lighting power density is one of the factors that could have a significant impact on the outcomes of lighting control systems. Also, it could vary significantly based on the occupants' behavior. Since no tests were conducted in this case study to measure the actual lighting power density, a range of 1.1-1.6 (W/Sq.Ft) was considered to account for this varianceDemand reduction is one of the important benefits of lighting control systems such as daylight sensors. The demand peak (KW) reduction of this option was estimated through eQuest. As described previously, the energy based models in this study were calibrated based on KWh consumptions, so that the predicted KWh matches the actual KWh. They were not calibrated based on their KW prediction. The predicted KW of the best base model (BM0) was compared to the actual values. The EER_{year} was 13.61%. This indicates that the BM0 was over-predicting the annual demand peak by 13.61%. Therefore, in order to account for this inaccuracy in energy models, a multiplier, in a range of 0.8-1, was considered to adjust the KW prediction in each case.

The five lighting retrofit cases were modeled using the five base models, explained in Table 2 through eQuest, which result in a total of 25 energy models/savings estimates. These 25 estimates are used to generate the distributions of energy savings and related financial performance indicators. An excel-based model, a Lighting Control Systems Analytics (LCSA) was then developed for estimating the final lighting controls energy savings and performing economic analyses for each case. This is an analytic tool that could take the KWh and KW estimates from energy models as inputs, and perform a comprehensive analysis to estimate energy savings and financial performance indicators such as simple payback, simple ROI, NPV and IRR as outputs. The assumptions for creating the five lighting cases are primarily based on the researcher's professional judgment and experts' interview.

2.3 Distributions of Energy Performance Indicators and Total Energy Cost Savings

In order to estimate the distributions of energy performance indicators, 1) the impacts of daylight harvesting, occupancy sensors, and different lighting power density on energy savings were first calculated by modeling the 25 cases (five cases by five base models) in eQuest; 2) The outputs, including KWh and KW estimates for both lighting and whole building, were taken to the LCSA; 3) The impacts of high-end trimming, personal dimming control, and demand peak adjustment factors were then estimated and incorporated through the LCSA; and 4) The distributions of MWh savings and KW savings, presented in Figure 4 and Figure 5, were generated based on the 25 saving estimates.

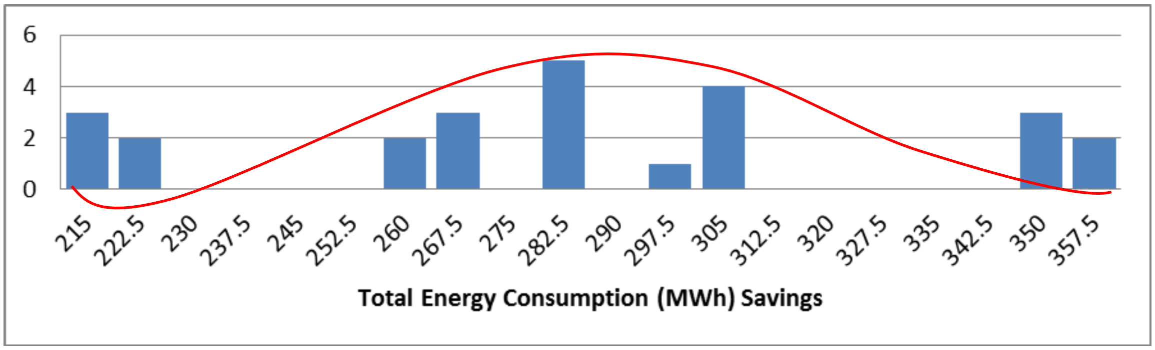

Figure 4: The Distribution of Energy Consumption Savings (MWh) .Source: (Author 2012)

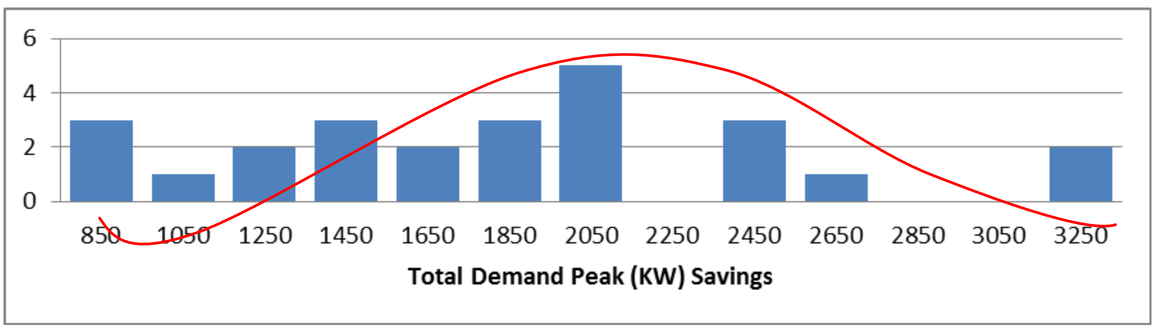

Figure 5: The Distribution of Peak Demand Savings (KW). Source: (Author 2012)

3.0. FINANCIAL ANALYSIS

3.1 Simple Cost-Based Analysis

The entire capital costs data for lighting control systems including equipment and installation costs were obtained from Lutron Electronics. Capital costs could vary significantly based on the building characteristics, number of existing lighting fixtures, users' expectations, lighting contractors, etc. For the purpose of this analysis, five capital cost estimates were developed for the lighting retrofit cases 1-5 to account for the potential uncertainty associated with cost approximation suggested by Lutron Electronics. The utility provider for the building provides incentives for lighting equipment replacements / retrofits and lighting control systems. The total incentives were estimated for the five cases based on assumed ranges for numbers of sensors and ballasts and were subtracted from the total capital costs to calculate the total investment costs.

3.2 Life Cycle Cost Analysis (LCCA)

Cash flows for a period of 20 years were developed. NPVs and IRRs were estimated over four time horizons of 5, 10, 15, and 20 years to show the financial performance of the lighting retrofit over various life cycles. The costs of lighting replacements at the end of their useful life (UL) cycle were included in the cash flows for two conditions. The two conditions are 1) When a lighting retrofit option is undertaken and new control systems are installed— the replacement costs can negatively impact the cash flow at the end of the new systems useful life 2) When no lighting retrofit is undertaken and existing lighting fixtures will be replaced with similar models—the costs can positively impact the cash flow at the end of the remaining useful life of the existing lighting fixtures. Distributions of NPVs and IRRs over various periods of 5, 10, 15, and 20 years were generated. Table 3 shows a summary of statistics of financial outcomes:

Table 3: Min, Max, Mean, and Standard Deviation of Financial Outcomes. Source: (Author 2012)

Financial Metrics	*Min*	*Max*	*Average*	*Standard Deviation*
Total $ Savings	$26,975	$49,829	$38,163	$6,656
Simple Paybacks	5.6	10.4	7.7	1.4
Simple ROI	9.62%	17.89%	13.35%	2.41%
5-Year NPV	($152,667)	$22,199	($78,550)	$61,199
10-Year NPV	($28,430)	$225,171	$97,429	$68,462
15-Year NPV	($3,390)	$334,067	$150,239	$101,059
20-Year NPV	$53,661	$478,213	$249,254	$129,192
5-Year IRR	-23%	11%	-8%	12%
10-Year IRR	9%	27%	17%	5%
15-Year IRR	9%	29%	18%	6%
20-Year IRR	12%	30%	20%	5%

3.4 Interpretation of Distributions of Final Outputs

Probability distributions provide information about the probability of achieving the estimated outcomes. Based on the empirical rule if a distribution is approximately normal then the probability is about 68.26 percent of the estimates will lie within one standard deviation of the mean (mathematically, $\mu \pm \sigma$, where μ is the arithmetic mean), about 95.44 percent will be within two standard deviations ($\mu \pm 2\sigma$), and about 99.74 percent will lie within three standard deviations ($\mu \pm 3\sigma$) (Ott & Longnecker, 2001)

The distributions of NPVs in this scenario are approximately normal, and therefore, the following information could be understood from the distribution of average 5-year NVP:

- There is about 68% chance that the 5-year NVP falls between -$139,749 and -$17,351.
- There is about 95% chance that the 5-year NVP falls between -$200,948 and +$43,848.
- There is about 99.5% chance that the 5-year NVP falls between -$262,147 and +$105,047.
- There is less than 13% chance that the 5-year NVP is positive.
- There is about 84%chance that the 5-year NVP is not less than -$17,351.
- There is about 2% that that the 5-year NVP is higher than +$43,848

The above information provides investment decision-makers with more insight into risk associated with achieving the expected financial outcomes. As a result, decision-makers would be able to make more informed decisions concerning investing in green retrofit options.

4.0. DISCUSSION ON USING MULTIPLE BASE MODELS FOR SIMULATING RETROFIT OPTIONS

The hypothesis here is that considering the inaccuracy of a base model in the modeling process could improve the level of confidence associated with simulation outcomes and enhance the quality of investment decisions regarding green retrofits. This sub-analytic attempts to test this hypothesis towards the broader goal of assisting decision-makers to make more informed decisions about investing in green retrofits.

In order to measure the impacts of simulation with multiple base models on financial outcomes, the low-end and high-end impacts were estimated by comparing the minimum and maximum of each financial outcome to related average value of the best model (BM0). The assumption was that the retrofit options would be modeled using the best model (BM0), if multiple base models would not be used.

Table 4 shows the impacts, both absolute values and percentages, on different financial indicators:**T**

The results of the analysis show that including inaccuracy of base models could have the potential to impact the financial outcomes and influence the investment decisions. There were few conditions in the NPV analyses, 10-year and 15-year NPV, where one case has a negative NPV with the best case (BM0) but positive NPVs with other base models. Thus, if an investor bases her/his decision on the result of modeling with a single base model, she/he would not agree to invest in the lighting controls option. The 4% increase in a 5-year IRR or $16,625 in a 5-year NPV could alter an investment decision from ‘no go’ to ‘go’.

It should be noted that many factors might play roles in the magnitude of impacts. Factors include level of calibration, type of retrofit options, investors return’ horizons, building characteristics, or level of analysis. Accordingly, the inaccuracy of base models could potentially impact the investment decisions at the property level, when selecting the retrofit options. It could alter an investment decision from ‘no go’ to ‘go’.

Table 4: **Impacts of simulating by multiple base models on financial outcomes Source: (Author 2012)**

Financial Indicator	*(Min - BM0)*	*(Max - BM0)*	*Low-End Impact*	*High-End Impact*
Total $ Savings	-$744	$3,563	*-2%*	*13%*
Simple Paybacks	-1.2	0.2	*-12%*	*2%*
Simple ROI	-0.3%	1.3%	*-2%*	*13%*
5-Year NPV	-$3,596	$16,625	*-38%*	*136%*
10-Year NPV	$0	$65,771	*0%*	*253%*
15-Year NPV	-$9,181	$39,206	*-334%*	*2708%*
20-Year NPV	-$11,334	$46,742	*-10%*	*79%*
5-Year IRR	-1%	4%	*-17%*	*74%*
10-Year IRR	-1%	2%	*-3%*	*25%*
15-Year IRR	-1%	3%	*-4%*	*32%*
20-Year IRR	-1%	2%	*-2%*	*20%*

Therefore, if the lighting controls option was only modeled using one calibrated base model:

- The total savings could have been underestimated by 13% ($3,563) or overestimated by 2% ($744).
- The Simple Payback could have been underestimated by 2% (0.2 year) or overestimated by 12% (1.2 years).
- The 5-year NPV could have been underestimated by 136% ($16,625) or overestimated by 38% ($3,596).
- The 5-year IRR could have been underestimated by 74% (4%) or overestimated by 1% (17%).

CONCLUSION

Decision-makers often rely on the results of the energy simulation when making investment decisions about energy retrofit options. Thus, it is important for modelers/consultants to examine potential strategies to improve the reliability and level of confidence associated with simulation outcomes to ultimately enhance the quality of investment decisions. Towards achieving this objective, this paper presents how to define and include ranges for uncertain factors in the energy retrofit assessment process and explains how to generate distributions of outcomes to communicate risk associated with achieving the expected outcome. The proposed process is numerically demonstrated through a case study on evaluating a combination of lighting controls package for an existing office building.

When simulating a new retrofit option in an existing building, there are two factors that could influence the distribution/variance of savings associated with the retrofit option: 1) ranges of assumptions for new retrofit options and 2) the inaccuracy of base models. The final simulation output distribution is the result of interaction between these two factors. In current practice and literature, the second factor, the inaccuracy of base models, is often ignored. The analysis shows that considering the inaccuracy of a base model in the modeling process could improve the level of confidence associated with simulation outcomes and enhance the quality of investment decisions regarding green retrofits. It could alter an investment decision from 'no go' to 'go'. However, the result of this single analysis cannot be generalized. Therefore, depending on the level of analysis, modelers are encouraged to consider the inaccuracy of a base model in addition to the uncertainties associated with each retrofit option when making investment recommendations about green retrofits to decision-makers.

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Visualizing the Expressive Use of Technology in the Design of Parametrically Generated Eco-envelopes

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ABSTRACT: This paper illustrates how computational design has surfaced in the architectural discourse. One particular area of interest has been in parametric design. The authors argue against Parametricism, an avante garde movement which is limited to the issues of style and aesthetic fitness. Instead, an approach that uses parametric modelling, simulation and visualization in an iterative way to generate design solutions for complexities of contemporary design problems is favoured. The authors present a particular case study where parametric design is utilized in the development of a research project that looks for appropriate solutions for building envelopes in hot and humid climates. The process involved the selection of geometrically dependent parameters and their translation into variable fields, variable instances and range values. The parameters and the possible values were based on literature reviews and digital simulations (pre-evaluations) of different types, but categorized as functional, technological and environmental. Even though the project is ongoing, the generation and evaluation of the designs carried out as part of the present research have already yielded results that can guide designers towards informed solutions of the problem studied. More importantly, the study presents a methodology that, understood as part of so many other similar proposals, can assist in the construction of new and more efficient digitally driven design and research processes.

KEYWORDS: Parametric Design, Computer Aided Design, Simulation, Brise Soleil and Building Envelope

INTRODUCTION: From the conventional understanding of design (analogue and/or digital) to an iterative systems approach facilitated by computation

> It appears to me that the age of tools has now given way to the age of systems, exemplified in the conception of the earth as an ecosystem, and the human being as an immune system. - Ivan Illich

Advancement in modeling and visualization was stagnant for hundreds of years until the drawing machines of the Renaissance gave way to a new type of machine just 65 years ago.[1] Following the invention of the 167 square meter (1800 ft2) ENIAC computer, Programma 101 followed twenty years later as the world's first desktop computer, and with the prophetic 1968 presentation of Douglas Engelbart, a new future reliant on computational technology was envisioned.

In spite of a relatively slow process which has spanned the past three decades, continual improvements in hardware and computing power paired with the rapid evolution in software have created a favorable condition for the absorption of computing into the practice of architecture. This has generated interest and inquiry by both practitioners and scholars in the field of architecture.[2] Organizations such as; the Association of Collegiate Schools of Architecture (ACSA) demonstrate the significance of the digital discourse as their centennial conference of 2012 concentrated on the theme “Digital Aptitude”. Attention of this sort is necessary because the architectural discipline, both in academics and practice, has grappled with the way to which computation should be absorbed as a tool in design processes for decades. At the commencement of the digital discourse and until recently, computation was just understood as a way to expedite traditional processes (a representational utilization of digital tools). However, what has surfaced is a growing interest in the possibility to use parametric tools which can facilitate an iterative systems approach to design that supplants the original notions of Computer Aided Design (CAD). (Bermudez and Klinger 2003)

1.0 PARAMETRIC DESIGN IN ARCHITECTURE

1.1 A glimpse at the trajectory of parametric design in architecture

Parametric design is one area of the discourse that has recently received significant attention though the term is nothing new. This concept was an important premise for Ivan Sutherland in the development of *Sketchpad* fifty years ago. Various architectural software has incorporated limited parametric functionality ever since. That being said, the general flexibility of the software and use has been limited to expediting representational notations. The explicit determination of designers to incorporate multidimensional parametric design thinking in their work flow and as a tool to explore design intent in an iterative way is a recent development. There has been a learning curve that has slowly revealed that a parametric approach requires that the mantra of the 'part to whole' is conceived as a system of relationships in which the author*(s)* must define the connections as well as the constraints. (Woodbury, 2010) This provides a clear break in the tradition of *apriori* design manifestation.

While the possibilities of developing parametric design methodology are virtually unlimited, an interest in geometric has become a focused area for exploration. In particular an organic aesthetic of non-Euclidean forms has become rather common as interfaces for scripting and programming have become more intuitive (as seen in the Grasshopper plug-in for Rhinoceros and Bentley's Generative Components). Intending to solidify and increase coherence for this new movement, Patrik Schumacher states:

> Contemporary avant-garde architecture is addressing the demand for an increased level of articulated complexity by means of retooling its methods on the basis of parametric design systems. The contemporary architectural style that has achieved pervasive hegemony within the contemporary architectural avant-garde can be best understood as a research programme based upon the parametric paradigma. We propose to call this style: **Parametricism**. (Schumacher, 2008, 1.)

After establishing the criteria and describing the characteristics of the evolving style which he calls *Parametricism* in a 2008 manifesto, Schumacher's ambitious agenda has involved an attempt to establish the validity of Parametric Design as an important movement within the history of architecture. In a chapter of the text *The Autopoiesis of Architecture, Volume II: A New Agenda for Architecture* (2012), the parametric paradigm is explained at conceptual and operational levels. In spite of these efforts to substantiate a new style in architecture, criticism of this proposal easily points out that the material wastefulness in virtuous form making exuberant aesthetic proposals have no place amidst the environmental crisis now being actively faced by the fields of architecture, engineering and in the construction industry.

> The new terminologies and procedures of designing and planning lose both their realism and their validity as soon as they cease to reflect the personal issues which matter most to the people who take decisions or are affected by them." (Jones, 1992, 73.)

Without the development of a more comprehensive strategy, *parametricism* might have a bleak chance of further development, whereas *eco-logically conscious parametric design* provides much potential.

1.2 Potential of eco-logical parametric design

Being that the parametric design process offers a systematic organizational structure to confront design problems, it lends itself as a powerful tool to address the complexities of the contemporary architectural design problem that not only must create form, but also involves providing solutions for; material, structural and environmental performance. Interest in computational design tools and processes in the architectural discourse has the potential to be of greater value if capable of expanding upon the *parametricist* scope of design as a research program and aesthetic theory to an agenda which includes other narratives that incorporate criteria of use and performance.

> Constructing narratives of utility provides an escape from tautological parametric solipsism without forsaking formalism by providing an instrumentality of form, which could include pragmatic performance, the visceral, as well as the intellectual, discursive, or meaningful.(Meredith, 2008, 8.)

Considering that those 'affected' by architectural constructions include 83% of North Americans polled by Gallup to be pro-environment, designing in an environmentally sensitive way through parametric modeling could be meaningful on many levels. (Americanprogress 2011)

2.0 RESEARCH INITIATIVE IN PARAMETRIC DESIGN: Developing a methodology that prioritizes environmental performance

2.1 Background

As architectural professors in the undergraduate program at the Universidad Piloto in Bogota, Colombia, we are involved in teaching and researching about facade systems. In our institution and as we have witnessed in numerous institutions, there continues to be difficulty with technology from a pedagogical perspective. Generally electives are offered as courses in software, but not in computational design thinking. Relegating computation to knowledge of software packages perpetuates ignorance in professional practice, as seen through practitioners that view *Building Information Modeling* as little more than an extension of drafting and modeling. Our belief is that the contemporary student must manage technology; nevertheless this skill set should be seen as secondary. Developing analytical problem solving should take precedence. Being that these tools are robust and that computing is much more than an instrument for drafting. The student should not only rationalize this, but be able to apply design methods to real world situations.

Due to a lack of literature related to design for the climatic conditions of Colombia, a research is being undertaken at our institution which looks to fill this gap. The activities of this project include modeling, simulation and comparative analysis with the performance of physical prototypes located in the hot and humid tropical climate. This project seeks to generate a useful body of knowledge for students and designers. Participants include biologists and architects and range from the level of student to full professor with doctoral degree.

2.2 Research question

Reflecting on the institutional agenda for this research, the authors have defined a line of inquiry that relates digital discourse with environmental performance. We have formed the following question:

> How might digital aptitude (and visualization) aid architects in the quest to develop solutions that mitigate negative environmental impact and strive to achieve maximum performance through the agency of parametric modeling? (Brakke and Velasco, 2012, 7.)

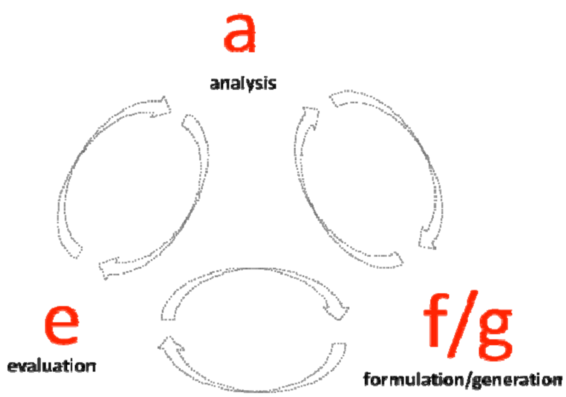


Figure 1: Iterative Design Process. Source: (Author 2012)

2.3 Case study: Eco-envelope research project

The Eco-envelope project is one example which we have created an integrated and iterative approach that defines, analyzes and considers a set of parameters which guide the development of a brise soleil system to serve as the building skin. This is currently a work-in-progress, so this article does not put forward the results as authoritative, but intends to present the development hitherto. Within this section of the article, the methodology used in the generation of the facade system will be explained. Three stages have been identified which include; 1) Formulation of the problem, 2) Development of a parametric model, and 3) The application of this model.

2.4 Geographic location and climatic data

The climatic, ecological, and economic conditions found in a typical tropical location near the equator are characterized by heat and humidity. This climate is common to great part of the Colombian territory, but the town of Girardot, Colombia was chosen as the exact location for this study. This town is located at 4.16° N Latitude and 74.49° W Longitude. This town has an average humidity of 80% and the average day time temperature is over 27 ° C, though temperatures exceed 32 ° C 75% of the year and peak highs surpass 40 ° C. Obviously the mitigation of solar radiation becomes a primary task to consider in the design of the building envelope. Natural ventilation is also a priority as we seek to create solutions of low environmental impact that strive to provide internal comfort.

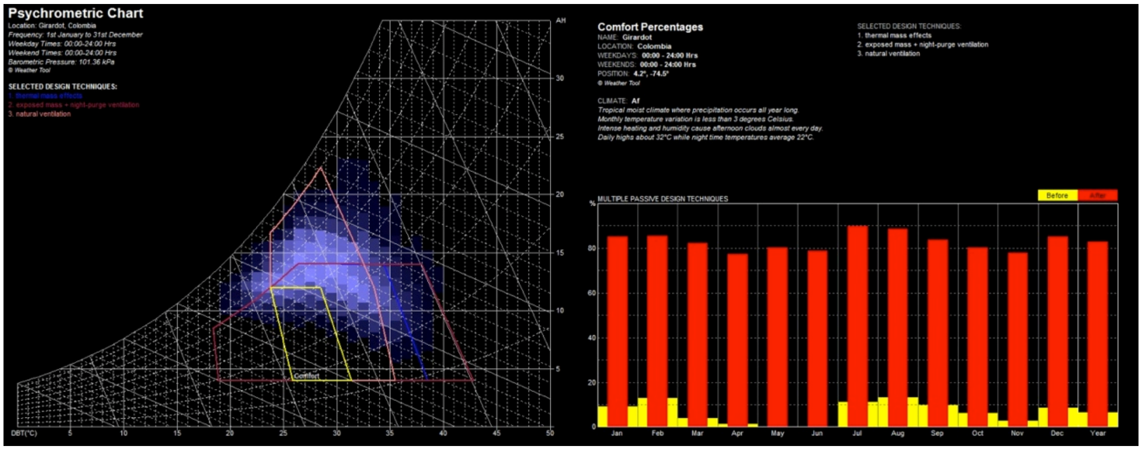


Figure 2: Psychometric Chart for Giradot and forecast rates of comfort with the use of selected passive strategies. Source: (Author 2012)

2.5 A literature review and subsequent definition of the design problem

The first stage was dedicated to the *definition and formulation of the problem* which involved a study of issues pertinent to state of the art facade design through a comprehensive review of special facade designs and existing literature. The literature review prior to the development of this research has shown that most of the publications on the subject tend to classify envelope systems based on a single parameter, the type of material used in the solution and demonstrate such categorization through case studies. There is a scarcity of information that documents methodical analysis based on the configuration of layers or integrated systems in the envelope system. The existing literature that complies with the scope of integrated systems is generally related to specialized double skin glass facade systems typical of solutions for structures that are situated in high-latitude climates. (Ulrich Knaack 2007, 2008)

In parallel with the literature review, several three-dimensional digital models were created and analyzed (simulations in Ecotect and Design Builder were conducted) to gain insight and provide preliminary data about the performance of particular solutions in hot and humid climates.

The analysis of the information in the literature review and preliminary simulations resulted in the identification of three types of major determinants necessary to understand in the creation of any type of building proposal, these factors include; *functional, technological and environmental*.

Functional factors relate to the way in which the skin of the building, working as a protective barrier, provides human comfort zones inside. These factors determine the degree of comfort that the system provides to the covered spaces. Four main criteria related to function have been identified: thermal control, light transmission, ventilation and soundproofing.

Technological factors deal with the means and technologies used to know about how the proposed building envelope is built. We have identified four factors that determine how the performance of the proposed design may come to be evaluated and control the degree of articulation of the proposal in terms of technology and construction: structural capacity, construction efficiency, safety and durability, and costs and maintenance.

Environmental factors relate to the global physical environment in which the possible envelope is located. This includes everything from energy issues to biodiversity (native plants and/or other living species).These factors define the impact of the system on the natural environment that surrounds it at local and global scales, which may imply requirements in terms of various subjects such as embedded energy, absorbed-emitted thermal energy, support for local biodiversity and production of O2.

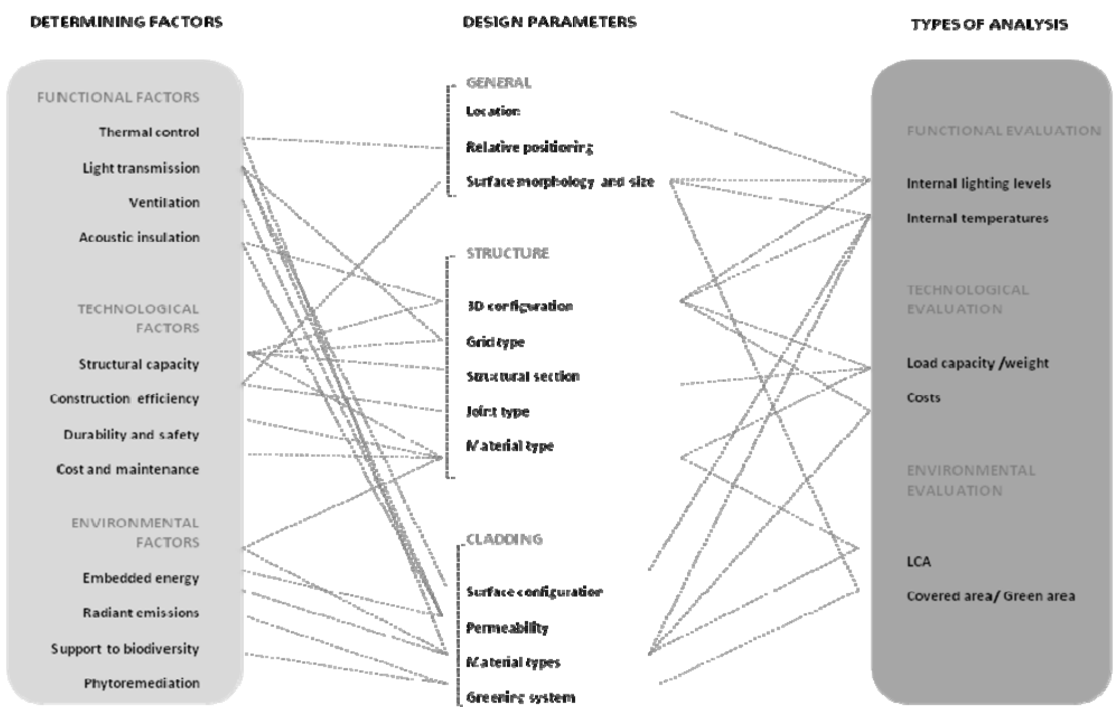
A series of factors that could be assimilated as groups of system requirements is included in each of these categories. These groups were classified into specific requirements having the potential to be evaluated, and thus incorporated as types of analysis and as feedback for the generated proposals. The first emphasis of the Eco-Envelope project is on the articulation of these systems and subsequently on the architectonic designs which are created through the enmeshing of these defining factors. In this study, design is to be understood as the integrator.

2.6 Design parameters

Three groups of design parameters that were to be implemented as design variables were then defined for the generation of design possibilities. These groups include; general parameters, structural parameters and cladding parameters. These groups of design variables formed a structure from which we were able to produce a set of configurational possibilities which were subsequently tested by different types of analysis relative to the original determining factors. [See Table 1]

We have identified 12 parameters to define the design and characterization of architectural envelopes for tropical climates: location, relative position, surface morphology, scale, structural configuration, grid type, sections of structural work, joints and anchors, structural material, type of closure, permeability, and materials for closure and plant support. The table below shows the relationship between the determinants and proposed design parameters for this research, defined into three main categories: general, structure and cladding.

Table 1: Definition and relationship between; Determining Factors, Design Parameters and Types of Analysis. Source: (Author 2012)



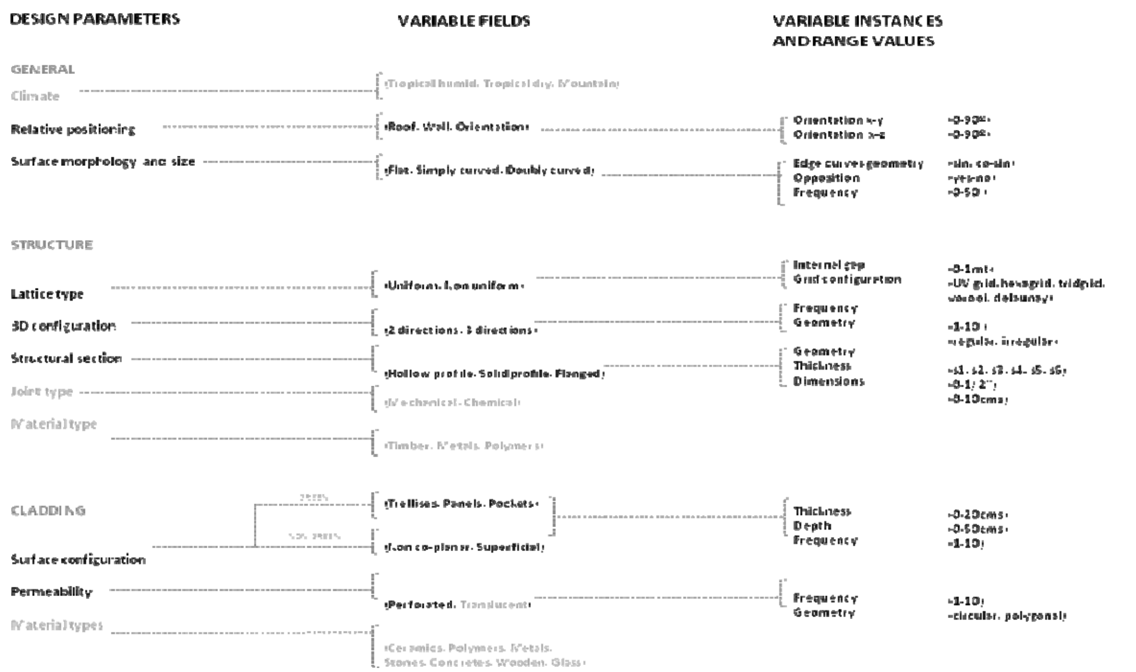
2.7 The development parametric structure and rules for configuration

A parametric structure is synonym of an inter-relational organization, where the parts are connected within a coordinated system, thus implying automatic recreation/reconfiguration of form as the variables are modified. (Woodbury, 2010, 11.) Accordingly, the following had to be defined; the parts of our model, the way and the ranges by which they change, and the general rules of the system. These parts have been called “design parameters” which generally involve particular configurable types (variation fields), where internal definitions (variables) can have differential values of specified ranges (values). The following section explains the general rules and the definition of the parametric structure providing the framework for the use of digital tools.

General configuration rules are given by previous analysis of research conducted within the frame, where passive strategies were explored in warm humid air to achieve reasonable levels of comfort within the covered building. As shown through basic pre-analysis, the most important strategies were ventilation, thermal inertia, solar protection and night cooling.

The proposed research involves the use of double-layer systems that may allow selectively indoor and cross ventilation. Thus, seeking the application of these promising strategies and guided by the requirements proposed as determinant factors, we have considered only a limited number of design parameters. These general parameters of design are related to the general definition of the envelope, its structure and enclosure: the proposed configurations would be constituted by double-enclosed particular combinations using the interior void as the cavity for the structure. This allows for the possibility of permeability, the use of vegetation, and the use of recycled or renewable materials. The current thinking is to develop panels that will be constructed from prefabricated components which will also allow for easy assembly and disassembly.

Table 2: This table shows the definition of structure and design parameters. The dark names indicate a direct relationship to geometrical, thus to be included in the 3d parametric model definition. Source: (Author 2012)



2.8 Design Generation

Following the above mentioned structure where the technological, environmental and functional factors that demarcate our particular space for physical configurations were integrated, we further defined the variable fields of seven design parameters whose functional and technological behavior could be importantly influenced by their geometrical configurations. As discussed above, the design parameters were constrained into three groups, the first corresponding to the general conditions, the second for the structure, and the third defining the cladding, this to be subdivided into external and internal.

The diagram above [Table 2] shows a further description of the proposed design parameters for this research, the geometrically related design parameters (in black) can be directly controlled from three-dimensional parametric definitions built on Rhinoceros-running Grasshopper, producing specific digital models to be evaluated using structural and environmental software packages. Material and functional parameters were to be defined using an Excel based spreadsheet, where options are linked to specific pre-determined values and computed with the incoming data resulting from evaluations of the three-dimensional model.

Here we shall briefly describe each of the general fields:

The first field is called *General Parameters*: These parameters define the general shape and conditions of the building envelope in terms of morphology, position and size. The first variable is called *Relative position:* The relative position is probably the main parameter determining the degree of influence of the external environment on the envelope surface. There are three possibilities for this parameter, vertical position,

operating strictly as a wall (whichever the orientation), horizontal position, operating strictly as a roof, and intermediate positions between the above two conditions. The second is called *Surface morphology and size:* The morphology and relative position of the surface defines the positioning of the surface relative to the external environment, involving, for example, higher levels of solar radiation, exposure to wind or rain. As for surface morphology, we defined three possible variations, flat, singly-curved, and doubly-curved. The main implications that each option entails, are structural and constructive. Size implies the magnitude of the envelope in 2 directions.

The second field refers to *Structural Parameters:*This category includes lattice type, 3d configuration and structural section.*Lattice Type*: The lattice type has direct implications for the structural work, the construction process and particularly on the paneling and modulation of the cladding elements in the system. We have identified two cases of lattice, uniform, and non-uniform. The first indicates a total modular standardization case; the second indicates a semi-standardization provided by the use of two or more modules. *3D Configuration:* The structural configuration is understood as skeletal-type construction, defining two degrees of connectivity between elements, and involving changes to the structural work sections of the elements. We have identified two possible variations to the structural configuration, a structure in two directions and in three directions. The higher degree of connectivity provides greater structural stability to the system, but usually implies more weight and more constructive assemblies. *Structural section:* Defines the profile shape, depth and plate thickness used for the structural configuration of the structural system.

The last field relates to the *Cladding Parameters:* Cladding parameters define how the system interacts with the surrounding environment at the surface level, determining the types and levels of energy exchange of various kinds. *Surface Configuration:* The physical configurations of the modular elements that cover the envelope system define the system relationship with the external environment. We have identified three major changes in this parameter; elements coplanar, surface, and mass. Type of greenery system and plant species were studied to find appropriate plant material in areas that make up the cladding. We have identified three possible configurations for positioning, the first would be given by a mesh of wires to support climbing species, the second would be given by receptacles forming horizontal hard pockets, and the third would imply the use of vertical panels. *Permeability:* The permeability of the surface elements is also (at a material level) defined by the modular configuration and/or type of material used, involving two types, perforated and translucent. We shall only translate the former into the 3d model.

2.9 Application and performance simulations

The designs were analyzed in terms of their performance as climatic barriers and providers of comfort. In order to run the simulations, temperature, lighting and ventilation evaluations were carried out using the software packages Ecotect and DesignBuilder.

The evaluations have been realized against the performance of the reference model which simulates the vernacular techniques of a plastered or face brick facade and flat roof in concrete or fibrocement as implemented in nearly all of the constructions in Girardot. The highest performance models have been compared with the referent construction and the Girardot climate in order to choose the best environmental and of thermal performance options. After a comparative analysis of 48 different cases, three models were identified as highly performing and environmentally friendly: ventilated envelopes of hollow flat bricks, with light coloration, green walls and roofs with native species of easy propagation and locally cultivated, supported by bio-plastic boxes reinforced with mineralized vegetal fibres, and laminated bamboo panels, immunized and preserved against the humidity and UV radiations. The three selected model solutions, even with different thermal curves, show an improvement of the thermal comfort from the interior of 10oC in the warmest day and ≥5,8oC in 75% of the days. The generated models were adapted to the particularities of such materials-components.

Using the material assumptions discussed above, the parametric model is being used to “fine tune” the best geometrical attributes to design a particular case, being that the west facing facade of the existing university buildings in Girardot. Thermal and CFD simulations were carried out to evaluate the original conditions, and to be compared with the performance of 60 design configurations given by the proposed parametric definition. [FIGURE 4

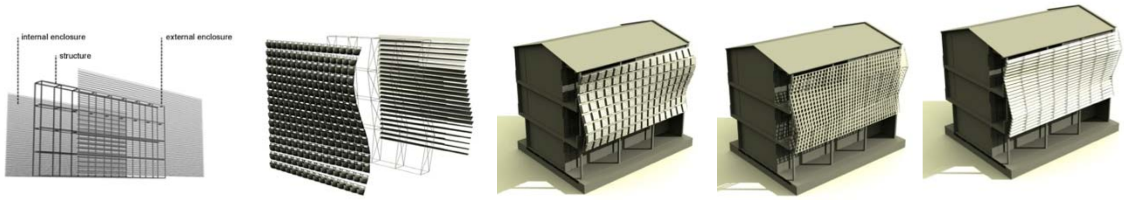


Figure 3: Diagram of enclosure and structural system chosen. Examples of three geometrical configurations produced from the parametric definition. Source: (Author 2012)

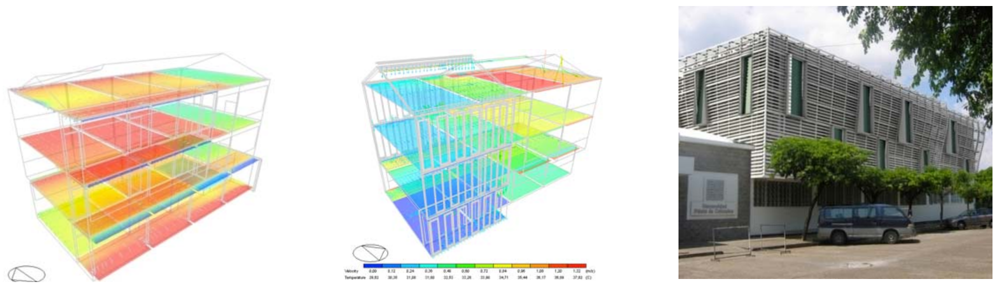


Figure 4: Left: The images on the left are visualizations and simulations of internal temperature of classrooms in an existing building at the Universidad Piloto in Girardot. The simulation on the right shows that the results with the proposed facade (modular ceramic and brick interior wall) achieves a decrease in internal temperatures close to 6º C (10º F). Right: A render of the existing building with the brise soleil solution on July 21st at 12 PM. Source: (Author 2012)

CONCLUSION

This paper illustrates how the development and formulation of a parametric facade system has been created to address the specific climatic situation near the Equator. While digital tools continue to evolve, what becomes more important is how the architectural design process is approached. As design processes, such as; parametric modelling, building information modelling (BIM) and architectural visualization software are utilized, architects are encouraged to look beyond the surface and incorporate feedback from the physical and cultural contexts as parameters to design innovatively.

Architectural design is discursive and even though this document reveals an ongoing project, there are already results that can guide designers towards informed solutions for projects of similar characteristics. The parametric design process is one that relies on the visualization of models not only to understand form, but also performance. The culmination of research to date will not provide a defined equation which explicitly states the manner to which an ecological digital design process should be approached. Rather what is illustrated is how we have gone about using parametric modeling in our exploration of designing and developing brise soleil facade systems that seek a high level of performance. This study presents a methodology that, understood as part of a body of work along with other similar proposals, can assist in the construction of new and more efficient approaches to design. These approaches are digitally driven and strive to achieve maximum performance through the agency of parametric modeling. The *visibility* of the results is evidence that not only does our design solution mitigate the negative environmental impacts of building but is also able to achieve levels of internal comfort highly desired by the inhabitants.

ACKNOWLEDGEMENTS

We would like to thank the Universidad Piloto, Dr. Claudio Varini and Eco-envelope team for the continued work on this project which has constructed physical prototypes and is currently monitoring the thermal behavior. We also thank Voxel for their support with the acquisition of software.

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ENDNOTES

[1] Though J.N.L. Durand's *Précis des leçons d'architecture données à l'École royale polytechnique* was a significant contribution to the methodology of the presentation of design drawings, no other advances in architectural drawing and modeling were made until recently.

[2]ACADIA (Association for Computer Aided Design In Architecture) was founded in 1981. This organization "facilitates critical investigations into the role of computation in architecture, planning, and building science. There is an international network of 5 sibling organizations which also provide an environment for research in computation and design matters.

SIMPLE BoS: Towards a Multidisciplinary Integration of Photovoltaic Energy in Buildings

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ABSTRACT: The Department of Energy has outlined the SunShot initiative, a plan to increase the adoption of solar energy by making it more cost competitive without requiring subsidies. A key component of this plan is to reduce costs associated with the balance of systems (BoS), which accounts for more than 40 percent of the total installed cost of solar energy systems. Balance of Systems encompasses the reduction of costs derived from all aspects related with the use of solar other than the photovoltaic panels and inverter. A careful understanding of architectural factors that may influence building energy performance is a critical and under-addressed aspect of the problem. The Solar, Installation, Mounting, Production, Labor, and Equipment Balance of System (SIMPLE BoS) project addresses the problem through a multidisciplinary team with emphasis on the integration of solar photovoltaic panels into buildings. Our goal is to produce new photovoltaic module racking and mounting designs, integration strategies, materials and wire management methods aiming to reduce the hardware and associated labor costs by fifty percent. Industry PV installers, university research engineers and students measured the field installation time of current commercial systems on project sites, providing a labor cost benchmark for BoS. Concept designs have been systematically improved through aerodynamic analyses, advanced structural optimization and building systems design integration. According to our estimates, material use reduction, part count reduction, use of commoditized materials, and low cost manufacturing processes have enabled greater than 50% BoS material cost reductions in residential, commercial, and utility designs. Cost-critical aerodynamic and structural aspects have been validated through complete and underway wind tunnel test, computational fluid dynamics (CFD), and finite element analysis (FEA). Current design concepts are introduced as case studies of multidisciplinary collaboration. The implications of multidisciplinary building systems integration is discussed, with reflection on education and practice of architectural design.

KEYWORDS: Solar photovoltaic systems, renewable energy, balance of systems, building systems integration, multidisciplinary collaboration

INTRODUCTION

In the United States alone, the market for solar photovoltaics (PV) has grown by 800% from 2005 to 2012, with installed capacity rising from 4.5 GW to 65 GW. At this rate, it is expected that the cost of alternative generation of electricity could become equal or cheaper than conventional generation. To reach this goal, known as grid parity, it is necessary to push the cost of PV systems down by 50-75% (Energy.gov 2011). Historically, the cost structure of solar PV systems was dominated by the cost of silicon. In 2012, given the significant decrease in cost of raw silica, the market has seen PV module prices dropping from $4.00 per Wp to $1.00 per Wp (Aansen 2012).

However, focusing efforts solely on efficient utilization of silicon is no longer a viable long-term strategy for maintaining the market growth rates. Module prices might be expected to decrease another 30%, but this alone will not drive the system cost to reach grid parity. Experts in the field agree that the most significant contribution needs to come from a drastic reduction of the “balance of system cost" (Bony et al. 2010). Balance of Systems (BoS) costs are all costs associated with a PV system, except the cost of the PV modules and the inverters. It encompasses all auxiliary components that allow the system to work, as well as labor and soft costs required to implement a solar panel system project. From the hardware side, balance of system includes mounting and racking hardware, electrical hardware and monitoring equipment; labor costs include mounting, racking, and electrical labor; soft cost include permitting, inspection, interconnection agreement, overhead, and profit. Currently, BoS costs account for more than 40 percent of the total installed

cost of solar energy systems, while inverters and panels are each 20%-40% percent respectively, with variation occurring across applications, module types and other factors (Green Tech Media 2012).
In recognition of the potential of solar PV to contribute to US energy independence and security goals, the United States Department of Energy launched the SunShot initiative in 2010. The SunShot initiative aims to decrease the cost of solar energy by 75% by the end of the decade. The goal is to be achieved by reducing technology costs, grid integration costs, and other soft costs and through economies of scale (U.S. Department of Energy 2012).Given the diffuse cost structure of solar PV systems, there is the need to recognize that no single component can accomplish alone the SunShot cost reduction objective. Multiple cost drivers must be concurrently addressed, including material cost, manufacturing cost, business process, on site labor and equipment usage. This condition implies the need to identify new opportunities for systems integration that could eventually lead to more significant innovation in the field.

One strategy to deal with the complexity of BoS is a "divide and conquer" approach. This strategy entails the optimization of individual components and activities, launching isolated cost reduction efforts. A benefit of this approach is that it allows a high number of stakeholders to engage in relatively low complexity tasks. The downside is the high cost of maintaining compatibility standards between sub-systems, while missing the opportunity to achieve more innovative solutions through development of multifunctional components. Alternatively, a systems design approach revisits the requirements from the top down and focuses on fulfillment of system level objectives. A characteristic of this approach is that it questions legacy solutions, shifting the focus towards opportunities to produce more revolutionary results (Department of Defense 5000). The existing DoE SunShot Initiative takes a pragmatic hybrid approach. Components and activities with low degrees of interdependence have been portioned out while highly interdependent subsystems have been kept intact and funded via systems design projects. The Georgia Tech led SIMPLE BoS project, is one such project that aims to reduce balance of system cost, a highly interdependent subsystem that has only recently been brought into research domain. A key component of this interdependency is the need for better integration of PV systems with buildings, in a way that allows different aspects of building performance to remain uncompromised, and are eventually improved through PV system integration. The complexity inherent to the problem necessitates a multi-disciplinary approach and fuels the opportunity for transformational solutions.

1.0 RESEARCH PROBLEM

The SIMPLE BoS project is committed to developing solutions with at least 50% cost reduction for racking and mounting hardware as well as associated labor cost for the installation of PV systems in residential and, commercial buildings (for existing and new construction), as well as utility (ground mount) markets. Currently, the project is in its second year of development, which includes extensive testing of selected prototypes. By the end of the three-year project, these solutions should be commercial ready, with safety certification, pilot projects and viable business models.

To achieve such drastic reduction goals in labor and hardware costs, while maintaining acceptable levels of safety and performance, is a difficult problem. The main obstacle is the identification and management of negative interactions that emerge among different and often conflicting requirements. For example, a change of materials used for framing PV panels, from aluminum to carbon fiber, would increase the productivity of installers, given the resulting lightweight panels. However, it would also increase material and fabrication costs significantly. On the other hand, it is also important to understand potential chemical interactions between new materials and environmental factors that could potentially cause structural degradation further in the lifetime of the system.

Therefore, there is a need to approach the design of BoSsystems from a holistic perspective, with a careful consideration of requirements that become relevant at different stages of the system lifecycle and the relationships that emerge among them. The analysis of the most critical lifecycle requirements and the design methodology intended to fulfill them is presented in the next section. An overview of the main criteria for performance evaluation is also introduced.

2.0 OVERALL APPROACH AND METHODS

Our analysis of life cycle requirements led to the classification of eight main phases related to BoS: 1) fabrication, 2) transportation, 3) installation (assembly), 4) operation (including systems level integration for building performance), 5) maintenance, 6) disassembly, 7) reuse and 8) recycling (Goodman 2011). Each phase contains a group of requirements that are loosely classified under different first-principle domains. Thus, the installation phase contains requirements that belong to ergonomics and usability domains (e.g. ease of learning to reduce installer training costs, safety factors, etc.), requirements belonging to the mechanic domain (kinematics of moving parts for quick deployment, easy assembly, etc.), requirements from the structural domain (e.g. loading conditions applicable to the PV system as well as the building structure during installation), and electrical domain (e.g. wiring and electrical testing among others). The operation stage includes several technical requirements as well as aesthetic requirements related to the way the building form is affected and perceived.

To address the variety of requirements in a holistic manner, the SIMPLE BoS team is composed of members from diverse disciplines, including architectural design, structural engineering, aerodynamic analysis, biologically inspired design, electric systems, mechanical engineering, physics, business, and systems engineering. The general philosophy adopted to capitalize on this diversity of backgrounds is through the reformulation of the specific problems from the solar panel systems domain into more general descriptions. This is done through different methods, based on functional decomposition and generalization through abstraction (Pahls 1996, Bhatta 1996). The intent is that team members may recognize familiar patterns in the general problem formulation that could eventually evoke precedent solutions from their own domain. Once a precedent or relevant example is found, the effort is shifted towards the identification of its general working principle and its transferability to the specific problem in the form of a design concept (Goel 1997). Preference was given to concepts that embraced multi-functionality at different levels and across several lifecycle stages, and had the potential to fulfill the levels of performance required by the industry.

2.1 Functional decomposition analysis

Along with identification of the main lifecycle requirements, the research team studied how the satisfaction of these requirements is being addressed by current commercial products and industry best practices. In partnership with industry members Suniva and Radiance Solar, a solar PV panel manufacturer and installer respectively; and experts from the Rocky Mountain Institute (RMI), a think-and-do tank, the SIMPLE BoS team developed analyses of different projects, gathering data to determine a current benchmark of the PV systems market. This data included labor costs based on installation activities and a detailed breakdown of hardware and material costs for current commercial, residential, and utility scale racking and mounting systems.

Combined with data provided by the Department of Energy, the research team identified a subset of functional requirements that have the most significant impact in cost across system types, and therefore became the main targets to achieve the 50% cost reduction goals. The subset includes ground equipment, accommodate handling, fix position, maintain electrical connection, align PV arrays, and keep operational temperature (Figure 1, in solid red boxes).

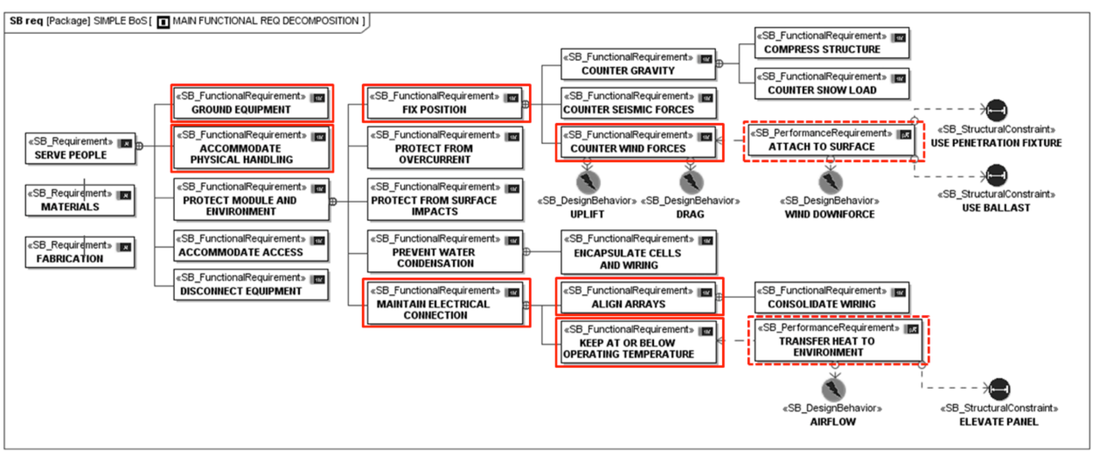


Figure 6: Function decomposition analysisfrom left to right, in SysML language. Red boxes depict functions identified as priority for cost reduction. Bottom functions, in dashed lines depict performance requirements that can be optimized.

For example, in commercial building rooftops, the requirement "fix position" has different challenges than residential roofs. In many cases, commercial roofs are covered by thin film membranes that cannot be penetrated to allow mechanical attachments to the roof structure, otherwise the warranty of the membrane would be voided. The conventional solution to avoid penetration is a combination of ballast and wind-deflection devices to keep the system attached to the roof. However, this implies additional complexity to the system, requiring the use of many heavy ballasting elements that increase the loading condition on the roof. The use of ballasts also has consequences on the cost of installation. Given that the load needs to be distributed, ballasted system usually rely on high number of small ballast units (e.g. CMU blocks), that need to be carried individually, with the associated risks of damaging the solar panels, the thin film membrane, or of injuring the installers. Given these conditions, it is estimated that the requirement of countering wind forces account for approximately 75% of the structural cost of commercial rooftop systems (Bony 2010).

2.2 Design based on functional integration

After the main limitations of conventional rooftop systems were identified and the relations between conflictive requirements were understood, the research shifted towards the identification of solutions in external domains that could be applied to the problem in hand. In the case of commercial building rooftop systems, an useful analogy came from the world of concrete masonry construction, from which some members of the team have extensive experience. Given that ballasted systems are already making use of CMU block as source of weight, the research team decided to take advantage of the natural compression capabilities of CMU blocks and use them as racking structures. In this manner, the function of ballast was merged with the function of PV panel support at a given tilt angle.

The new design, called the Concrete Curb, brings important advantages regarding installation costs. Since the same CMU block can be used as ballast and racking element, the number of installation activities is reduced significantly. The same rationale can be applied to reduction of material and manufacturing costs.The main motivation for this design came from the ubiquity of existing concrete masonry unit manufacturing facilities and their standard equipment. The block specifications are based on typical CMU manufacturing tolerances and the logic of lifting masonry blocks by voided cells for efficient deployment by a small installation team. The blocks can be produced rapidly within the constraints of standard specialized CMU machines.

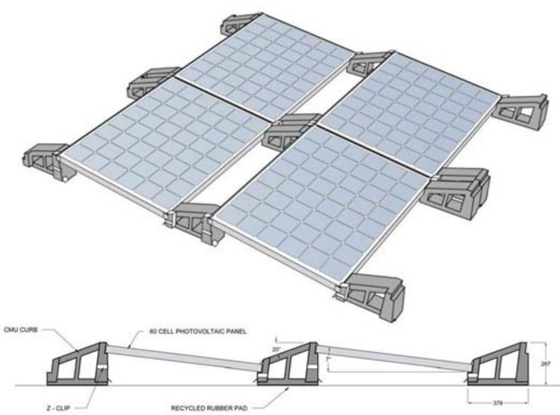


Figure 7 Concrete curb design concept: ballasting and racking functions merged in one element.

Other design concepts for commercial rooftops developed so far include racking structures made of injection molded plastic and sheet metal. Each concept takes advantage of different material characteristics and manufacturing techniques that could contribute to cost reduction, while improving many performance aspects related to installation, operation and maintenance requirements.

2.3 Evaluation of design performance: general approach

As introduced earlier, the project adopts a systems level approach to design, following many principles from systems engineering related to specification and management of requirements (Gilb 2005). In particular, the project focuses on the specification of metrics for validation of requirements and for verification of performance for proposed design solutions. Recently, this approach has been introduced by Augenbroe in the context of performance-based building design (2011). In this model, functional decomposition is not necessarily a deterministic method, but rather intended to be negotiated and agreed upon by various design stakeholders. At the bottom of the decomposition, there must be a set of functional requirements that can be formulated as measurable expressions of performance, described in terms of a Performance Indicator (PI). A functional requirement expressed in terms of a PI becomes a specialization called Performance Requirement. Since a functional requirement can be satisfied in various ways, it may be specialized in more than one performance requirement, each characterized by one particular PI.

Many of the performance requirements and measurement metrics (PI), related to PV systems are already prescribed in available standard codes, such as NEC 690 for electric requirements applied to PV systems, UL 1703 and 2703 for PV module structural and electrical integrity respectively, ASTM E-1830 and ASCE 7 for static and wind loads (NEC 690, 2011; UL 1703 and 2703, 1993; ASTM E-1830, 2012; ASCE 7-05, 2006). Other requirements are not prescribed and therefore need to be elaborated by the research. Some of these requirements are related with installation of PV systems, and current efforts are underway to define them according to the level of feasibility of verification experiments. Table 1 presents some of the performance requirements in SIMPLE BoS.

Table 5: Performance requirements. Green cells represent target values.

Requirements	Criterion	Measurement (PI)	Residential	Commercial	Utility
Submit and review permits	system size	kW	5	100	1000
	install time	man hours	24	120	640
Install system	tool count	number of tools	less than best	less than best	less than best
	part count	number of parts	less than best	less than best	less than best
	Skill level required	description	$22.5/hr	$40/hr	$45/hr
	wire management system	Y/N	Y	Y	Y
	squaring/leveling capability	Y/N	Y	Y	Y
Inspect System	dynamic and static loads	ASCE 7	See Detailed	See Detailed	See Detailed
	electrical requirements	See NEC 690 tab	See Detailed	See Detailed	See Detailed
Physical Characteristics (operation requirements)	power density	watts/square foot	15	15	15
	multifunction: roof shading	roof life increase (years)	Y	Y	N/A
	multifunction: insulation	R value increase	Y	Y	N/A
	racking impact (penetrations)	# of penetrations	Low	0	N/A
	charge acumulation	leakege current	N	N	N
	grounding required	Y/N	N	N	N/A

The purpose of performance characterization in terms of PI's is two-fold. First, it allows the specification of the type of quantification method (e.g. a feasible experiment given the constraints of the project) required to verify that a requirement is satisfied. Second, it promotes the identification of all relevant design elements, as well as parts, features, and actors from the operating environment that have a role in the satisfaction of the given performance requirement. The identification of the collection of elements that have a role in the satisfaction of a requirement, either positively or negatively, is critical for the purpose of the project. More specifically, whenever two or more elements have a positive role in the satisfaction of requirements, there is a potential for integration of functions, such as the one described in section 2.2.

2.4 Teaching, learning and research: The SIMPLE BoS pedagogical structure

An early motivation of the Simple BoS proposal was to directly engage both undergraduate and graduate students across various disciplines in order to simultaneously impact teaching, learning, and research at Georgia Tech. The DoE recognized the enduring benefits of strong student participation in the research, not only as it directly impacts the Simple BoS outcomes, but also in terms of fundamental cultural shifts in the future of the design and construction industry. As such, thirty-five students and nine faculty members from Architecture, Mechanical Engineering, Civil Engineering and Biology contributed through design studios, capstone courses, and a PV systems seminar to develop 24 concepts over a four month period in the spring of 2012, with weekly industry collaboration and review sessions. The structure of the cross-disciplinary design problem was organized around a three credit hour PV seminar open to architecture, engineering, and biology students. The seminar served as a solar industry fundamentals course and disciplinary 'mixing chamber,' where knowledge, ideas, and methodologies could be exchanged between students, faculty, and industry partners. The course provided in-depth lectures on PV system principles, manufacturing, business practices, utility integration, and installation procedures. This content fed laterally into a third year architectural design studio and a fourth year capstone design problem in mechanical engineering. The greatest source of design tension among the group was highly standardized and flat form of current PV modules. Because structural depth enables so many positive attributes in structural systems and in nature, it is an obvious consideration for designers, but not one fully exploited by the solar industry

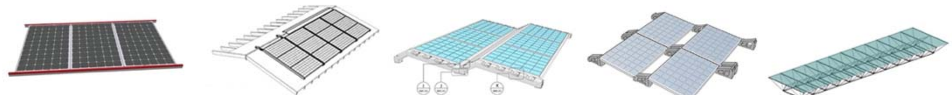
The different classes challenged students to develop different aspects for integration of next generation PV systems in both retrofit applications and for new construction. Projects and exercises focused on different market segments, from small (residential) installations of five kilowatts on sloped roofs, medium (commercial) installations of one hundred kilowatts on flat roofs, and large (urban/utility) ground-mount and canopy installations of one megawatt or larger. Design solutions were developed at the detailed design level, supported by typology analysis, solar orientation/optimization, architectural integration, aesthetic, mechanical and thermal stresses, wind loading, manufacturing strategies, material specifications, deployability, installation procedures, attachment hardware, and overall system costs.

The PV seminar, architectural design studios and engineering capstone courses contributed to the overall goals of the Simple BoS project by providing a platform for students and faculty alike to first gain in-depth understanding of the problem through research and analysis, and then to generate a wealth of novel solutions from which the most promising could be further developed. This experience was critical in providing practical insight for the functional requirements of a PV system described earlier, and informed many decisions in later designs. Members of the design team and advisory board selected nine of the concepts for proof of concept design and five systems are currently being fabricated as prototypes.To date, the project team has filed 14 invention disclosures based on many principles and concepts developed during these courses.

3.0 PROTOTYPE DEVELOPMENT, TESTING AND EVALUATION

Based on the methods described above, and in many of the contributions developed by students in the classes integrated to the project, the research selected five main design concepts for further development and potential commercialization. Our results on labor cost and material cost savings on these concepts are still preliminary, but promising given the feedback provided by our industry partners. The reduction on labor costs are based on the reduction of part and tool count first, then in more detailed, fine grained time and motion studies which are still in development. The basic criteria to achieve these results are the reduction on the number assembly steps, simplification of tasks and the increase of speed, particularly on commercial rooftop solutions (Sheet-metal Curb and Concrete Curb). Reduction of material costs are also preliminary, but consistent with three main design principles: 1) avoidance of expensive materials and associated manufacturing methods, such as aluminum or stainless steel (e.g. Sheet metal Curb); 2) reduction of volume for the most expensive parts wherever possible; and 3) reduction on number of parts by using aggregation strategies (e.g. pre-assemblability of Mega-Module and Quad Pod) and functional integration (e.g. Concrete Curb, Sheet Metal Connection Clip and Quad Pod). A summary of these concepts is presented in Table 2.

Table 6: Design concepts selected for final development, with preliminary estimates on cost reductions.



	Mega-Module		Solar Ridge		Sheet Metal Curb		Concrete Curb		QuadPod	
	Cost Savings ($/W)	% Reduction	Cost Savings ($/W)	% Reduction	Cost Savings ($/W)	% Reduction	Cost Savings ($/W)	% Reduction	Cost Savings ($/W)	% Reduction
BoS Labor	n/a	n/a	0.24	72.1%	0.30	>70%	0.30	>70%	0.05	71.4%
BoS Materials	0.07	5.8%	0.17	55.0%	0.16	53.3%	0.29	>70%	0.13	65.6%

Meanwhile, other fundamental requirements are also being tested, to ensure that full functionality is achieved. Some experiments completed so far include wind-tunnel tests for tilt angle optimization, computational structural analysis and physical testing to verify the satisfaction of load conditions. One example where extensive testing is currently underway is for the Quad Pod concept for utility (ground mount) markets with several potential architectural applications.

3.1 The Quad Pod

The Quad Pod is a lightweight three-dimensional truss system that uses ¾" EMT struts and aluminum-framed PV modules to create an inexpensive and quick-to-assemble module aggregation technique for ground-mount applications. Following the design principle of functional integration, this design makes use of the aluminum frames of conventional 60-cell PV modules as top chords of the truss, thus taking advantage of structural capabilities already existing in this product, while saving material.

The first Quad Pod structural tests will follow the requirements of UL 1703 and UL 2703 for the so-called "above roof mounting" configuration. According to ICC AC 428, this system would be described as a "freestanding system." These two tests will assess the efficacy of the system under extreme wind down-force and uplift. Per the requirements of UL 1703, the basic design load wind pressure is 30 psf, with a down-force multiplier of 1.5 (load case 1) and an uplift multiplier of 1.95 (load case 2). The loads will therefore be 45 psf [2.15kN/m2] in down-force and 60 psf [1.72kN/m2] in uplift (as, from a practical standpoint, the uplift multiplier can be conservatively taken as 2). Passing these load tests will allow the system to be used in most of the United States, with the exception of regions with unusually high wind or snow loads.

The test article consists of a 2 module by 4 array of Suniva 60-cell modules, each module having an area of 1.62 square meters or 17.44 square feet. With an allowance for a ¼” gap between modules the total area of the test article is calculated to be 140 square feet. The reduction in uplift force is borne out by UL 2703, requiring an uplift force loading should be 36 psf. Therefore, the required down-force load for load case 1 will be 6,300 pounds and the required uplift force for load case 2 will be 5,040 pounds. The load will be applied using dead load ballast of small bags of pea gravel. In this first series of tests, the quad-pod will be oriented in the horizontal configuration (0 degrees), and thus all of the loads will be vertical on the modules. In practice, the installation will likely be tilted, and thus wind loads will apply a combination of vertical loads (down-force or uplift) and horizontal loads (drag).

The series of tests on Quad Pod is expected to demonstrate one or more of the anticipated failure modes. Some failure modes are: 1) Bolt shear in the strut bolts, 2) Block shear of the end of the strut, 3) Buckling of the end of the strut, 4) Buckling of the strut, 5) Local buckling at the crimp, 6) Combined shear / tension of apex bolt, 7) Block shear in the clamp connectors, 8) Eccentric bending of clamp connectors, 9) Combined axial / flexural failure of aluminum frames used as top chords, 10) Tear out of module angles and 11) Overstress in module glass laminates. Figure 5 (on the left) illustrates the first completed down-force test. For this first test article, the connections at locations 1 and 2 (right), identified as critical locations in preliminary analysis, began to yield given eccentric bending of clamps (failure mode 8) at a load of approximately 70% of the test load. The test was discontinued, and these critical connections are being currently redesigned to increase their capacity.

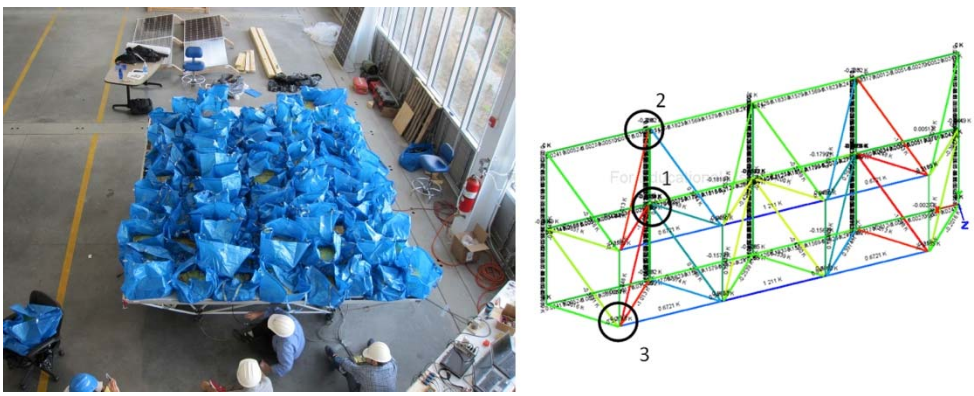


Figure 8: On the left, down-force structural test using gravel bags. Sensors and instruments were installed to measure real-time stresses. On the right, free body diagram (FBD) anticipating possible failure points.

CONCLUSION

The paper described a multidisciplinary research project aiming to produce new PV racking designs, new integration strategies, and new materials and installation methods aiming to reduce racking/mounting hardware costs along with associated labor costs by fifty percent of current industry best practice. Through an unprecedented partnership between industry and university, 35 students and nine faculty members from Architecture, Mechanical Engineering, Civil Engineering and Biology contributed through studios, capstone courses and a PV systems seminar to develop 24 concepts over a four month period, with weekly industry collaboration and review sessions. To date, 14 invention disclosures have been filed by the project team, nine of them have been developed as proof of concept design and five systems are being fabricated as prototypes for testing. Industry PV installers, university research engineers and students measured the field installation time of current systems on actual project sites. These data provides a benchmark for the cost of labor for each design concept through a series of ongoing time and motion studies. BoS concept designs have been systematically improved through several aerodynamic analyses, advanced structural optimization and revision of performance requirements for building systems integration.

One of the main challenges being addressed by research team is to provide a common language to enable communication and collaboration among members with diverse domain background. While the method of functional decomposition proposed originally by Pahl and Beitz (Pahl 1996) has been used for several years in many engineering design domains, its use in architecture has been restricted. One recurrent critique to this method has been its reductionist view of design, and the delusion of deterministic ‘one-to-one’ mappings from problems to solutions, that almost never apply in real design situations. While these critiques have valid points, they do not preclude the usefulness of the method as an analytic and communication tool. In the systems design variation adopted in this research, the emphasis has been put in the use of functional decomposition as a representation medium to express views and needs from diverse stakeholders. It also supports negotiation on the selection of critical functional requirements, and their description as measurable expressions of performance. The final intent is to facilitate the validation of designs, and to verify that important high level design requirements are being met. The methods of generalization and analogy transfer allow retrieving potential solutions from other domains, while the emphasis on functional integration supports discovery of 'one-to-many' mappings from problems to alternative solutions, in ways that are more akin to creative design processes.

From an industry perspective, while the current research is focused on optimizing the installation of existing conventional PV panel modules through innovations in the BoS space, future work will focus on fundamental design shifts in the design and manufacture of silicon based PV generators. New module designs will require overhauling the current manufacturing infrastructure and will take significant time to implement. These changes will open new markets for ubiquitous low cost PV integration in the built environment.

ACKNOWLEDGEMENTS

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Campus Buildings & Student Engagement in Institutional Sustainability Efforts

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ABSTRACT: Colleges and universities are presently engaged in efforts to address the environmental impact of their operations, facilities, and activities. In an effort to provide a way for diverse institutions to compare their efforts in a consistent format, a number of publicly accessible self-reporting systems have emerged since 2006. This paper reviews self-reported sustainability data related to green building and student engagement activities submitted by a sample of 55 institutions that participate in three reporting systems: STARS, ACUPCC, and The College Sustainability Report Card. The objective is to determine the range of approaches across campuses, the usefulness of the data in revealing campus efforts, and unique approaches. Findings suggest that campuses vary widely in enrollments, size of building area, and energy usage, but employ many of the same green building standards and student engagement strategies. Nevertheless, the limitations inherent with the use of self-reported data are addressed.

KEYWORDS: campus, sustainability, green buildings, student engagement

INTRODUCTION

Sustainability is nothing new for colleges and universities, many of which date back more than one hundred years. Some of the earliest environmental activities and efforts began on academic campuses in the 1960s and 1970s. However, over the past decade many institutions of higher education have begun to respond to and take responsibility for the dramatic environmental impacts of their campus operations, facilities and activities through comprehensive efforts focused on a wide range of sustainability issues, which include climate impacts, energy use, greenhouse gas emissions, building performance curricula, student engagement, travel, transportation, waste mitigation, purchasing, habitats, landscaping, environmental stewardship, and more. Many colleges and universities have found addressing sustainability at an institutional scale to be a complex and challenging task.

Nevertheless, since a significant portion of the greenhouse gas emissions that campuses are struggling to mitigate result from the burning of fossil fuels for heating, cooling, and powering campus facilities, it makes sense that many institutions have focused efforts on improving energy efficiency in buildings. The Leadership in Energy and Environmental Design (LEED) rating system has been used by many colleges and universities as a framework and a benchmark for achieving higher levels of building performance. In fact, many institutions have established policies that reference green building standards to guide the design and construction of campus facilities.[1]

But, energy conservation is not simply a matter of building design and system efficiency; occupant choices impact overall resource consumption considerably.[2] This is particularly true for colleges and universities, where student turnover at regular intervals is high. As a result, many campuses have initiated a series of programs for students aimed at raising awareness of environmental issues and changing behavior to conserve resources. Some common approaches include: competitions[3], real-time feedback of energy usage[4], orientations, student groups, and living and learning options.

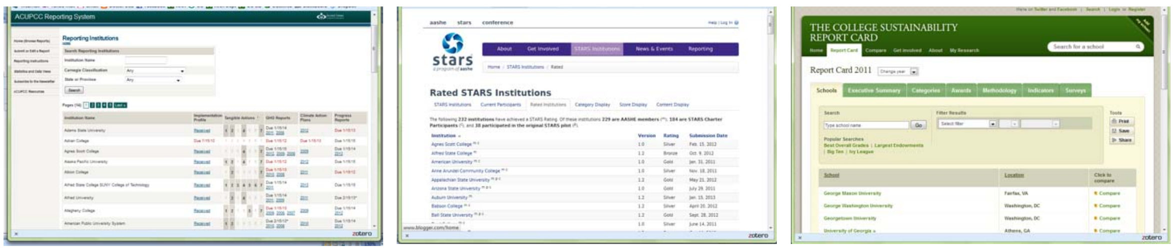
There are vast differences in the myriad approaches that institutions take with respect to sustainability, with little of the consistency necessary for valuable comparison between peer institutions. In response, several organizations were established to enable institutions to report efforts using consistent frameworks and to track their progress over time. This development has dramatically increased the visibility of sustainability efforts beyond the campus boundaries and has assisted institutions in setting goals and targets and and receiving ratings for these efforts. Through this wealth of publically accessible information, there are untapped opportunities to mine the self-reported data in detail with respect to how campuses are using facilities to engage students in activities aimed at resource conservation and environmental stewardship in green buildings.

This study asks three critical questions. First, what are individual campuses reporting or saying about their student engagement and green building efforts? Second, how useful is the self-reported data available at gauging the range of approaches to student engagement and green building activity across a large number of different institutions. Third, what approaches do campuses appear to share and what strategies appear unique among schools?

1.0 SUSTAINABILITY REPORTING

1.1. Transparency and information exchange

In just the past six or seven years, a number of organizations focused on sustainability in higher education have emerged and established transparent reporting systems that allow individual institutions to submit information related to campus sustainability efforts, share data and experiences with other schools and the public, and, in some cases, have their reported efforts evaluated. The most prominent and widely used systems are The College Sustainability Report Card, the STARS system, and the Presidents' Climate Commitment. All three systems employ publically accessible websites where data from self-reports, surveys, and other documents can be easily reviewed and tracked over time. See Figure 1.



The College Sustainability Report Card website
Source: (ACUPCC)

STARS website
Source: (STARS)

UCUPCC website
Source: (The College Sustainability Report Card)

Figure 1: Sustainability data reporting websites

Among the many benefits of such reporting systems are the ability for institutions to reach beyond the boundaries of their own campuses to publicize sustainability efforts, learn from other school's successes, share best practices, and, perhaps, to see how they measure-up. Never before has there been a way to easily compare the sustainability activities of one school with those of another using information self-reported according consistent questions and categories. There is some redundancy in the data reported between the various systems, which can result in conflicting information reported by the same institution at different times. Nevertheless, each reporting system also has its own unique focus and user interface.

1.2. The College Sustainability Report Card

In 2007, the Sustainable Endowments Institute (SEI) pioneered the evaluation of campus and endowment sustainability efforts by introducing the The College Sustainability Report Card program. The program was intended to help identify colleges and universities in the United States and Canada that demonstrate leadership in sustainability as well as to provide information and experiences that schools could share with others working to improve their sustainability efforts on campus. Unlike other reporting and evaluation systems that seek increasing numbers of participants, SEI chose to focus on the 300 institutions with the largest endowments plus 22 others who requested to be included. Enrollments at these 322 institutions total more than 4.2 million students.

Institutions are asked to respond to one or more surveys related to sustainability in campus operations, endowments, dining services, and student activities. The primary data is self-reported from the institutions through the survey responses, but SEI obtains some information about the schools though publically accessible sources as well. A school's overall grade is calculated from grades received in nine subcategories, which encompass a total of 48 sustainability indicators. Subcategory grades correspond to a percentage of points earned: 0% for "F", 10% for "D", 30% for "C", 50% for "B", and 70% for "A".[5]

1.3. Sustainability, Tracking, Assessment & Rating System (STARS)

STARS is a framework and rating system that allows colleges and universities in the United States and Canada to measure and self-report their sustainability performance. The program is intended to support sustainability efforts across the higher education sector by providing a transparent repository of sustainability data that is easily accessible. The program was developed by the American Association for the Advancement of Sustainability in Higher Education (AASHE) with the participation of the higher education community. Initiated in 2007 with a series of pilot projects, STARS 1.0 was officially launched in 2009.

Currently, 367 schools participate and/or have been rated. Institutions submit their scores or points accumulated related to: education and research; operations and planning; administration, engagement, and innovation. Rating levels correspond to a minimum number of points reported: 25 for Bronze, 45 for Silver, 65 for Gold, or 85 for Platinum. In addition, schools may choose to participate as a "Reporter" without having their scores shared. Rankings are based solely upon data self-reported by the participating institutions and neither AASHE nor the STARS program independently verifies the validity of the self-reported data submitted.[6]

1.4. American College & University Presidents' Climate Commitment (ACUPCC)

The President's Climate Commitment was established in 2007 and is intended to be a "highly visible effort" to address global climate change through college and university commitments to emissions reductions and climate neutrality. To date, 665 presidents have signed the commitment, which requires institutions to set a target date for climate neutrality, complete an emissions inventory, take at least two immediate short-term "tangible actions," integrate sustainability into curricula, and to develop a climate action plan.

The ACUPCC provides a framework to assist institutions in determining and documenting the status of an institution's carbon emissions profile as well as charting a course toward dramatic emissions reductions in the future beginning with immediate action in one of seven categories: instituting a LEED Silver standard requirement for new construction; creating a purchasing policy for Energy Star rated products; establishing a carbon offset program for air travel emissions; encouraging the campus community to use public transit; purchasing or producing 15% of electricity through renewable sources; encouraging endowment investments to provide sustainable investment options; and adopting a waste minimization plan.[7]

2.0 SELECTION CRITERIA

In the United States alone there are more than 4,300 colleges and universities.[8] Reviewing sustainability efforts at such a large number of unique institutions one-by-one would certainly be daunting and a laborious task for any researcher. Fortunately, voluntary third-party sustainability reporting systems help to facilitate the comparison of sustainability-related efforts across campuses for a much smaller subset of schools. As described above, the aim of this study was to examine three sets of publicly available self-reported data. However, the three reporting sites have different numbers of participants. For example, ACUPCC includes 665 reporting signatories, the College Sustainability Report Card includes the 322 institutions with the largest endowments, and the STARS system includes 232 institutions that have received a ranking. The data set for The College Sustainability Report Card alone consists of more than 10,000 pages of reported information. Therefore, the methodology followed for this data analysis was to narrow the review to institutions that participate in all three reporting systems, which resulted in a sample of 55 colleges and universities in the United States.

3.0 INSTITUTIONAL DEMOGRAPHICS

The 55 schools reviewed include a diverse assortment of colleges and universities. 27 states and the District of Columbia are represented in the sample. Dividing the sample among United States Census regions, we find twelve schools in the Northeast, fourteen in the South, five in the Midwest, and fourteen in the West. The sample included 26 private and 39 public institutions. The average age of the institutions reviewed was 146 years with the oldest dating to mid 18th century and the youngest to the early 1960s. The campus enrolments ranged from just under 800 to nearly 67,000 full-time students. Building space ranged from just over one million to nearly 23 million gross square feet. Building energy consumption ranged from just over 68,000 MMBtus to more than 5,000,000 MMBtus of heating energy per year.

Two of the three reporting systems used provide evaluations of reported data. The STARS system assigns one of five ratings to efforts reported: Platinum, Gold, Silver, Bronze, and Reporter levels. Among the 55 schools reviewed, the average rating was a bit higher than Silver with 20 at the Gold level, 25 at the Silver level, seven at the Bronze level, and four at the Reporter level. Reporter institutions choose to be included in the data set, but are not required to report scores. No institutions yet rated have achieved a Platinum level. The College Sustainability Report Card system assigns grades "A" through "F" for efforts reported. Among the 55 schools reviewed, the average grade is between a "B" and a "B+" with 16 in the "A" range, 37 in the "B" range, and two in the "C" range. No school reviewed received an "F" grade.

4.0 STUDENT ENGAGEMENT AND INVOLVEMENT

Competitions are a common student engagement strategy across the campuses reviewed. By far, the most popular competition is the annual Recyclemania Tournament, where schools compete with each other to minimize waste in a variety of categories. Of the institutions reviewed, data suggests that 67% participate in the annual Recyclemania Tournament competition in addition to their other waste mitigation activities. However, energy competitions, particularly those run in and between residence halls, are also common.

Most schools reviewed have student groups focused on sustainability issues, but there is little consistency among the campuses with some having many and others only a few. This review finds that 73% of institutions employ student sustainability representatives (eco-reps) to assist with student engagement and behaviour change efforts. Some colleges and universities have multiple types of eco-reps, although these positions are most common in residence halls. Themed housing or residence halls with a sustainability focus are equally popular. However, these housing types vary considerably among campuses. Some themed housing is simply a hallway in a larger building, while some are small, freestanding (often purpose-built) eco-houses. 87% of the campuses reviewed include sustainability in their freshmen orientations, by far the most common engagement strategy. Only about 31% of the institutions have a model dorm room for students to experience firsthand. Refer to Figure 2.

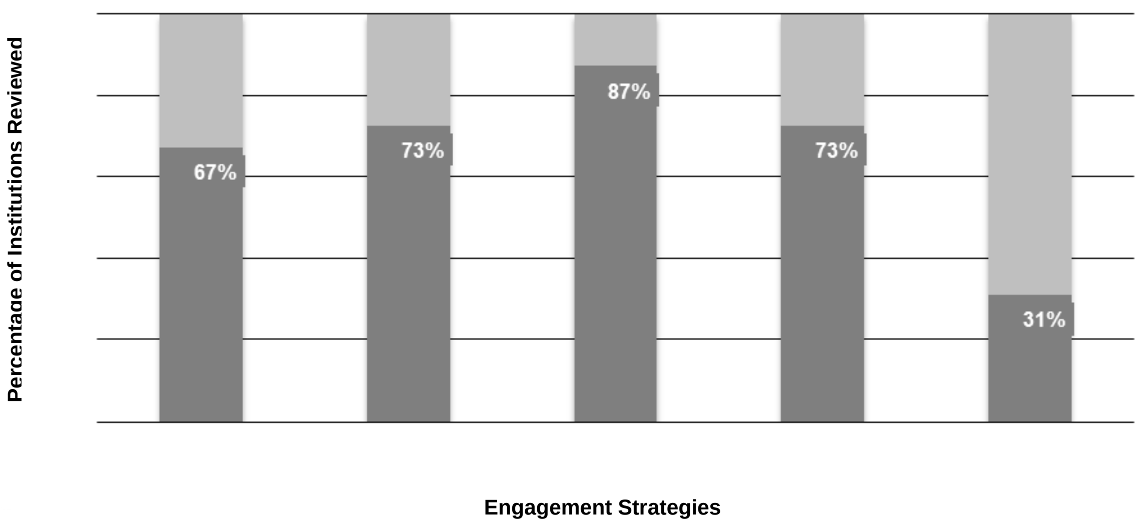


Figure 2: Most common student engagement strategies

5.0 GREEN BUILDING EFFORTS

The data revealed that 82% of campuses reviewed have, or are in the process of implementing, a green building policy that requires new buildings to meet minimum a LEED Silver standard equivalent and 77% have, or are in the process of implementing, a policy to purchase efficient Energy Star certified equipment and appliances where possible in campus facilities. See Figure 3.

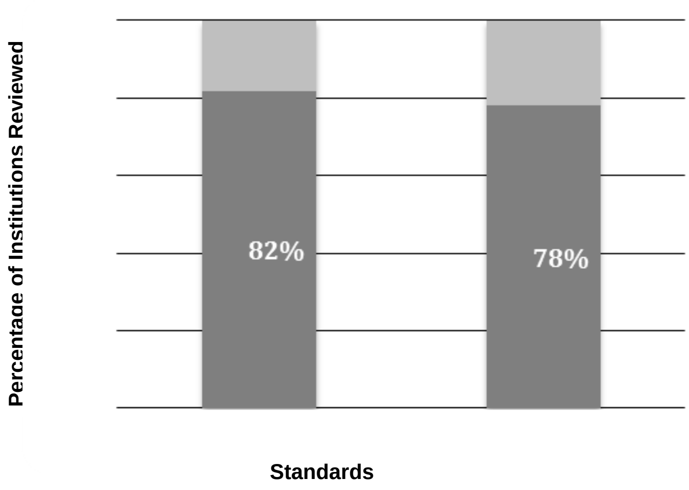


Figure 3: Green building and energy efficient equipment policies

Information reported on green buildings completed varied widely by institution. However, it appears that, all together, there are about 21.5 million gross square feet of building space designed to LEED standards, are in the certification process, or have received a certification, which represents about 6% of the overall gross square footage of building space at the institutions reviewed. Also, it is clear from the data that the amount of building space on campuses is growing in almost all cases, but the overall increase appears marginal at about 5% above 2005 figures. Heating energy consumption has also increased, but only by about 3% with many campuses showing dramatic energy and emissions reductions since 2005. See Figure 4.

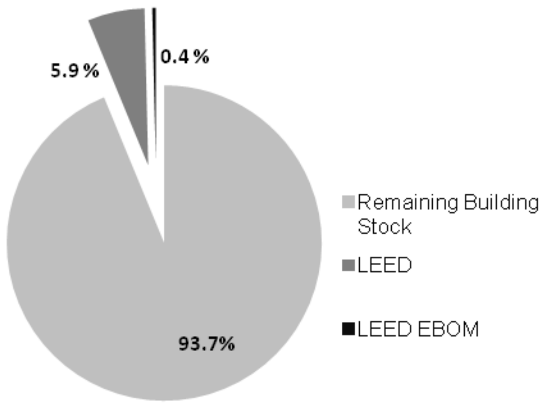


Figure 4: Percentage of overall building square footage designed to LEED standards, certified, or pursuing certification

6.0 THE USE OF BUILDINGS IN ENGAGEMENT EFFORTS

The data reviewed suggest that sustainability-themed housing and competitions, both those open to the larger campus community and those restricted to students, are among the most common ways that institutions are using campus buildings to engage people in institutional sustainability efforts.

The data also reveals several popular waste minimization efforts taking place in campus buildings including: trayless dining to reduce food waste and hot water consumption for cleaning; signage to explain recycling protocols; water bottle refilling stations to limit plastic water bottle usage; and optimizing the locations of recycling receptacles. However, the extent to which these activities are related to green building efforts remains unclear.

Some of the more interesting examples of strategies found in the data include kinetic energy capture on elliptical machines in a recreation center, E-cycler units to expand recycling options (batteries, ink cartridges, etc.), involving students in green building committees, solar carts to illustrate renewable energy strategies, and participation in Solar Decathlon projects. In addition, although only a handful of the institutions reviewed report using real-time energy feedback systems, anecdotal evidence suggests that they are more prevalent than the data suggests and certainly growing in popularity in recent years.

7.0 LIMITATIONS OF THE DATA

Although there is a staggering amount of information available through the three reporting systems used in this review, there are a number of limitations inherent in the presentation of the data that should be acknowledged.

The PCC data that is comparable across institutions is limited. Institutions submit climate action plans and progress reports in their own formats and content and length vary widely. The only information that is truly directly comparable is the “Implementation Profile” information that documents which “Tangible Actions” schools commit to take within two years of signing-on. However, the relationship between engagement and buildings is not easily discernible from the majority of the data presented. Categories are quite discrete and the information provided is brief. The STARS reporting system asks for information to be submitted in easily comparable categories, but the information submitted is lengthy and it can be difficult to navigate between the categories. Detailed information is included, but it is difficult to sort through when comparing institutions. The College Sustainability Report Card survey responses appear to strike a nice balance between easily comparable categories and descriptions of efforts. However, many schools left questions blank or incomplete. In addition, SEI has suspended the report card program to focus efforts on the Billion Dollar Challenge, which means that the data available dates from 2010 and will not be updated.

One significant limitation is that all the data reported is a snapshot in time and, thus, it is impossible to know what changes have resulted since the information was originally reported. This is particularly true of LEED and other building rating certifications, which may be in process. Finally, the greatest limitation is that the data is self-reported by the institutions themselves. Those reviewing the data have no easy way to independently verify that the data is accurate and the reporting systems do not perform this function. As with all self-reported information, the reader must trust that it reflects the truth.

CONCLUSION

Since 2006, a number of organizations have established systems that allow higher education institutions to report sustainability information, to share this data with the public and other institutions, and, in some cases, to receive evaluations of their efforts. This paper examines three such reporting systems (STARS, The College Sustainability Report Card, and the Presidents' Climate Commitment) to see what the data available reveal about the range of approaches different campuses are taking with regard to student engagement and green buildings. Findings suggest that the data available is extensive among the three systems. However, the data are reported in ways that tend to compartmentalize the sustainability issues being addressed and fail to highlight the relationships between discrete activities. In particular, the data reveal that there is a great deal of green building activity and student engagement activity happening across many campuses, but the degree to which these two areas interact remains unclear. Future research is necessary to assess the degree to which green buildings being constructed at colleges and universities support student engagement and behavior change efforts.

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Biomimetic performance

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ABSTRACT: Making sure buildings perform responsibly is a key issue today, in part due to our global environmental crisis. “Humanities footprint first exceeded the Earth’s total bio-capacity in the 1980s; this overshoot has been increasing since then.” (Living Planet Report, 2008) Nature is the ultimate in performance-orientated design so it is no wonder that attention is finally being paid to its processes. This paper discusses research from the 2011-2012 academic year at the University of Arizona, where investigation was centered on the principles of natural systems, biomimetics (the abstraction of natural principles into design). The overriding goal of one particular project was to renegotiate the interface between the built and natural environment.[1] This developed in a conceptual and literal sense with material research into the area of porous cellular ceramics and concrete. Controlling the density (the ratio of solid to void space) allowed for a unique material to develop, whose properties could be tightly controlled to environmental criteria. Testing focused on thermal properties, compressive strength and evaporative cooling. The material was ultimately incorporated into an evolutionary, digital design proposal whose form was optimized with the incorporated material research.

KEYWORDS: Material science, biomimetics, porosity, computation.

1.0 INTRODUCTION

Biomimetics is the study and application of biological principles as essential design parameters. This study goes beyond a metaphor; it is not about mimicry, but about understanding the nature of the material itself. In the English speaking world the term, biomimetics has appeared as equivalent to the German, bionik, coined by Otto Schmidt in the 1950’s. On the website of the German Bionik Network, bionik is defined as the, *decoding of inventions of animate nature and their innovative implantation in technology.* The Center for Biomimetics at the University of Reading, England defines biomimetics as *the abstraction of good design from nature*. Negotiating design and performance with engineering and fabrication is one of the central topics of architectural discourse today. Driving this is a growing awareness of how important the subjects of ecology and sustainability are, of which nature is obviously a successful model to aspire to. Although buildings and biological organisms are both subject to the same physical laws, from gravity to carbon cycles the connection goes beyond conventional scientific relationships. The interest in biomimetics is not just about being performative in a technical sense, it also relates to the larger issue of humanity’s relationship to the natural world. Gregory Bateson discusses this phenomenon in *Mind and Nature*, “We are parts of the living world” but “most of us have lost that sense of unity of biosphere and humanity which would bind and reassure us all with an affirmation of beauty” (Bateson 1979). Part of the following design goal was to re-establish these connections between humans, mind and body and the natural world.

2.0 POINT OF DEPARTURE

Arnim von Gleich et al. in their book, *Potential and Trends in Biomimetics* have identified three main strands of developments in biomimetics, these are; functional morphology (form and function), biocybernetics, sensor technology, robotics and nanobiomimetics. In many cases some of these strands merge. In addition to the three strands of development they also distinguish 3 levels of learning from nature:

> Learning from the results of evolution (hook‑and-loop fasteners, the aircraft wing, etc.), learning from the process of evolution (optimisation techniques, evolutionary optimisation strategy (e.g., Evolutions-technik, see Rechenberg/Schwefel), genetic algorithms, etc.), and finally, learning from the success principles of evolution (closed loop economy, adaptability, etc.) which is the third and most abstract level (von Gleich et al. 2009, 24).

Generally the more areas that are covered imply a richer approach. Natural systems are complex, so reductive designing will not get us to where we need to be, at the same token complexity for complexities sake is not the solution either. Nature is constantly adapting whereas most buildings are static in every sense of the word. How literal does this adaptability need to be? Sometimes moving parts can just add to the complexity of a project without much gain. Generally, if sustainability is a true goal then as many passive design moves and systems should be employed as a first step in the design process.

Reyner Banham has documented in his book, *The Architecture of the Well-Tempered Environment*, that as technology developed (e.g. air conditioners) it has increased our ability to control our environment which has generally led to a separation of the inside from out. This happens often without any relationship to a particular climate or region. Ironically, technology today is generally seen as the solution to the world's environmental problems. That being said the need for computation to study and model this complexity is paramount. John Frazer, a pioneer in the use of computers in architecture has written that,

> The modelling of these complex natural processes requires computers, and it is no coincidence that the development of computing has been significantly shaped by the building of computer models for simulating natural processes. Alan Turing, who played a key role in the development of the concept of the computer (the Turing Machine) was interested in morphology and the simulation of morphological processes by computer-based mathematical models (Frazer 1995, 13).

Michael Weinstock, Founder and Director of the Emergent Technologies Master's Program at The Architectural Association, London has stated that,

> Material is no longer subservient to a form imposed upon it but is instead the very genesis of the form itself (Weinstock 2012, 104).

Today with increasing technological tools, these environmental and material properties can be incorporated as parameters into the digital model. Achim Menges, Director of the Institute for Computational Design at the University of Stuttgart has worked for the last decade on how to generate a design approach related to performance and specific physical materialization. He has stated,

> Computation, in its basic meaning, refers to the processing of information. Material has the capacity to compute. Long before the much discussed appearance of truly biotic architecture will actually be realized, the conjoining of machine and material computation potentially has significant and unprecedented consequences for design and the future of our built environment (Menges 2012, 16).

3.0 APPROACH

It was important to have a design approach with the material properties being the key driver. Porous materials were selected as conceptually they have the potential of blurring the boundary between inside and out – the human built environment and the natural world outside. Also, the research showed that,

> a close analysis of materials found in nature reveals that most of them have a cellular structure and thus contain a significant amount of porosity, which plays a key role in optimizing their properties for a specific function (Scheffler and Colombo 2005, xix).

The specifics of the porosity and what this meant architecturally was what the research intended to analyze. Initially ceramics was the chosen material as it is a fairly conventional building material with some research data available in its porous form. According to Paolo Colombo, porous ceramics,

> display a rather unique combination of properties, such as low density, low thermal conductivity, low dielectric constant, low thermal mass, high specific strength, high permeability, high thermal shock resistance, high porosity, high specific surface area, high wear resistance, high resistance to chemical corrosion and high tortuosity of flow paths (Colombo 2006, 110).

Most of the following research was conducted by a single Master's student, Nicholas Johnson.[2] The author was chair of his thesis committee. Some of the earlier work with ceramics was developed with some additional undergraduate assistance in an elective by the author on biomimetics. Initial research showed that there are three common methods of creating porous soft materials. The first option, *Replication*, involves an application of foam slurry to a template that is burnt out during firing. The second option is *Direct Foaming,* which is usually developed through physical agitation and the third option is *Pore Burn Out*, which incorporates additive materials, usually in the form of beads or particles. The Replication option was initially selected as it seemed to be the easiest method to obtain uniform results. The templates chosen ranged from soft sponges to various examples of pre-manufactured foam. Samples were created by soaking the particular template in a clay slurry, then air drying, then kiln firing to burn out the template and form the ceramic (Fig. 1)

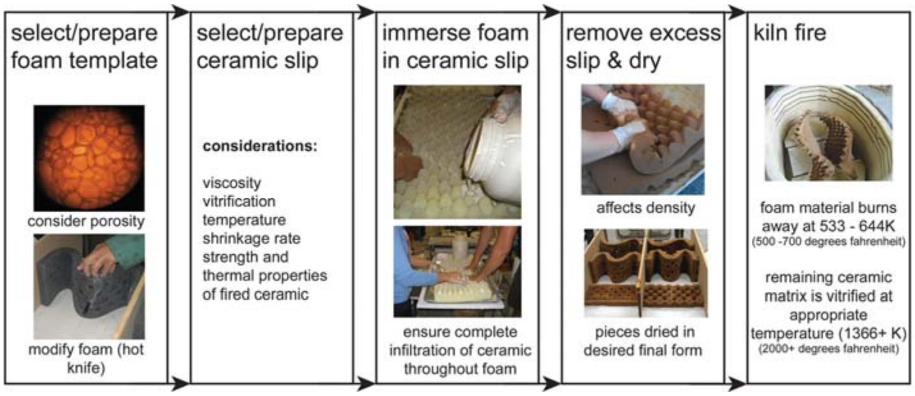


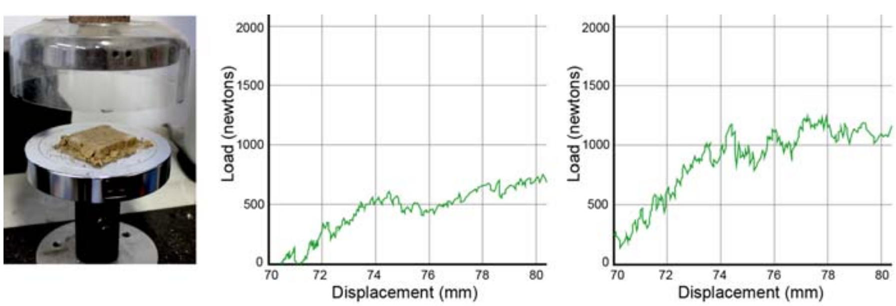
Figure 1: Process of Replication to make cellular ceramic. Source: (Johnson 2012)

The project began with the relationship between three critical properties, which were researched and tested: density, water holding capacity (relating to the degree of porosity, surface area and interconnectedness of cells), and structural capacity (compressive strength). Various samples were made with different densities by adding more or less ceramic material to the foam template. Despite a difference in weight between the two samples of 35%, the difference in porosity is only 2%, and the difference in the percentage of water volume to void volume is only .02%. This suggests that increasing the amount of ceramic material has only a limited negative affect on the water holding potential of the block. Thermal surface temperature testing confirmed this (Table. 1). Finally, compressive strength was tested using a method of crush testing on the Instron machine. These tests showed that while ceramic density may not have a significant effect on the evaporative cooling ability of the cellular ceramic it does have a significant effect on the structural capacity. The sample with the greater density (B) had almost double the compressive capacity of the lighter sample (A) (Table. 2).

Table 1: Results of surface temperature testing with saturated samples, A and B. Source: (Johnson 2012)

	STATIC AIR	Initial	AMBIENT AIR	5 min	10 min	15 min	DIRECT AIR	5 min	AMBIENT AIR	5 min	STATIC AIR	5 min	10 min	
A		291		289	288	286		283		286		286	287	Ambient Air: 296 K (73 deg F) 18% humidity All measurements in kelvin
B		291		290	288	286		284		286		286	287	
Dry		296		296	295	295		294		295		295	295	
		MAX				MAX		MAX		MAX			MAX	

Table 2: Results of Instron compressive tests. Sample A (left) and B (right). Source: (Johnson 2012)



Even though these results looked very promising with regards to using porous ceramic as an evaporative cooler, it was decided to move away from ceramics and the replication process. The energy consumption of the firing process and the toxicity of the burn-out material seemed to be a contradiction to the overall goals of the project. The reliance on the template material was also seen as a restriction as we were limited by the range of existing materials. For these reasons the possibilities of using cellular concrete was then evaluated.

In situ direct foaming was selected to get a greater variety of options. Richway Industries (http://www. richway.com) provided the foam generator and foaming agent. The resulting porosity (and related properties) depends on 1) the properties of the concrete mixture (raw materials, ratios, and additives), 2) the quality of the wet foam (affected by water purity and concentration of foaming agent) and 3) the ratio of foam added to the concrete slurry (density).

If the material was going to be effective as an evaporative cooler then it was critical how the material interacts with water. The cellular ceramic was effective because it could absorb water and also retain it within its cellular structure. With the foam concrete, one issue became the nature of the edge condition – it needed to be cellular and open to enable the water to enter. This edge is affected by the formwork and the pouring and curing processes. Additionally the degree of permeability is dependent on the density of the final product, which is controlled by the amount of foam added to the mix (Fig. 2).

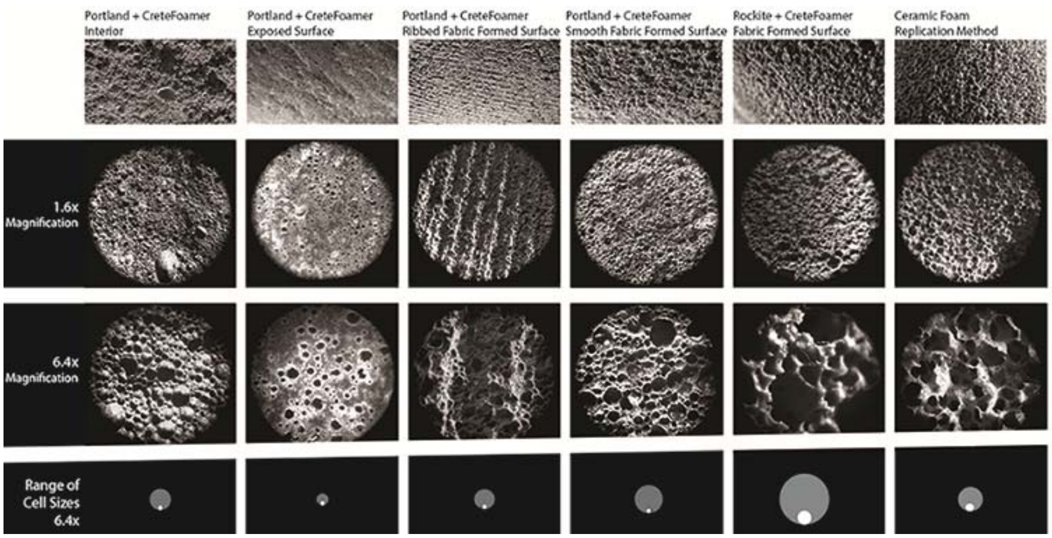


Figure 2: Microscopic Images of various samples using various material compositions and forming techniques. Source: (Johnson 2012)

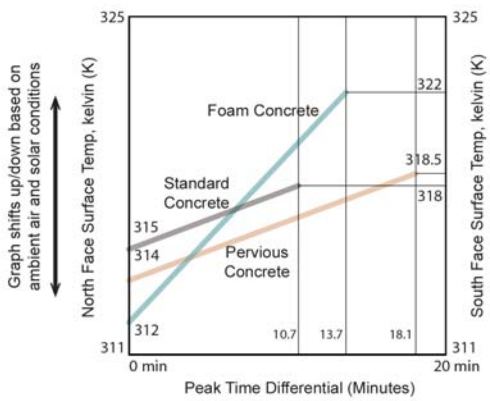
Obviously the desire for increased porosity needed to be balanced with its structural stability. Testing showed that the potential to hold water was dramatically reduced near a threshold of 0.8 g/cm3 (50 lbs/ft3). This corresponds to a compressive strength of less than 6,205 kPa (900 psi) (based on established density and compressive strength data found on the cretefoamer website).[3] The data showed that in its most effective water holding range, the foam concrete cannot be used as a structural material. This led to two possible options - the first one being that it could be conceived as a cladding material requiring a structural frame. The second option, which was selected, was to research the possibility of it becoming part of a hybridized material with another material whose properties would complement the properties of the foam concrete. Pervious Concrete was ultimately selected to be this second material. Part of the reason for this selection was the fact that the two materials are essentially made from the same range of materials and can therefore have a similar construction process. The other determining factor was pervious concrete's high density and structural capacity. It has a macro-porosity compared to the micro-porosity of foam concrete which means that although it could provide the desired structural properties it is not an effective evaporative cooler, as water flows through it instead of being stored.

4.0 THE DESIGN PROCESS AND FINDINGS

Various tests were implemented on the created samples so that specific data could be incorporated into the digital modeling process along with environmental data. Foam and Pervious concrete are not new materials, so there is existing data in many areas. Their potential use as an evaporative cooler is new and undocumented though. The tests were broken down into ones that could establish issues of thermal performance (time lag, performance/thickness ratio, effects of shading/solar exposure) and evaporative cooling (thermal effects of saturation). The evaporative cooling tests were conducted outside and in the College's wind tunnel facility. Samples were saturated and then allowed to dry in the wind tunnel, under various conditions, while data was collected on both sides of the material.

The results of the material research and testing showed that foam concrete is an effective insulator, has a high evaporative cooling efficiency, a low permeability, and a low compressive strength. Whereas pervious concrete is effective as a thermal mass, it has a lower evaporative cooling efficiency, a high permeability, and a high compressive strength. These properties led to a design strategy which would utilize the foam concrete for insulation and evaporative cooling while the pervious concrete would be used as a thermal mass and the structure (Table 3).

Table 3: Summary of surface temperature results for foam, pervious and standard concrete. Source: (Johnson 2012)



The design project's site was to be in Tucson, Arizona in the Sonoran Desert in the southwest United States. The Sonoran desert is generally categorized as a hot, arid region. Barrel Cacti, African Termite Mounds and Mining Bee's Nests were studied for their ability to survive in desert conditions. Desert species have formal criteria that relate to self-shading and orientation as well as material qualities that allow for expansion and contraction during dehydration, they also have insulative and reflective properties. In the case of the Mining Bee vents to the nest are lined with clay walls with a high water content allowing for evaporative cooling. Each example optimizes passive strategies in order to gain comfort. The passive design strategies that had been identified for their positive response in regulating comfort in hot, arid climate zones were evaporative cooling (due to low humidity), high thermal mass (due to extreme heat and solar energy), night ventilation (due to large diurnal temperature shift), comfort ventilation, shading, and in the winter time, direct solar gain.

Initially a simple pavilion-like dome structure was chosen for its minimal surface properties and because of its more fluid environmental exposures. One of the issues raised was questioning what the acceptable levels of comfort should be and whether these should be specifically related to individuals, time of day and year or a particular climate rather than a one size fits all. Comfort and health, like sustainability in general goes beyond a physical issue, it extends to environmental, social, economic and psychological areas.

The first step in the design process was to mold the form of the initial dome shape in an specified way relating to the basic material functions outlined in the schematic design (Fig. 3)

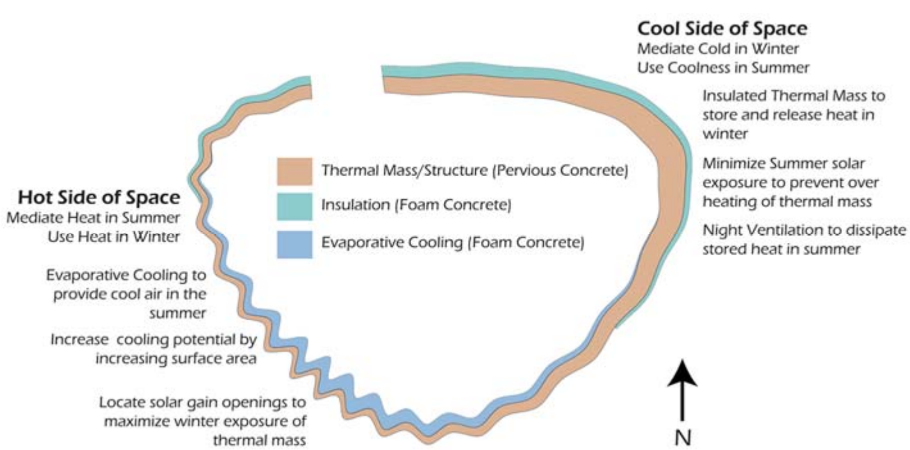


Figure 3: Schematic plan showing placement of foam and pervious concrete. Source: (Johnson 2012)

The digital model was given a wide range of potential formal deformations relating to solar radiation. The goal was to minimize solar radiation on the north side in the summer (to further cool that zone) and maximize solar radiation on the southwest side in the winter to allow for solar gain. An opening was also optimized which would allow the sun to enter in winter to charge the thermal mass of the floor and the north wall. Formal iterations were generated by inputting parameters into Galapagos, a software plug-in for Robert McNeel's Rhinoceros software, developed by David Rutten. Design iterations were then sent to Autodesk's Ecotect for summer and winter solar radiation analysis. The data was then brought back in to Galapagos to determine its relative success or failure and then it generated the next iteration and so on (Fig. 4)

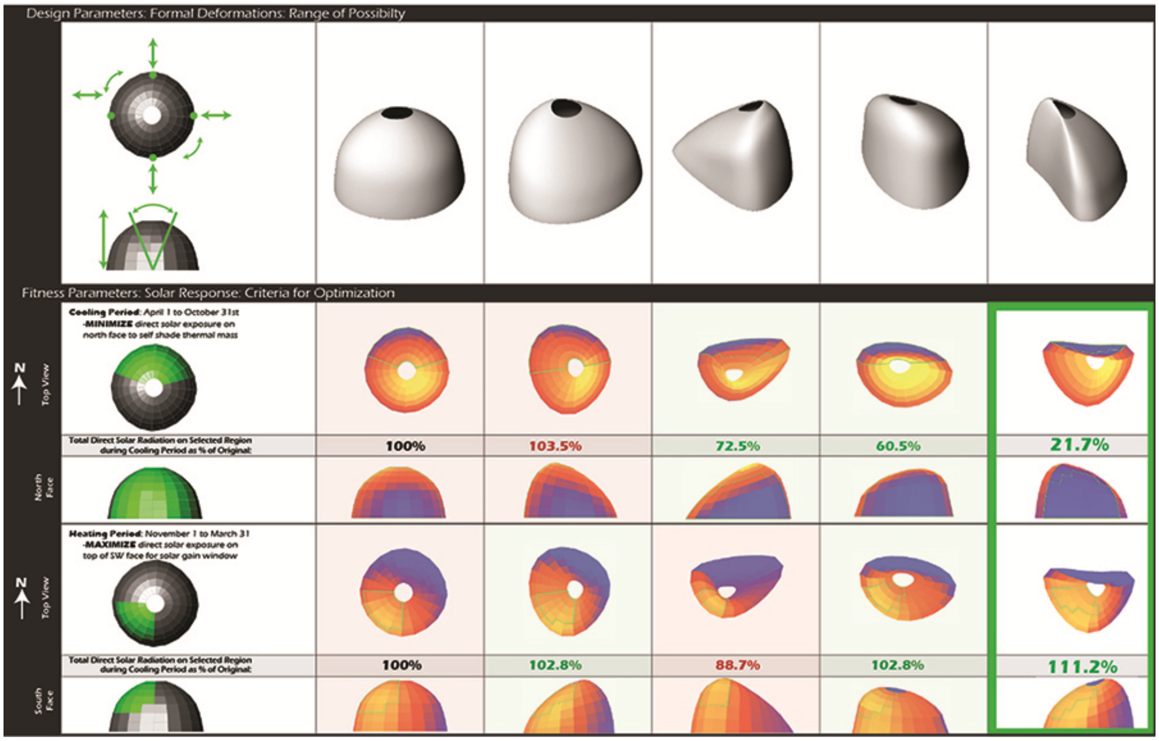


Figure 4: Results of digital optimization process relating to solar radiation. Source: (Johnson 2012)

The next step in this process dealt more directly with the material properties themselves. The goal was to determine the optimal material thicknesses throughout and also optimize the size of the openings. This was accomplished by inputting specific material performance data into the parametric model and again using Galapagos to generate formal iterations which were then fed into Ecotect to get solar gain data. This was then incorporated into mathematical equations within the model that related material properties and thicknesses with environmental data. These equations calculated Thermal Time Constant (TTC)[4] which should be maximized year round, and Diurnal Heat Capacity (DHC)[5] which should be maximized in the winter for heating. These fitness parameters were balanced and the results helped generate the next iteration in Galapagos (Fig. 5).

Due to time constraints, this was the last step in the design process. In an ideal world the next step would be to optimize the evaporative cooling function and maximize its effect on the form. It was noted that formally there would probably have been a difference if all the operations had run concurrently too. Although the computer is calculating the design iterations, there is still control of the parameters which are in the designer's hands. The goal was not to design the form, but to design the system that would generate the best form based on the design criteria for the specific environment where it exists. The various software tools are still in the early stages of development, so the process is sometimes slow and clunky, although developing daily.

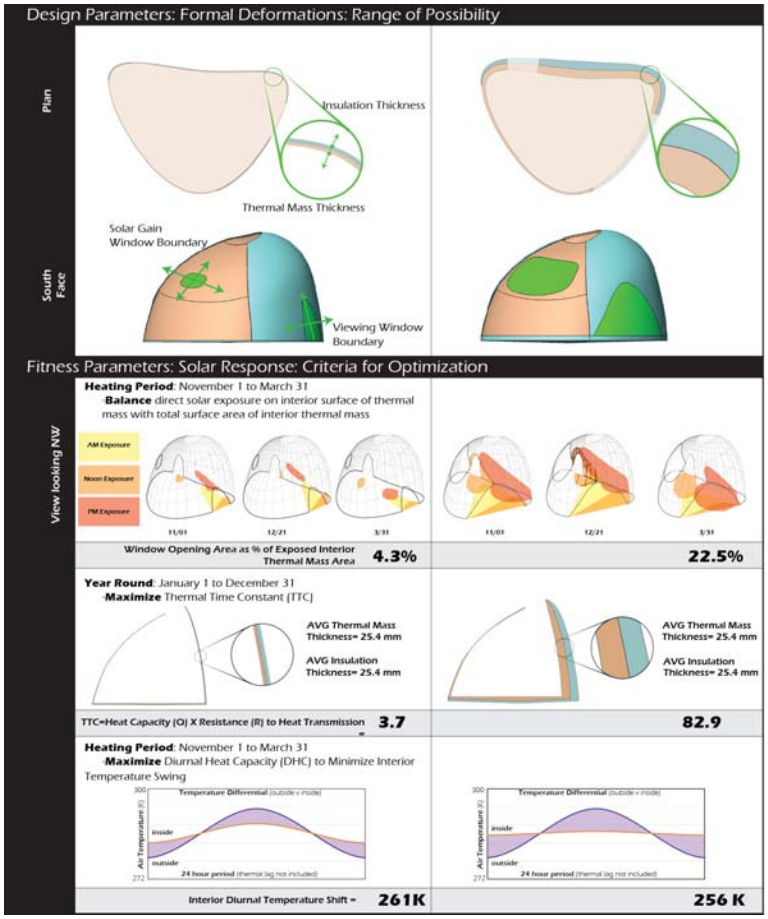


Figure 5: Results of digital optimization process relating to material thickness and direct gain openings. Source: (Johnson 2012)

5.0 CONCLUSION

It was apparent throughout that understanding performance and attempting to emulate the natural world is a complex task indeed. This particular example emphasized materiality as a design driver, but obviously it is crucial to be multi-faceted in order to see the issues holistically. This relates to the idea that as humans we need to become more integrated with nature in a literal sense, which has vast implications for traditional levels of comfort, on which much of our often static performance criteria is based upon. Humans need to be a bit more willing to adapt to living in certain climates rather than expecting environmental systems to manage everything.

The material research showed that there is significant potential for these materials to be developed for arid regions as an evaporative cooler. Specifically, it was assumed that water would be added to the system depending on the exterior conditions. To optimize the system further a mechanical fan would be placed at the top to draw the air through the small holes and through the space. It was realized that a further development of an adaptive shade structure would really improve the results too, but this was not executed in any level of detail due to time constraints. Beyond the specifics of this project there is also a more general potential for the optimization and hybridization of materials so they are used more intelligently and sparingly related to their specific properties in a given location.

One of the other and perhaps most applicable aspects of the project is the use of the computational design process itself. Digital design applications are a given today and with the advancements in Building Information Modeling (BIM) we are starting to see more data and information incorporated into our digital models. The thrust to make our virtual world have more materiality is obviously growing, but these aspects as design drivers are still in their infancy. Using the computational power of computers is crucial in developing our designs to be more reflective of the natural world as there are many behaviors and forces to integrate which are never static. Our digital models, although virtual simulations, are getting more and more sophisticated about modeling environments in live ways and thus becoming less abstract. It is a real positive to be able to immerse ourselves in these virtual realms in the hope that our built projects, which take large investments of time, energy, materials and money, will be smarter, more comfortable on multiple levels and not necessarily more expensive because of it. John Frazer has stated,

> It must be re-iterated that this exploration and resolution cannot be carried out symbolically, at an abstract level. The forming of material is the process of calculation, mapping and resolution of differences. The information thus gained is not absolute knowledge about either the world or form. It is relational; not a measure of either participant in the dialogue, but a measure of the dialogue itself. (Frazer, 1995, 117)

ACKNOWLEDGEMENTS

I would like to acknowledge the other members of Nicholas Johnson's Thesis Committee; Nader Chalfoun, Larry Medlin and Beth Weinstein. It is important to also thank Professor Emeritus Alvaro Malo, who began this process with Nicholas Johnson as the lead of the Master's Program of Emerging Material Technologies at the University of Arizona.

ENDNOTES

[1] The project mentioned was Nicholas Johnson's 2012 University of Arizona Master's Degree Thesis, "Renegotiating the Interface between the Built and Natural Environments."
[2] Some of the following text is cited from Nicholas Johnson's 2012 University of Arizona Master's Degree Thesis, "Renegotiating the Interface between the Built and Natural Environments." Johnson is also cited for all figures and tables with some small graphic and title changes by the author. Consistent changes by the author were made in units of temperature (Fahrenheit to Kelvin).
[3] Cretefoamer. "Cellular Concrete Technical Information," http://www.cretefoamer.com/index.html?page=TechInfo1
[4] Givoni, *Climate Considerations in Building and Urban Design*, 133-135.
[5] Jones and Wray, "Simplified Methods," in *Passive Solar Buildings*, 194-195.

ERRATUM

Erratum added on October 18th 2014 to clarify Nicholas Johnson's contributions to the paper. Changes consisted of adding endnotes i and ii and listing Nicholas Johnson's University of Arizona Master's Degree Thesis as a cited reference.

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Visible Ventilation: A Return to Passive Cooling

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ABSTRACT: In 2007, the University of Oregon signed the American College and University Presidents' Climate Commitment to take steps toward becoming a carbon neutral campus by reducing greenhouse gas emissions and integrating sustainability into their curriculum. With fossil fuels supplying 76% of total building sector energy consumption (Architecture2030), campuses must adopt energy efficiency policies, which establish more stringent energy targets for new and existing construction, while utilizing renewable energy sources.

There are more than 60 double loaded corridor buildings on the University of Oregon campus that rely solely on mechanical cooling. Pacific Hall, which is one of these types of buildings, is the focus of this study. It is a long, narrow building oriented north-south, and occupants on the east and west sides often complain of thermal discomfort in the morning and the afternoon. Over the years, renovations have covered transoms above doors, openings to the corridor have been blocked, and windows, though operable, are generally left closed. Our approach to determine the passive cooling potential includes: 1) climate analysis, 2) building measurements (enclosure and interior wall systems, building proportions, operable glazing ratio), 3) onsite measurements of building base case conditions (temperature, humidity, surface temperatures, air movement, CO_2 levels), and 4) development of appropriate climate-responsive renovation strategies. The effectiveness of these strategies is evaluated through 5) prediction of comfort using the ASHRAE Standard 55-2010, Thermal Environmental Conditions for Human Occupancy, 6) manual calculations using passive cooling guidelines and computer simulations to examine energy use comparisons, and 7) a carbon emissions saved calculation.

We found that Pacific Hall can rely on passive cooling for 5 months of the year with minor interior renovations. Energy analysis revealed an EUI savings of 149.5 kWh/m^2 (25.3 kBtu/ft^2) per year. Such a protocol reveals a fairly easy approach to examine other buildings on campus and estimate the overall campus carbon reduction that is possible through a shift from mechanical to passive cooling.

KEYWORDS: ventilation, campus buildings, passive cooling, natural ventilation, energy conservation

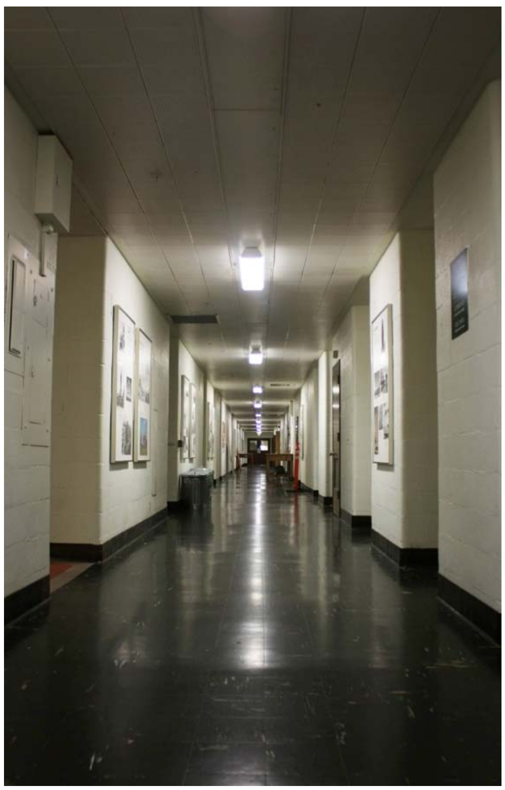
INTRODUCTION

Not long ago, most campus buildings functioned as naturally ventilated, passively cooled buildings, but with the rising demand for air conditioning, many have moved toward active systems. As new energy conscious buildings are constructed on campus, we wondered about the potential to renovate existing campus buildings to provide occupant comfort with passive cooling.

With the building sector continuing to contribute almost half (46.7%) of the emissions to the atmosphere (U.S. Information Administration on Architecture2030.org) from the burning of fossils fuels to run HVAC and electrical systems, we must seek reversible ways to reduce or eliminate such emissions. One of the opportunities to do so lies in the extraordinary amount of square footage needing renovation in existing buildings. It is estimated 75% of the current building stock in the US will be renovated or newly constructed by 2035 (Architecture2030.org). Such renovations would primarily involve envelope retrofits (insulation, new windows, tightening); replacement of mechanical systems; re-lamping spaces (already underway in many buildings), and thermostat/building automated systems. Rather than tear down usable buildings, the research focuses on examining a common campus building type (double-loaded corridor) and determining its potential for natural ventilation. Though the study is somewhat hypothetical in nature, staff from the university campus facilities and planning are curious about these issues relative to building systems, operations, energy, and comfort.

1.0 BUILDING BACKGROUND

On the University of Oregon campus, there are more than 60 double loaded corridor buildings, constructed more then twenty years ago. These buildings rely on continuous ventilation, operated by a simple building operation system, which does not take into account CO_2 or variations in occupant load. This ventilation system operates with the heating and cooling system, however it is not tied into the heating units. The temperatures and minimum ventilation for the occupancy are the driving factors behind the ventilations system. This system utilizes a large amount of energy, since there is a tight temperature range that most occupants find too warm, which could be saved by relying on passive ventilation for a few months of the year. Pacific Hall, constructed from concrete masonry units (CMU), is a double loaded corridor building, meaning there is a central hallway with rooms on either side. The hallways receive no daylight (see Fig. 1a) as the interior walls are also constructed with floor-to-ceiling CMU and solid wood doors leading into each room. Currently the building has a variety of uses, the second floor, the section chosen for this case study, houses architectural studios and a few office laboratories. However, when Pacific Hall was completed in 1951, the intended use was a variety of science laboratories, which required individual ventilation of each room. Because of this requirement, a “breather corridor” (see Fig. 1b) was built on either side of the hallway to contain all of the mechanical and electrical systems for each room. All of the doors from the laboratories into the corridor originally had transoms above them, which provided air circulation and daylight, however these were covered in the 1980s.



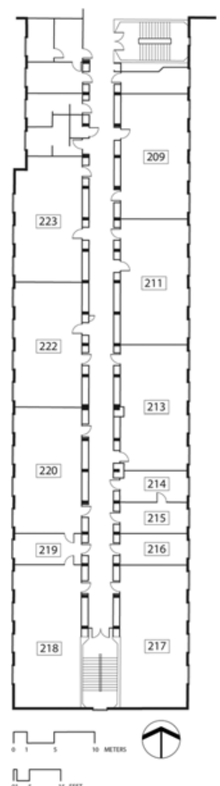


Figure 1: (a) Pacific Hall double-loaded corridor hallway; (b) Second floor plan of Pacific Hall with design studio classrooms and walls, called “breather corridor” containing the unused ventilation ducts.

The individual room ventilation systems are no longer in use since the chemical laboratories have been converted into architectural studios. The ventilation system outputs a consistent amount of fresh air, based on the occupancy of the entire floor. The heating system is separate from the ventilation system: heat for the classrooms is provided through large radiators, fed by the campus steam tunnel, which sit below the windows in each room.

The hypothesis of this paper challenges the current mechanical ventilation strategy of Pacific Hall by proposing that passive ventilation will be as successful as the primary ventilation strategy from May to

September. The hypothesis assumes the success will involve opening the non-structural interior walls to the hallway and reusing existing ductwork from most of the rooms to exhaust hot air directly to the roof.

2.0 METHODOLOGY

The methodology evaluates base conditions and seeks an appropriate low-energy, passive climate response; manually calculates the passive cooling potential; evaluates and verifies the manual calculation with building energy simulation and provides a reasonable design solution for Pacific Hall.

2.1. Base Conditions

Using the psychrometric chart and Climate Consultant 5.4 (UCLA), we determined that natural ventilation is a comfortable and viable strategy for the climate of Eugene, Oregon, from May to September. Passive cooling analysis indicates cross ventilation and stack ventilation as the most feasible strategies. Three rooms on the east side of Pacific Hall, (222, 223 and 220) and one room on the west (213) were selected as classrooms to study because of their use as architectural studios and our ability to easily access those rooms. We gathered temperature, humidity, and carbon dioxide levels in each classroom. These conditions were measured with Onset HOBO data loggers and Telaire carbon dioxide meters over a six day period to capture weekday and weekend occupancy. The existing mechanical system output was spot measured with a balometer. Students were asked not to open the windows so we could determine the conditions based on the HVAC systems. Additionally, information on the structural system and materials of the building were gathered to help guide renovation schemes to reach the performance goals.

2.2. Development of Climate Responsive Design

We examined additional user criteria to achieve successful cross and stack ventilation strategies, such as the use of the rooms, and the occupants needs. These rooms are completely closed with solid doors that operate with a key code. Occupants of the studio classrooms desire more visibility between the rooms to facilitate communication with their classmates. Faculty thought more visibility would develop better camaraderie when the students could see each other’s work. The idea of opening up the walls to the corridor takes into account occupant desires and also facilitates the cross and stack ventilation strategies.

2.3. Evaluation and Analysis Procedure

Two methods were used to determine the viability of the these passive strategies: 1) manual calculations using equations in *Mechanical and Electrical Equipment for Buildings* in which the ventilation from stack and cross ventilation were compared to the current ventilation and heat load in each room, and for the floor as a whole; 2) a building energy modelling simulation tool, DesignBuilder, to determine energy utilization intensity. Since specific construction details for Pacific Hall were not available, certain assumptions were made: U-value of 2.27 W/m^{2}K (0.4 Btu/hft^2°F) for the walls; internal gains for people and equipment, 12.0539 W/m^{2}K (3.4 Btu/hft^2°F) for office typologies (Grondzik, et al, 2010). The average load over time is assumed to be the same as an office, despite the fluctuating all-night occupancy of architectural studios.

The actual energy use for the building from utility bills, are unavailable due to the segmenting of energy use to buildings on campus. Most buildings run on steam (for heating and cooling) from a central plant on campus; and electricity is not submetered at the building.

3.0. RESULTS AND DATA

3.1. Climate Data

The initial climate data for Eugene shows a fairly short cooling season (July, August), and a potential for cross and stack ventilation during this short cooling season. The psychometric chart, (see Fig. 2), shows that on the warmest day, 8 hours of the day are above the comfort zone, shown by the red line to the right of the comfort zone. However, these 8 hours all lie within the range of natural ventilation. For the warmest part of the year, passive ventilation could also become a cooling strategy for these classrooms. The average wind speed for May-September (Fig. 3), is 11km/h (7 mph). However, the design calculations can rely on no more then 9.7km/h (5 mph) since that is the lowest value, and it is better to underestimate than overestimate the wind for cross and stack ventilation.

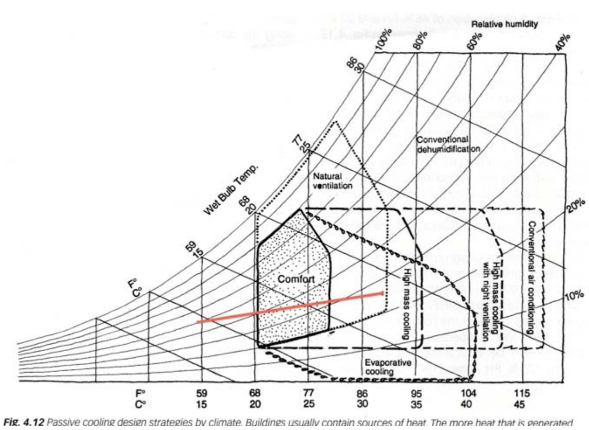


Figure 2. (left) Averaged climate data for Eugene plotted on the psychrometric chart. Source: Grondzik, et al., 2010.

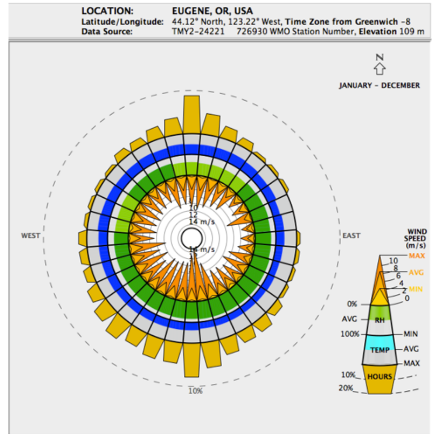


Figure 3. (right) Wind rose for Eugene from May to September. Source: Climate Consultant.

3.2. Base Classroom Conditions

The interior and exterior temperature, relative humidity and carbon dioxide levels were recorded in each case study studio from November 9, 2012 at 1pm until November 14, 2012 at 12pm. The data (Fig. 4) reflects the fluctuation in conditions provided by the mechanical systems. The interior temperatures in all four classrooms show relative thermal consistency between 18°C (65°F) and 22°C (71°F), with the exception of room 220, where the temperature drops at 8pm and increases rapidly again at 4am; this seems characteristic of HVAC timer control. The other classroom temperature dropped slightly as well, but the system seems to maintain consistent comfort temperatures. Classroom carbon dioxide levels generally fluctuated between 400 ppm and 850 ppm. Though not shown on the chart, outdoor carbon dioxide levels during the period of study was 331 ppm, and the existing mechanical system had a measured output of 0.24 m^3/s (160 cfm).

The temperature and CO_2 increases appearing on November 12 from 12pm to 5pm correspond to full occupancy because the students were preparing for a design review during the following day. In room 222, CO_2 levels spiked irregularly as high as 2400 ppm on November 13 between 7:45 pm and midnight. We do not know if this was due to a malfunction of the CO_2 monitor or due to something occurring in the mechanical system. In room 223, the CO_2 levels were consistently 200 ppm higher then the other rooms, likely due to larger number of occupants in that particular room. There was no difference between CO_2 levels based on east or west orientation. We determined from the data that the current mechanical system runs constantly, regardless of carbon dioxide levels, is fairly responsive to occupancy, and maintains physical conditions within the comfort zone specified by ASHRAE Standard 55-2010.

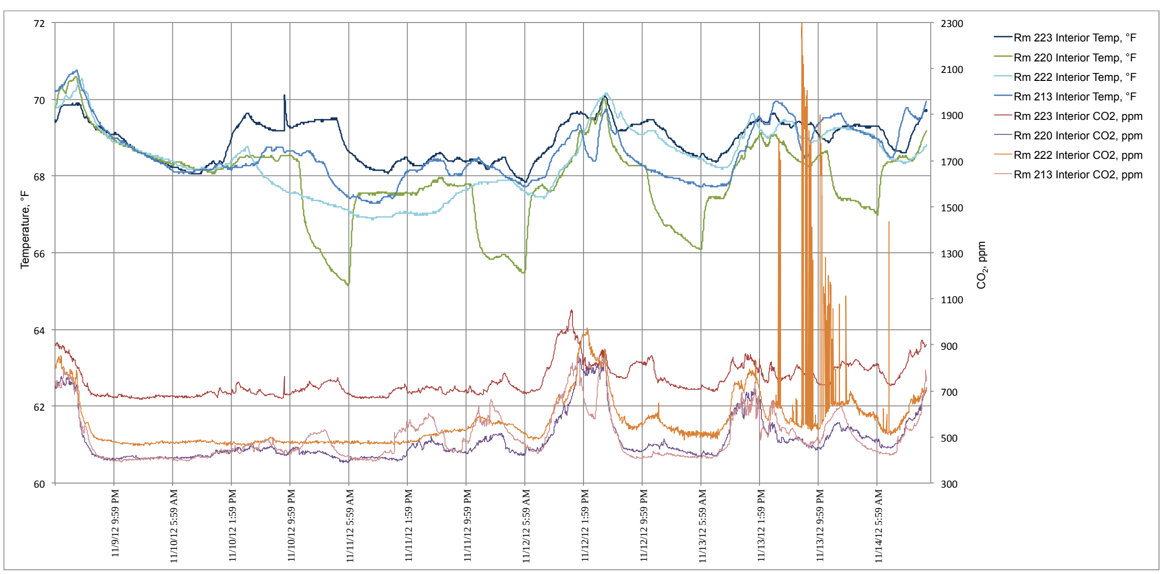


Figure 4: Temperature and carbon dioxide levels in Pacific Hall classrooms from November 9-14, 2012.

3.3. Manual Calculations and Analysis

The 88.1m^2 (948ft^2) studios in Pacific have 2.1m^2 (23ft^2) of operable window area, but only 2.0 m^2 (21ft^2) of operable door area to the interior corridor. In order to accurately calculate the passive ventilation needs of the studio rooms, we first determined the heat gains for each case study room. Per table F.3 in *Mechanical and Electrical Equipment for Buildings*, the internal heat gain from people and equipment is estimated at 11 W/m^2 (3.4 Btu/hft^2), while the internal gain from electric lights, based the room's daylight factor of 2.7%, is 6.3 W/m^2 (2.0 Btu/hft^2). Through the envelope, the gains through the walls are 8.2 W/m^2 (2.6 Btu/hft^2), while the gain through the windows, with interior blinds, is 19 W/m^2 (5.9 Btu/hft^2). Since the other walls, floor, and ceiling are shared with conditioned interior space, the gains and losses between these spaces are negligible. The total gain for each case study room in Pacific is 44 W/m^2 (13.9 Btu/hft^2), which on the hottest day of the year means that 931.2 W (13,177 Btu/h) are required for cooling. The minimum ventilation requirement for these studios, based upon 20-person occupancy, is 94.4 L/s (200 cfm).

Initially stack and cross ventilation were looked at as individual strategies to see if either one alone could provide the necessary ventilation and cooling on the warmest day of the year. For both stack and cross ventilation, the procedures are based upon the methods in section 8.14 in *Mechanical and Electrical Equipment for Buildings*. In both calculations a maximum interior temperature of 24°C (75°F) is used.

Stack ventilation calculations are based upon the following equation.

$V = 1000KA\sqrt{(2gh(T_i\text{-}T_o)/T_o)}$
V = Ventilation airflow, L/s
K = discharge coefficient, 0.65
A = Inlet or outlet area, whichever is smaller, m^2
g = gravitational coefficient, 9.8 m/s^2
h = stack height from inlet to outlet, m
T_i = the indoor temperature, °R
T_o = outdoor temperature, °R
°R = °C + 273.15

The initial calculations looked at stack ventilation solely utilizing the existing chemical hood ventilation, with the existing 1 square foot of opening, and height to the roof of 12m (38 feet), neither increasing the diameter, nor the height above the roof. The results show a capacity of 165 L/s (349.7cfm), which equates to 1916.6 W (6539.0Btu/h) on the warmest day of the year. Therefore, although the stack by itself would provide sufficient ventilation, it would not provide enough cooling to fully replace air conditioning on the warmest days of the year.

The cross ventilation calculations began by assuming the openings into the corridor would equal the operable window area of 2.1m^2 (23 ft^2) in the adjacent studios, as well as a maximum reliable wind speed of 8km/h (5mph). Since the windows are perpendicular to the prevailing wind, there is an effectiveness reduction factor of 0.6. Pacific Hall is also located in an area of dense buildings, so there is an additional urban reduction factor of 0.35. In addition to these wind reductions, another reduction of 0.45 is made for hopper windows, which allow 45% of the total opening to pass air into the space. The following equation is used for cross ventilation calculations.

$V = 1000C*A*v_w$
V = Ventilation airflow, L/s
C = effectiveness factors
A = operable window area multiplied by window type reduction factor, m^2
v_w = Wind velocity multiplied by urban reduction factor, m/s
1000 = conversion from m^3/s to L/s

This equation yielded a ventilation rate of 458 L/s (970.1cfm), higher than the required ventilation rate of 94.4 L/s (200 cfm). This converts to 1251 W (4268 Btu/h) on the warmest day of the year, an insufficient amount to replace mechanical cooling. On their own, both stack ventilation and cross ventilation strategies would provide the required ventilation but not the required cooling on the warmest day of the year. However if the two strategies are combined, they could together cool Pacific during the warmest time of the year, while providing adequate ventilation during the remaining portions of the five months for which we determined passive ventilation is a viable strategy.

Opening the hallways to a portion of operable window area, 1.3m^2 (14ft^2), in each studio would yield 785 L/s (1,663.2cfm) and 2,144 W (7,318 Btu/h). Allowing the stack vents to remain as is, and combined with the partial opening of the hallway would yield a total of 819 L/s (1735.5cfm) and 4,065.5 W (13,857.3 Btu/h), which is both adequate for ventilation and cooling in the peak of summer.

3.5. Building Energy Model

For the building energy model, DesignBuilder was chosen to analyze energy use, cross ventilation and air movement via computational fluid dynamic (CFD) analysis. In the simulation, the first floor and northern segment of Pacific Hall were excluded from the simulation. All surfaces adjacent to excluded spaces were defined as adiabatic and do not contribute to heat loss or heat gain. Custom construction templates (based on modified IECC-1998 Semi-exposed, medium weight construction) were defined for the exterior wall, interior partitions, floors and windows to match the transmissive properties used in the manual calculations. Given the nature of the equipment activities and schedules associated with Pacific Hall, the “Office-OpenOff-Occ” template was used in this simulation. Steam to hot water DHW supply, radiator heating fixtures, shading from adjacent trees and contributions of adjacent buildings were additional elements that were excluded.

Given our interest in examining the potential for passive ventilation to substitute the mechanical cooling and ventilation systems, the simulation time period was constrained from May to September.

Table 1: Summer site energy EUI for case study building area

	Energy Per Total Building Area kW/m^2 [kBtu/ft^2]
Pre-Renovation	126 (39.8)
Post-Renovation	45.7 (14.5)

Simulated results for the summer season (May 1 - September 30) indicate a pre-retrofit EUI of 126 kW/m^2/summer (39.8 kBtu/ft^2/summer) and a post-retrofit EUI of 45.7 kW/m^2/summer 14.5 (kBtu/ft^2/summer), representing a 79.8 kW/m^2/summer (25.3 kBtu/ft^2/summer) or a 65% decrease in energy consumption for the simulated time period. Since the retrofitted area of 537 m^2 (5,780 ft^2) represents 23% of the total simulated area 2408.7 m^2 (25,927 ft^2), there would be a larger savings in energy over the entire building.

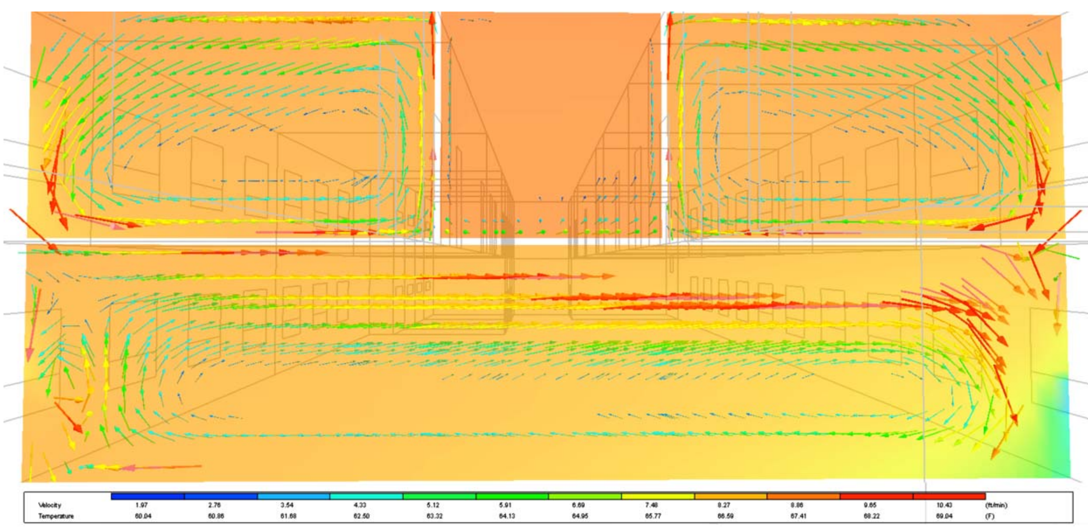


Figure 5: Computational fluid dynamics analysis illustrating the range of cool (blue) to warm (red) temperatures. The colored arrows indicate air velocity from 0.003 m^3/s (1.9 cfm) to 0.02 m^3/s (10.4 cfm).

A single CFD slice for the cross ventilation strategy through the renovated simulation model (see Fig. 5) shows a clear comparison of typical existing conditions (top floor) and typical renovated conditions (bottom floor). In the above illustration it is apparent that 1) there is a cooler and more even distribution of temperature across the building section, and 2) there is a higher velocity of air movement within the renovated building area. Both these factors will contribute to decreased energy use and increased occupancy comfort during the summer months. Due to an underestimation in difficulty of time and scope that it would take to do an accurate CFD model for the stack ventilation strategy, that component was excluded from the simulation.

Similar to the manual calculations performed, this simulation suggests that there is a net energy savings and increase in occupant comfort as a result of passive cooling. However, both the CFD and energy analyses present a scenario that is less effective than the manual calculations indicate. This discrepancy raises the question of whether the manual calculations are not accurately accounting for complex variables, or whether the simulated models are underperforming due to a lack of detail and specificity within the modelling parameters. Our inclination is toward the latter, which presents a further dilemma. Without question, digital simulations of this nature produce results and graphics that are the product of a more robust calculation, and yet this does not necessarily equate to a more informed results, but rather a result with more information. All of this underlines the importance of consulting proven strategies and guidelines during these types of investigations.

3.6. Renovation Strategy and Architectural Impact

The renovation strategy for Pacific Hall relies on both cross and stack ventilation. Since there are existing ceramic vents from each room up to the roof, minimal construction would be required to convert these to stack ventilation cavities. Each room also has enough windows to provide cross ventilation, presuming the hallway can have the same size openings installed to allow proper airflow. The illustration (see Fig. 6) shows the corridor with lowered walls to allow for cross ventilation, better light distribution through the hallway, and increased visual connections to create a sense of community between studios.

The implementation of proposed ventilation strategies would greatly benefit the internal spatial configuration of the Pacific Hall studio spaces. The partial or full removal of interior corridor walls could simultaneously improve daylighting and social characteristics of space while achieving a highly efficient ventilation strategy. In Pacific Hall, there are concerns about noise levels with the opening of the corridor walls, since every surface is concrete, however, these can be dampened with acoustic paneling.

The design was first approached by looking at the locations of the existing ducts within the breather walls and their proximity to structural columns. Many of the ducts are not longer in use, or can be moved to alternate locations. Ducts that are next to columns will remain a single mass, while the remaining breather wall cavities are seen as opportunities for low walls or pinup spaces for each studio. As the renovation iterations continued, it became clear that a series of conditions had to be met to justify the implementation of a low wall, set at 48 inches from the floor. The security of each studio was a concern when developing renovation strategies, as these studios are currently closed. However, many of the architectural studios at the university are open, with the only locks being on individual student desks. The low walls would allow for a stronger visual connection into the studios by people passing, and most importantly, they begin to open the dark hallway and create connections between the many studios.

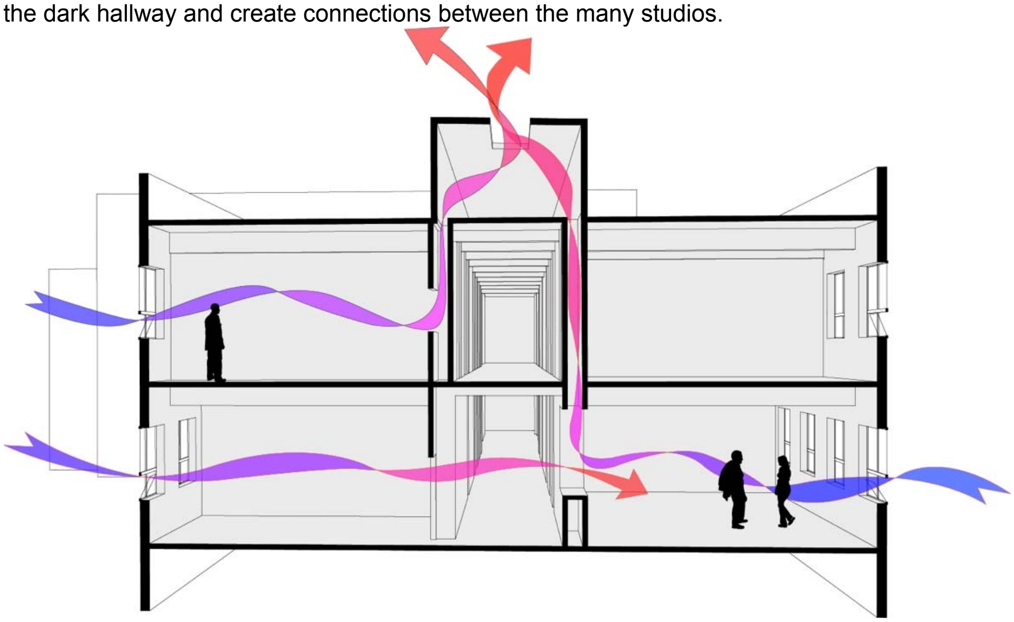


Figure 6: Renovated half walls to facilitate cross ventilation. Stack ventilation occurs through existing ductwork.

CONCLUSION

Although the building energy model and manual calculations have some discrepancies, they both reach the same conclusion that the proposed renovation in Pacific Hall would be an improvement over the current conditions. The manual calculations conclude that a hybrid strategy of cross and stack ventilation would be the best solution, while the building simulation model showed success with cross ventilation, despite the stack ventilation not being modeled.

Pacific Hall is fortunate to have existing ventilation stacks from each floor to the roof. This study found that Pacific Hall can be passively ventilated from May to September and cooled on the warmest day of the year by renovating the hallway and utilizing both cross and stack ventilation strategies. The passive ventilation reduces the EUI by 79.7 kWh/m^3 (25.3 kBtu/ft^2), which equates to a 7029.1 kWh (23,984.4 kBtu) savings per classroom, during the summer.

Despite the mostly correlating conclusions, we were surprised by the discrepancies between the two calculation methods. Each of these methods make assumptions about the surrounding conditions and the reliable amount of wind, yet the manual calculations are more sure of the feasibility of cross and stack ventilation as a combined strategy for natural ventilation. With all the new CFD and building simulation software available, as designers, we have many options for analysis. Yet, how do we rely on the accuracy of each method? Do we trust the manual calculations that have been tested over time and proven to work, or do we trust the new building simulation models that can take into account a multitude of factors? These questions are important for the profession, educators, and most importantly for the generation of future designers (students).

Many other buildings on campus can be examined in a similar evaluation of passive ventilation potential. Through this study, we have shown passive cooling to be a viable option in this typology of campus buildings with the climate of Eugene. However, implementation is not without barriers. In each building, a close look at the use of the spaces and feasibility of stack ventilation would be necessary in order to implement the same methods as Pacific Hall. In many buildings on the University of Oregon campus, which were not originally science buildings, an alternate method to stack ventilation, such as night ventilation of thermal mass might be a more viable option. Also, there are opportunities to look into advances in HVAC control and systems for hybrid ventilation strategies over the course of the year. This study serves to show the potential within many campus buildings to conserve energy during the summer months while keeping occupants comfortable. Converting even a few buildings to passive ventilation during the summer months would save the university money, reduce our carbon footprint, and help the university reach the goals agreed upon in the American College and University Presidents' Climate Commitment.

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Auto-tuning Daylight with LEDs: Sustainable Lighting for Health and Wellbeing

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ABSTRACT: While human life expectancy may be increasing due to advances in public health, technology and medicine, there are serious questions as to whether the quality of human life can keep up with this increase in longevity. Postindustrial society is experiencing a proliferation of light-related disorders and diseases specifically because our technologically-based society can operate 24 hours per day in illuminated indoor environments. Furthermore, illuminating interiors with electric lighting poses a dual dilemma: the energy efficiency of electric light versus natural daylight together with the impact of light itself on human health and wellbeing. This paper investigates sustainable design at the nexus of health, energy and technology by considering relationships between light and human health. By discussing the physiological effects of light on the body, the need for natural daylight in the human environment for improved cognitive functioning will be demonstrated. Because people spend a large portion of their time indoors, especially the elderly, unless a room is oriented to maximize light from the sun, it is necessary to illuminate the interior environment using electric light sources. However, artificially illuminating the indoors poses a sustainability issue because electric lighting is one of the largest contributors to energy consumption by buildings in the United States. Designing for older adults in health care environments, especially the elderly with age-related fragility, declining cognitive functioning and symptoms of dementia, is a particularly significant design challenge and one in which lighting can play a crucial role. To address both issues of health and sustainability, an energy-conserving diurnal daylight-matching LED luminaire is being developed to improve health outcomes for the elderly at St. Francis Country House near Philadelphia, Pennsylvania.

KEYWORDS: daylighting, health, low-energy lighting, older adults, sustainability

INTRODUCTION

The most ideal source of illumination is light from the sun, but natural daylight is not always feasible for the indoors. Illuminating interiors artificially using electricity poses a number of problems from an environmental standpoint—both for the natural environment and the indoor environment. The first dilemma has to do with lighting and sustainability; electric light uses a lot of energy, which in turn can negatively impact the environment. However, proper lighting utilization through low-energy systems that generate little heat could result in significant cooling energy savings for buildings and a smaller carbon footprint for the environment. The second dilemma is relationships between light and health; natural daylight has been shown to contribute significantly to human health and wellbeing. Natural changes in daylight synchronize and reinforce the body's circadian rhythms, which help determine sleeping and eating patterns, brain wave activity and hormone secretion to affect a cascade of responses throughout the human body. Therefore, for both improved health outcomes and energy savings, it is important to either use daylight itself in an energy-efficient manner or mimic the full spectrum of natural lighting using low-energy systems.

In this sense, sustainability becomes a broader notion than what is usually considered in architectural design, because it includes both the effects of light on human health and productivity as well as energy-efficient lighting design. The following research on this topic has been a process-based investigation that looks to nature as a way of remodeling the built environment by considering the human-building relationship as a complex, evolving ecological network (Benyus 1997). This type of approach requires a view toward indoor illumination using multiple perspectives – visual acuity, mood, chronobiology, health, energy efficiency, rapidly-changing lighting industry, etc. – in order to inform the technological development of a sustainable interior lighting system. Funded by a product innovation grant from the Green Building Alliance of Pennsylvania, an automatic diurnal daylight-matching LED luminaire is being developed for the St. Francis Country House skilled nursing facility. The goal is a daylight-matching, energy-efficient lighting system to help ameliorate symptoms of dementia in the elderly by using the non-visual aspects of light to improve cognitive functioning. To follow is a discussion of relationships between electric lighting and sustainable energy use, as well as natural daylight and its effect on health and wellbeing, to frame the rationale for auto-tuning daylight by using LEDs to develop a luminaire prototype that imitates natural light.

1.0 REVOLUTION IN LIGHTING

1.1. Light and energy use

Buildings consume 39% of the primary energy in the United States, of which approximately 18% is used by the lighting systems (DOE, 2006). Furthermore, the heat produced by a lighting system can generate up to 24% of the total building cooling load (Leslie, 2003). Proper lighting utilization through low-energy systems that generate little heat could result in significant cooling energy savings for buildings and a smaller carbon footprint. Due to studies demonstrating a connection between lighting levels and higher productivity/better performance from building occupants (Fay 2002, Leslie 2003), it is important to design a lighting system which is both sufficiently bright and energy efficient. According to the Department of Energy, solid-state lighting (SSL) technology holds the promise of reducing U.S. lighting energy usage by nearly one half by 2030, which will contribute significantly to strategies for climate change solutions. If SSL technology achieves projected price and performance attributes, then there will be even greater energy savings. It is anticipated that with advancement of the technology, light quality will improve, efficacies will increase, operating life will increase, and prices will drop (DOE 2013).

1.2. Solid-state lighting

Solid-state lighting has the potential to revolutionize the lighting market through the introduction of highly energy-efficient, longer-lasting, versatile light sources, including high-quality white light (DOE 2010). SSL refers to a type of lighting that uses semiconductor light-emitting diodes (LEDs), organic light-emitting diodes (OLED), or polymer light-emitting diodes (PLED) as sources of illumination rather than electrical filaments (used in incandescent or halogen lamps) or gas (used in arc lamps such as fluorescent lamps). The typically small mass of a solid-state electronic lighting device provides for greater resistance to shock and vibration compared to brittle glass tubes or bulbs and long, thin filament wires. SSL also eliminates filament evaporation, potentially increasing the life span of the illumination device (DOE 2013).

1.3. LED lighting

Unlike incandescent and fluorescent lamps, LEDs are not inherently white light sources. Instead, LEDs emit nearly monochromatic light, which makes them highly efficient for colored light applications such as traffic lights and exit signs, which were the first broad application of the technology. However, to be used as a general light source in building interiors, white light is needed. It is important to note that what is perceived as “white light” from the sun is actually comprised of the full spectrum of colors (Figure 1).

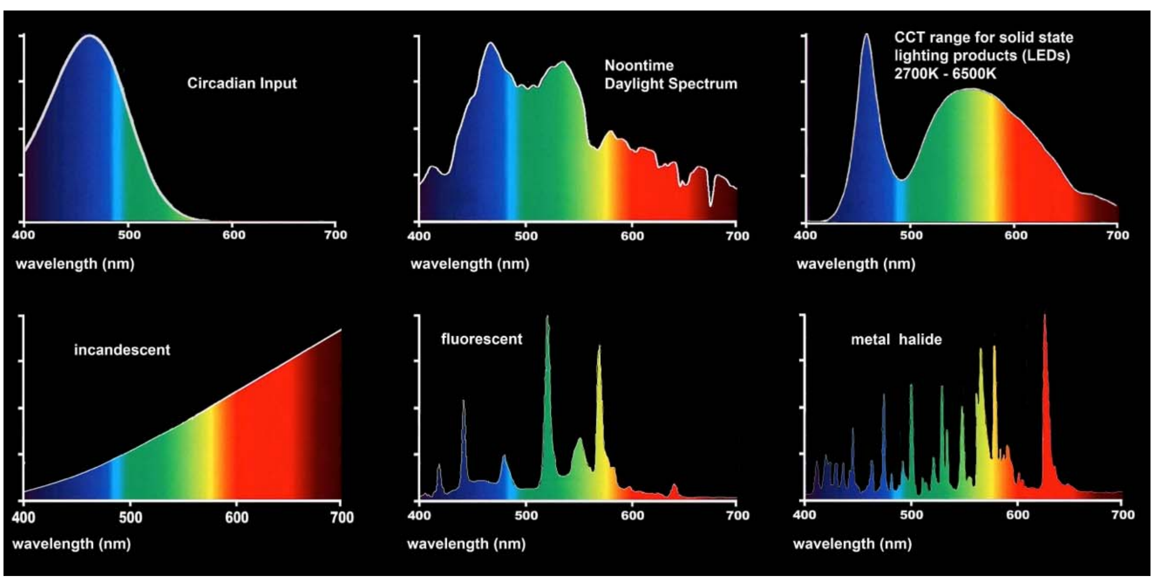

Figure 1: Comparative wavelengths for multiple light sources. Source: (adapted by author from Brainard 2010)

White light can be achieved with LEDs in three ways: 1) phosphor conversion (PC), in which a phosphor is used on or near the LED to convert the colored light to white light; 2) RGB systems, in which light from multiple monochromatic LEDs (red, green, and blue) is mixed, resulting in white light; and 3) a hybrid method, which uses both phosphor-converted and monochromatic LEDs. Their unique characteristics include: compact size, long life and ease of maintenance, resistance to breakage and vibration, good performance in cold temperatures, lack of infrared or ultraviolet emissions, instant-on performance, and the ability to be dimmed and to provide color control. Mixed LED sources have a higher theoretical maximum efficiency, potentially longer life, and allow for dynamic control of color (DOE 2013). Compared with either electric filament or gas lamps, LEDs most closely match the full spectrum of natural daylight (Figure 1).

1.4. Color Rendition

Color temperature is an important aspect of color appearance that characterizes how “cool” (bluish) or how “warm” (yellowish) nominally white light appears. Correlated Color Temperature (CCT) is a metric that characterizes the color of the emitted light from a source and is given in Kelvin (K). However, CCT distills a complex spectral power distribution to a single number, which can create discord between numerical measurements and human perception. For example, two sources with the same CCT can look different to the naked eye, one appearing greenish and the other appearing pinkish (DOE 2012).

Color Rendering Index (CRI) is a measure of fidelity or how “true” a light source appears when compared to a familiar, or reference, source. A score of 100 indicates that the source renders colors in a manner identical to the reference. However, two light sources with the same CCT and CRI may not render colors the same way (colors may still look different). Additional factors that contribute to Color Rendition include appeal (objects appear more pleasing) and discrimination (the ability of a light source to allow for a subject to distinguish between a large variety of colors when viewed simultaneously) (DOE 2012). For example, a certain tint might make red meat more appealing or a special combination of wavelengths might enable a surgeon to more easily distinguish one part of the anatomy from another during surgery.

1.5. LED futures

LEDs are individual points of light, which make it easy to mix different colors in one light source. Solid state lighting is comprised of drivers and integrated circuits, which allow for the control of LEDs individually, in series, or in clusters. For this reason, LED technology allows for the dynamic control of both light color and illumination intensity—Color Rendition a product of both the CRI of the individual LED, as well as the combination of LEDs and their intensity levels.

While SSL technology and LED lighting hold the promise of revolutionizing the lighting industry, there are considerations to keep in mind for luminaire design. A primary cause of lumen depreciation is the heat generated at the LED junction because LEDs do not emit heat as infrared radiation like other light sources. Therefore, the heat must be removed from the device by conduction or convection (DOE 2013). Characteristically, the heat is dissipated using a heat sink that pulls the heat away from the LED; this might include vents to facilitate natural convention, or an active fan, to cool the unit. Thermal management is arguably the most important aspect of successful LED system design.

While the characteristic luminaire provides illumination through the use of lamps that need to be changed out regularly (e.g. 2,000-20,000 hours for incandescent, halogen, fluorescent, metal halide, etc.), due to an extended lifespan potential of 50,000 hours, SSL lighting offers the possibility to integrate lamp and luminaire into one inseparable unit. By using LEDs, the luminaire could take the shape of an integrated fixture where the light source and fixture housing are one. The integrated luminaire could change color and intensity; the LEDS, driver and circuitry integrated into one complete, controllable, programmable system.

2.0 NATURAL DAYLIGHT AND HUMAN HEALTH

2.1. Daylight

Recent research indicates that lighting has increasingly become a public health issue (Pauley, 2004). These studies have shown that individuals working in natural sunlight are more productive, more effective, and happier than those who work under traditional artificial light (Fay 2002, Leslie 2003, Mills et. al. 2007). Natural changes in daylight balance the body’s circadian rhythm, which determines sleeping and eating patterns, brain wave activity, heart rate, cognitive functioning, and hormone production—virtually all physiological and behavioral parameters. Circadian phase shift and transmeridian travel have been shown to contribute to jetlag, seasonal affective disorder (SAD), delayed sleep phase syndrome (DSPS), and is implicated in more various diseases and disorders, including cancer (Roberts 2001). In industrialized nations it is estimated that up to 20% of the workforce is involved in some kind of shift work (Webb, 2006), which is associated with exposure to unusual or abnormal levels and/or patterns of light and dark. Studies have associated these unusual levels and patterns with higher incidences of breast cancer and colorectal cancers, as evidenced by those people involved in shift work (Aanonsen 1959, Akestedt and Gillber 1981, Czeisler et. al. 1990, Pauley, 2004). These studies reinforce the notion that the sustainability of human productivity and wellbeing, even life itself, is directly tied to environmental lighting.

To maintain health and save energy it is important to either use or *mimic the full spectrum of natural lighting*. Ocular light, or light reaching the eye, has both visual and non-visual effects on the body: 1) vision and 2) synchronization of circadian rhythms (Roberts 2008). The synchronization of circadian rhythms is one of the most significant non-visual effects of light. Circadian rhythms are regulated by changes in visible light from the sun throughout the day (Aschoff 1965) and are normally controlled daily by the full spectrum of natural light (photopic vision) together with darkness in the environment (scotopic vision). The full spectrum of light includes UVA, UVB and visible light: at noon there is high intensity in the blue light region, in the late afternoon blue light is preferentially scattered out of (removed from) incoming sunlight so that the late afternoon sun provides red and orange light, and when the sun sets it becomes dark. Circadian rhythms are controlled primarily by daily exposure to levels of light in the blue-green spectrum, concentrated in the wavelength region 446-477nm (Brainard 2001), together with alternating darkness in the environment. Blue light triggers the production of serotonin in the body, which enhances alertness and cognitive performance, while red or amber light signals the onset of dusk; the absence of light encourages melatonin secretion (Kaplan 1995, Roberts 2001, Brainard 2001, Lubkin et. al. 2002).

In architectural design, the challenge is to either provide daylight, *or mimic daylight* using artificial light sources, and ensure that lighting levels and color temperature change throughout the day in sync with nature's rhythms—including darkness at night. The *wavelength* of light absorbed by the body together with the *timing* of that light are the two most important factors for a biological effect. Returning buildings to a more natural light environment through the use of daylighting, or mimicking the full spectrum of natural light, would be energy efficient and would promote wellbeing.

2.2. Inner vision

In addition to object recognition—visual information—light provides data on the timing and intensity of light and dark in order to synchronize the body's biological rhythms. This non-visual photonic information is transmitted from the eye to the suprachiasmatic nuclei (SCN) located in the hypothalamic region in the center of the brain, which trigger a cascade of hormonal changes in the pituitary, pineal, adrenal and thyroid glands. Neural activity within the SCN modulates the release of pituitary hormones and the release of melatonin from the pineal gland. Through this and other pathways, the SCN synchronizes the circadian rhythms that regulate and modify virtually every physiological and behavioral process in the human body (Brainard 2010). The SCN controls a variety of events in the body including temperature, reproductive cycles, appetite, and mood. Circadian rhythms are phase shifted by visible light, which also suppresses melatonin production. When this process is disrupted through environmental light changes, it can lead to damaging emotional and physiological effects such as those associated with seasonal affective disorder, jet lag, delayed sleep phase syndrome, and may exacerbate serious conditions such as cancer.

2.3. Chronobioengineering

The emerging field of chronobioengineering is providing a new paradigm for health care design. *Chronobiology* is a field of biology that examines periodic (cyclic) phenomena in living organisms and their adaptation to solar- and lunar-related rhythms; whereas, *photobiology* is the scientific study of the interactions of light on living organisms such as the effect of light on circadian rhythms. *Chronobioengineering* translates these observations and concepts into practical applications (McEachron 2012), such as the automatic diurnal daylight-matching LED luminaire being developed for the St. Francis Country House skilled nursing facility. Designing for older adults in health care environments, especially the elderly with symptoms of dementia, is a very special and significant design challenge for health care architects, and lighting can play a crucial role (Noell-Waggoner 2004, 2006, ANSI/IESNA 2007).

2.4. Design for older adults

Residents in dementia units of skilled nursing facilities have special needs beyond the characteristic assistance with activities of daily living (ADL). Because their internal circadian clocks are out of sync with nature's rhythms, residents experience "sundowner's," or agitated behavior toward the end of the day, and difficulty sleeping at night (Wu and Swabb 2005). Additionally, residents exhibit a need for mobility and wandering (Doliansky and Dagan, 2006). Many of these symptoms have been linked to the disruption of biological rhythms (Wu and Swabb 2007). These symptoms reduce the quality of life of the individual with dementia, while sleep disruptions and behavioral disturbances also contribute to the burden on family and formal (paid) caregivers. In addition to the disease itself, symptoms are exacerbated due to institutional lighting levels that not only do not provide residents with the biologically required full spectrum of changing lighting levels throughout the day, but also do not provide total darkness at night—difficult to do when caregivers need to work throughout the night monitoring patient health and safety, as well as fulfilling their administrative tasks. While many skilled nursing facilities are often designed with sunrooms for their residents, it is not always possible to bring the residents to the daylight or the daylight to building interiors. Research has shown that dementia patients tend to receive significantly less exposure to environmental light than people living in the community (Campbell 1988, Mishima 2001). Due to the aging of the eye that leads to opacification and yellowing of the vitreous and the lens, circadian photoreception is compromised (Turner and Mainster 2012), which when coupled with the indoor lifestyle of the elderly (Torrington 2007) contributes to an overall out of sync circadian rhythmicity.

Links have been made between sundowning and the circadian timing system; studies have shown that bright light therapy can have some effect in reducing agitation and improving sleep for people with dementia (Burns 2009). While some researchers disagree as to the exact level of light required (Deschenes 2009), studies have shown that it is necessary to provide dementia residents with a minimum of 1000 lux “in the gaze direction” (vertical illuminances) for a significant portion of the day (Riemersma-van der Lek 2008, van Hoof 2009); however, for older adults with aged eye tissue, the illuminance levels may need to be at least 3 times higher due to the diminished light transmittance of the eye (Van Someren 1997, Aarts 2005, Sinoo 2011). Age-related losses in retinal illumination are reasonably uniform over time, with a ten percent loss per ten years of aging. Thus, a ninety-year-old would require ten times the light of a 10-year-old for similar photoreception. Effect on circadian rhythmicity is further exacerbated with age because the shorter violet and blue wavelengths (400-500nm) are most affected by yellowing of the aging eye (Turner and Mainster 2012). Latest research indicates that high-intensity light of at least 2500 to 3000 lux with a high CCT (6500K) improves circadian rhythmicity in institutionalized older adults with dementia and can reduce or alleviate insomnia; increase sleep efficiency, total sleep time, and restorative slow-wave sleep; and improve daytime vigilance and nighttime sleepiness (van Hoof 2009, Turner 2010, Sinoo 2011). Figure 2 depicts one Lighting Schedule being tested. This schedule slowly increases lighting levels upon residents’ awakening, peaks light intensity and CCT around the noontime hour, maintains relatively high lighting levels for the rest of the day for vision and visual acuity, and then the light intensity slowly “sets” to a low-level red for nighttime hours. Initially, the light will be installed in community rooms and corridors; levels and wavelength will be modified based on patient outcomes.

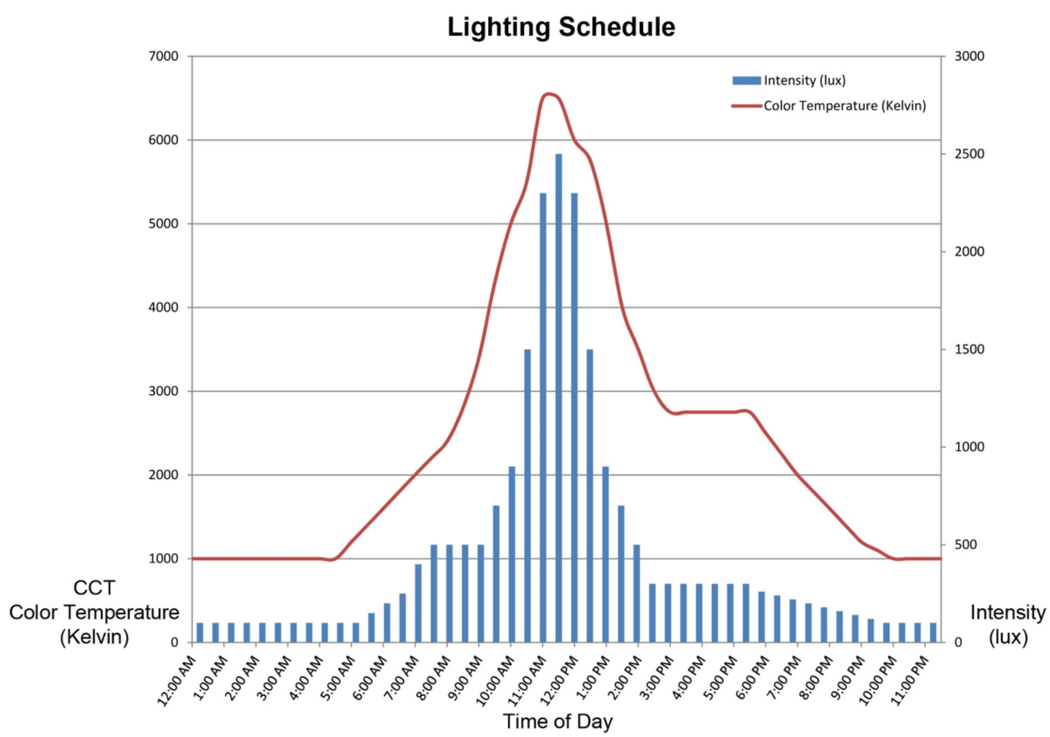

Figure 2: Lighting Schedule. Source: (authors)

3.0 AUTO-TUNING DAYLIGHT USING LED TECHNOLOGY

3.1. Introduction

Maintaining circadian rhythmicity in a postindustrial society is becoming increasingly difficult for a culture that spends a disproportionate amount of time indoors in artificially illuminated environments facing electronic screens that largely emit light in the blue spectrum. However, technological advances in the lighting industry are making it possible to create a more naturalistic indoor environment to support human biological rhythms and to improve cognitive functioning, especially for people with deteriorating systems. The technology of solid state lighting is making it possible to seamlessly imitate the lighting of the natural environment.

The hypothesis is that sleep patterns and global functioning of residents will improve. The goal is to help ameliorate symptoms of dementia in the elderly by using the non-visual aspects of light to improve cognitive functioning. Considerations include: 1) patient attention and concentration, 2) changes in vision due to the aging eye, 3) limited mobility, 4) wandering due to Alzheimer's disease and effects of "sundowning", and 5) difficulty sleeping.

3.2. Fixture design

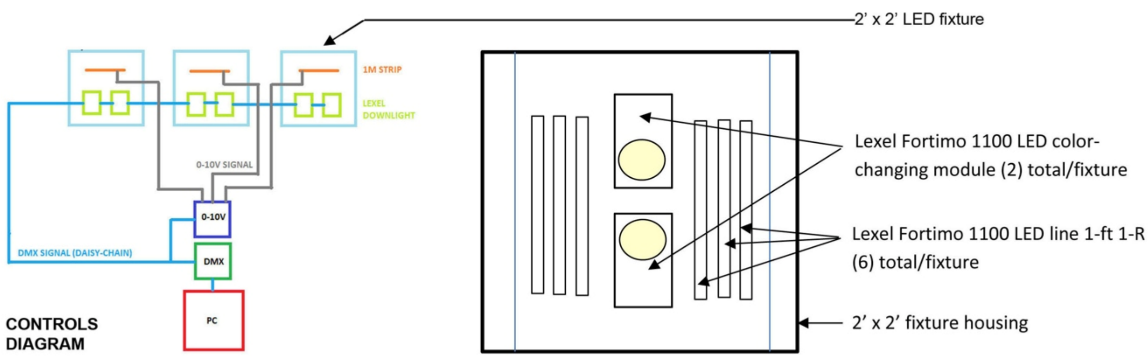

Figure 3: Fixture Design. Source: (authors)

Funded by a product innovation grant from the Green Building Alliance of Pennsylvania, researchers are developing an automatic diurnal daylight-matching LED luminaire for the St. Francis Country House skilled nursing facility. The retrofit 2'x2' LED luminaire will replace the existing traditional fluorescent artificial lighting. This LED luminaire will mimic the full spectrum of natural daylighting, including darkness at night—darkness will be achieved by using red LEDs, which are not recognized by the body as light for the circadian system. The LED luminaire is comprised of Philips Lighting components: (2) Lexel Fortimo 1100 LED color-changing DLM modules and (6) Lexel Fortimo 1100 LED lines to achieve the intense white light required at midday (Figure 3). The color-changing DLM modules are daisy-chained together using DMX cable to an interface and then to a computer to control intensity levels and emitted colors; a similar system is used by the music industry for audio controls to mix sounds (Figure 4). The white LEDs are simply dimmed.

3.3. Auto-tuning daylight

The advanced technology of solid state lighting is based on electronics and integrated circuitry controlled by drivers that can turn individual or groups of LEDs on or off, can dim them, and can connect them individually, or in series, or can daisy-chain groups of LEDs together. LED controls operate like an audio mixer in a recording studio; like mixing sound from multiple sources, LED controls have the capability to mix different colors of light. Auto-Tune is recent technology in the music industry, which is an audio processor created to measure and alter pitch in vocal and instrumental music recording and performances to correct off-key inaccuracies, allowing vocal tracks to be perfectly tuned despite originally being slightly off-key. In other words, auto-tuning synthesizes sound to match perfect pitch. Similarly, the LED luminaire being developed will auto-tune interior lighting to mimic the full spectrum of natural daylight throughout the day considering CCT, CRI and Color Rendition "tuned" for older adults. This would then provide quality illumination for visual tasks and help synchronize biological rhythms for better health, cognitive ability and performance. The theory is that by auto-tuning daylight with LEDs, a sustainable integrated LED luminaire can visualize energy efficiency and produce the non-visual lighting effects needed for human health, wellbeing and performance.

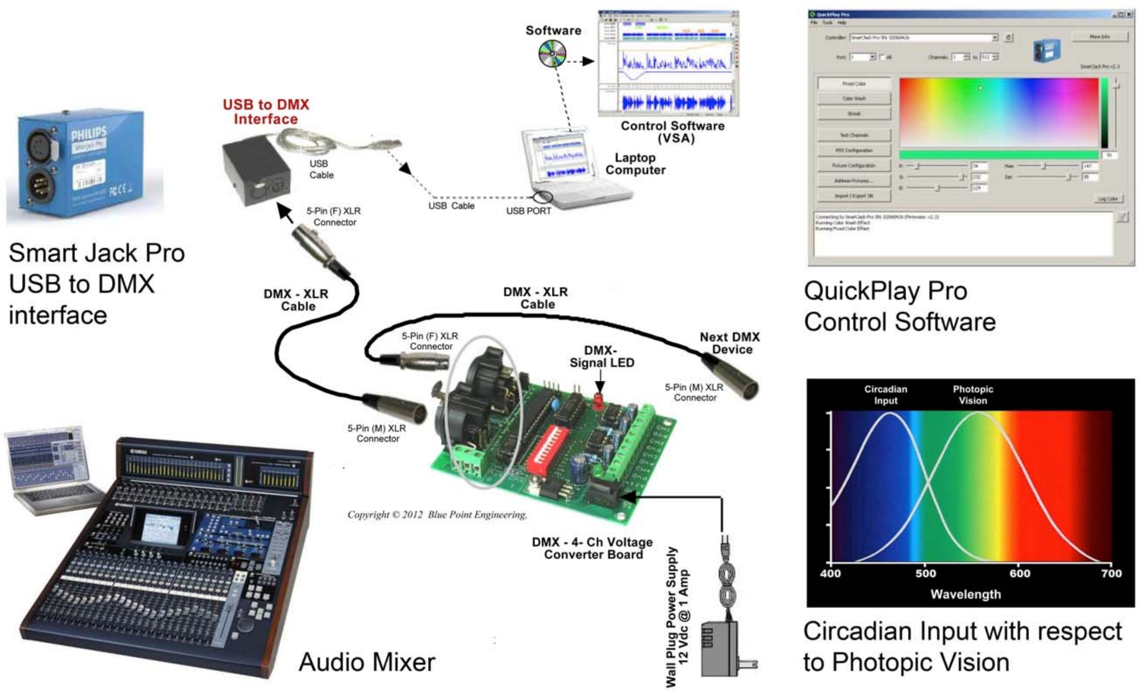

Figure 4: Lighting control system. Source: (Blue Point Engineering, Philips Lighting, QuickPlay Pro)

3.4. Current state of the art

There are a number of products on the market that claim to supply "full spectrum"[1] lighting in the form of CFL and induction lamp[2] luminaires, as well as a number of "dawn simulators". These "full spectrum" lighting products can provide consistent lighting levels using the full spectrum of *noontime* sunlight (Figure 1, metal halide and fluorescent). Some of these fixtures can be dimmable, but none of these products are capable of actually mimicking the full spectrum of natural daylight in both color temperature and light intensity. While CFL and induction lamp light sources can be energy-efficient, neither have the ability to change color throughout the day. Incandescent light is closer in color temperature to late afternoon light when blue light is preferentially scattered out of (removed) from incoming sunlight, when the late afternoon sun begins to turn red and daylight turns to orange light. On the other hand, it is possible through a combination of white and RGB (red, green, blue) LEDs to program the lights to change color throughout the day to actually mimic the full spectrum of natural daylight from dawn to dusk; to change the color from the rising sun to the setting sun and to illuminate building interiors with a low-intensity red light throughout the nighttime hours.

Energy use for this system was calculated and compared with a typical fluorescent fixture. While the LED system is a dynamic system, the calculations were based on average conditions for nighttime, daytime and noonday peak intensity for four hours per day. The fluorescent system was calculated considering an 8-hour nighttime condition of one-third illumination. Preliminary calculations indicate there would be a cost savings of 0.0538kWh/day/m^2. Considering there is close to 185,806,080m^2 of large hospital building floor space in the United States, of which up to approximately 25 percent could be circulation space in use 24/7, this could mean a significant savings in energy consumption and reduction of carbon footprint (EIA 2007).

3.5. LEDs and sustainability

Department of Energy research has shown that LED solid state lighting is more energy-efficient and longer lasting with lower lifecycle costs than other light sources (DOE 2010). Most significantly for this research project, the integrated LED luminaire has been documented by the University of Pittsburgh to be the best lighting technology from an environmental perspective, especially since LED lighting contains no mercury. The ecotoxicity of LED lighting lies primarily with the printed circuit boards and integrated circuits, as well as with the manufacturing process of the LED bulbs (Hartley 2009), both of which are a major component of this project. While the "full spectrum" lighting products currently on the market are manually dimmable, which gives the owner lighting control, these products are not automatically programmable to provide the recommended light intensity and color spectrum for time of day. These lighting systems are neither FDA-approved nor can they be prescribed by a doctor as therapy to ameliorate sleep disturbances.

CONCLUSION

Research has shown LED solid state lighting to be more energy-efficient and longer lasting with lower lifecycle costs than other light sources *and* that natural daylight controls the body's circadian rhythms and affects overall wellbeing. The objective of this project is an automatic diurnal daylight-matching LED luminaire appropriate for institutional settings. Moreover, this system satisfies the following criteria: 1) an integrated LED luminaire with changeable light source; 2) programmed to mimic natural daylighting in its full diurnal changing color spectrum and light intensity; 3) energy-conserving to operate 24 hours/day; 4) dims to the red spectrum to allow residents to go to sleep and still provide caregivers with the illumination levels they require to continue working and providing care to residents in need during the night; 5) constructed using sustainable materials; and 6) appropriate for retrofit conditions requiring minimal construction installation. This LED luminaire addresses the dual sustainability issues of energy efficiency and health/wellbeing of building occupants.

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ENDNOTES

[1] According to manufacturer Full Spectrum Solutions, “Full Spectrum Lighting is considered to be any lamp with a color temperature between 5000K and 6000K with a CRI of 90+”.

[2] BlueMax™ HD induction lamp By U.S. Patent #6,318,880 Lawrence Berkeley National Laboratory.

Energy Consumption Monitors: Building Occupant Understanding and Behavior

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ABSTRACT: Architects can help reduce CO2 emissions from buildings by helping occupants understand their energy usage, and providing motivation for behavioral changes. One of the most promising technologies being developed are energy monitors, which have shown the potential to reduce energy usage by providing building occupants the opportunity to understand and alter energy consumption. This paper analyzes existing studies of energy monitors, in particular the theories behind their design and the methods employed in testing these theories. Analysis of the studies raises some basic questions such as: what behavioral models are used in the design of the monitors, what information do these monitors provide, and do users really understand the information provided to them? Findings suggest that many aspects of energy monitor design and information communication can have an impact on energy consumption, but that this impact has limits. They also suggest that this potential is not yet fully understood, and that there are many aspects of energy consumption and behavioral motivations that could be explored in future studies.

KEYWORDS: energy monitors, energy behaviors, energy consumption, user interface, buildings

INTRODUCTION

Imagine that you go home, walk in the door, and turn on your lights. How much power are you using? How much is it costing you? What fuel source is the electricity being generated from? Building occupants are responsible for energy consumed in buildings, but often lack basic information about their consumption. It can be complicated to associate activities of energy consumption with effects of use or amount used without understandable and accessible information (Burgess and Nye 2008). This lack of transparency results in a situation of *double-invisibility* where occupants cannot tell quantities of energy being used in the home, and later cannot connect information to previous actions (Burgess and Nye 2008). Without this information, it is difficult for occupants to be motivated or make intelligent changes in behavior.

If we could remove buildings from the energy load of the United States, we would eliminate the largest consumer of energy and producer of carbon dioxide (CO2) emissions in the country. Buildings in the United States consumed 41% of *primary energy* in the country and 7% of total primary energy worldwide in 2010 (D&R International, Ltd. 2012). In the past several years there has been a large push for architects to help curb CO2 emissions from buildings through design. The 2030 Challenge has asked for buildings to become *carbon-neutral* [producing no CO2 emissions] by the year 2030 (Architecture 2030 2012). The idea that the building design and systems are the sole determinant of energy usage is not accurate though. While the efficiency of design and technology impact energy consumption, they are the mediums of consumption and occupant need and behavior are the generators and determinants of consumption. Peschiera, Taylor, and Siegel (2010, 1329) point out, “there is tremendous potential for reducing greenhouse gas emissions by motivating energy efficient behavior.” In seeking to reduce CO2 emissions from buildings architects must consider the potential of building occupant behavior as well as that of building design. Giving occupants understandable information about their energy consumption is a first step in helping them understand this problem, and their ability to change it.

Architects have traditionally sought to address the problem of CO2 emissions through the use of efficient building design and technological improvements in building materials and systems. The organization Architecture 2030 suggests reducing emissions through design, *integrating technologies*, and using *renewable energy sources* (Architecture 2030 2012). The green building rating system Leadership in Energy and Environmental Design (LEED) suggests options such as *optimizing energy performance*, *measurement and verification*, and *on-site renewable energy sources* (USGBC 2012). While these improvements in buildings can certainly abate emissions, they are one-sided solutions that don’t address the significance of occupant energy behavior in buildings. The problem of CO2 emissions from buildings is the complex result of many contributing factors, and will require a solution that addresses both physical and behavioral variables.

1.0 The Problem

Energy monitoring has been studied as a method to help occupants understand their energy usage and in turn reduce their consumption. Jain, Taylor, and Peschiera (2012) established in their review of previous studies that both simple and complex monitors demonstrated energy savings ranging between 5% and 55%. Many studies have asserted that these monitors have the ability to help occupants reduce their energy consumption, but found this reduction often to be limited and temporary (Chen et al. 2012; Hargreaves, Nye, and Burgess 2012; Hargreaves, Nye, and Burgess 2010; Peschiera, Taylor, and Siegel 2010). These studies suggest that energy monitoring has the potential to help reduce energy consumption through behavior, but have not been able to define or sustain that potential. Understanding why this has happened will help shape future studies examining how this information can be used to influence building occupant behavior.

Fields such as business, psychology, design, and engineering have used a large variety of design, theoretical, and methodological approaches in studying energy monitors (Table 1). This has resulted in vast information, but information that is varied, complicated to compare from one study to another, and sometimes contradictory. Additionally, it is often difficult to separate theory from design, as one is used as a medium to test another, and studies thus begin measuring one unknown with another. For example, Jain, Taylor, and Peschiera (2012) noted in their review of studies that some of the fluctuation in savings could be caused by the unique characteristics between *interfaces*. This acknowledges the difference that variation in design of the graphic user interfaces (GUIs) could have on the study results. Researchers need to know what information is valid and why it is valid to inform future studies.

Table 1: Theories and models used in energy monitor studies

Theory/Model	*Explanation*
Information-Deficit Model	The idea that providing more information about energy consumption will create understanding and that users will automatically make behavioral changes given this knowledge and thus reduce their consumption (Hargreaves, Nye, and Burgess 2010).
Social-Norms Theory	Postulates that users will not want to stray from what is considered the *descriptive norm*, or the definition of what is usually done (Schultz et al. 2007).
Focus Theory of Normative Conduct	Differentiates between *descriptive* or *injunctive* nature of norms, injunctive being what is usually approved or disapproved (Kallgren, Reno, and Cialdini 2000).
Social Network Theory	In threshold models the possibility that someone will assume a behavior can be related to the number of contacts within a social network who have the same behavior (Peschiera and Taylor 2012).
Feedback Intervention Theory	“FIT has five basic arguments: (a) Behavior is regulated by comparison of feedback to goals or standards, (b) goals or standards are organized hierarchically, (c) attention is limited and therefore only *feedback-standard gaps* that receive attention actively participate in behavioral regulation, (d) attention is normally directed to a moderate level of the hierarchy, and (e) FIs change the locus of attention and therefore affect behavior” (Kluger and DeNisi 1996, 259).
Computers As Persuasive Technology (CAPTology)	**“CAPT-ology aims to alter the mindsets, attitudes, and behaviors of users via machine–user interaction, program design, and research and analysis in conjunction with other means, excluding coercion” (Chen et al. 2012, 107).**

Beyond research design issues, there are several aspects of occupant understanding and motivation that remain to be explored or explained. Some of the most basic building blocks to understanding and behavior change, such as a comprehension of energy information, are not present in building occupants. In studying preferences for electricity feedback Karjalainen (2011) found that consumers couldn’t differentiate between watts or kilowatt-hours (kWh) and didn’t know how carbon dioxide emissions were related to electricity use. Bonino, Corno, and De Russis (2012, 385) also found that “…householders hardly understand energy usage in kWh…” In contrast, most people who own a car can describe how much they pay for a gallon of gas, how far a full tank of gas can take them, and how many mpg their car gets. One could theorize that information which building occupants don’t really understand might not be very effective in motivating them to change behaviors, and this lack of understanding could affect study results.

2.0 Theories and Methods in Monitor Design and Research

The task of studying energy monitors is multi disciplinary pulling together knowledge from computer science, psychology, social sciences, and economic sciences, etc. For example Chen et al. (2012) used *persuasive technology theory*, which is based in computer science, whereas Peschiera and Taylor (2012) used *social network theory* out of social behavioral sciences. As much as technology cannot be isolated from behavior in this topic, neither can the theories be isolated from the design of elements used to test them. Arguably several theories are already inherited based on design choices and purpose of the monitor itself (Table 2). For example, any monitor that uses a normative feature is already testing the theory of social norms. This complicates the opportunity to validate one theory superior to another.

Table 2: Information Options and related theories/models

Information Option	*Explanation*	*Theories/Models Drawn On*
Historical	Information about past energy consumption.	• Information Deficit Model
Disaggregated	Energy consumption is broken down by appliance load.	• Information Deficit Model
Normative: Descriptive	Information about other users consumption, what the *social norm* or *descriptive norm* is.	• Social-Norms Theory
Normative: Injunctive	Information about what levels of consumption are approved or disapproved, what the *injunctive norm* is.	• Social Norms Theory • Focus Theory of Normative Conduct
Goals	The ability to set a goal.	• Feedback Intervention Theory
Rewards/Penalties	Rewards or penalties are offered based on consumption patterns.	• Feedback Intervention Theory • Social Norms Theory

In methodological approach, previous energy monitor research can be divided into two categories: those studies which seek a solution in the monitor, and those which seek a solution in occupant understanding of energy, and understanding of the occupant energy behaviors. For example Jain, Taylor, and Peschiera (2012) sought to measure the relationship of user interaction with features to energy consumption. Meanwhile Hargreaves, Nye, and Burgess (2013) sought to fill a knowledge gap by using qualitative methods over a longer time period to review the impacts of energy monitors on energy use. These studies covered a spectrum from monitor feature design to energy behavior, but often only focused on one end of this spectrum. Studies that measured monitor features did not explain why features failed or succeeded, and studies that examined occupants and context didn’t measure the monitors in actual use. Both sides of this spectrum need to work congruently in order to address the problem of emissions.

2.1 Design as an Agent to Reduce Consumption

Studies that have focused on the monitor as an agent for reduced consumption have drawn on various design models, behavioral models and theories through the medium of information options and representations. Wood and Newborough (2007, 495) asserted that the largest savings from the most users would come from a monitor interface with an “optimal design arrangement”. Examining the studies of Chen et al. (2012), Jain, Taylor, and Peschiera (2012), Peschiera and Taylor (2012), and Peschiera, Taylor, and Siegel (2010) this seems to have been interpreted as meaning that finding the correct theory representing the optimal monitor design would result in the greatest savings. For instance, Jain, Taylor, and Peschiera (2012) wanted to test how different design components would affect interaction and energy consumption. Chen et al. (2012) wanted to test whether their monitor could portray information in a way that would be persuasive by creating an emotional response. Using monitors with only one design option to test theories inadvertently tests not only the theory, but the design of features as well, making it sometimes impossible to distinguish if the theory behind a feature or the design of the feature contributed to its success or failure. Furthermore designs that might be affective for one user may not necessarily be affective for another, and in seeking to accommodate all users this must be considered.

Historically the information deficit model has been the standard ‘go-to model’ in attempts to motivate behavior changes which impact the environment, with the idea that a lack of knowledge is what prevents people from making decisions that don’t harm the environment. However, education and encouragement have not been effective in changing behaviors (McKenzie-Mohr 2000). Furthermore consumer studies have found that people often behave or make energy choices based on needs which they deem more important than saving energy or money (Wallenborn, Orsini, and Vanhaverbeke 2011). This information points towards the failure of the information deficit model as a standalone solution to changing energy behaviors, although examination of a behavioral model for persuasive design developed by Fogg (2009) points toward the necessity of this information as simply one aspect in increasing the likelihood of behavioral changes, along with motivation and triggers. While only Chen et al. (2012) explicitly acknowledged their testing of *CAPTology*, or persuasive design, it could be argued that each of these studies is using persuasive design methods as each are designing feedback monitors on machines with the ultimate goal of changing behavior.

Both social norm theory and focus theory of normative conduct were used in many studies through providing normative information, which proved to have more success than just individual historical information. Providing information about the energy consumption of other occupants used social norm theory, and focus theory of normative conduct was used in providing information that also held judgment, portraying energy consumption as positive or negative in the eyes of society. Social norm theory was employed in Chen et al. (2012), Jain, Taylor, and Peschiera (2012), Peschiera and Taylor (2012), and Peschiera, Taylor, and Siegel (2010) through the use of normative information. Chen et al. (2012) also used focus theory of normative conduct to some degree as their information framing portrayed increased energy consumption as harmful or negative. Peschiera and Taylor (2012) tested social network theory as they compared what impact the relevance of network member consumption had on individual consumption. These theories and their employment in the studies demonstrated potential in contributing to behavioral changes.

While ultimately each of theses experimental studies tested a behavioral model, it was conveyed through a treatment that utilized information options and representations as a medium. Information options used in studies included historical, injunctive, disaggregated, rewards/penalties, and incentives/goals
(Chen et al. 2012; Jain, Taylor, and Peschiera 2012; Peschiera and Taylor 2012; Peschiera, Taylor, and Siegel 2010). Each of these data options offer a different way to interpret information and to some degree tests a model or theory about how different information can impact behavior. Additionally information framing was used as information representation options used in these studies included kilowatt/hours (kWh), simple comparison, or animals (Chen et al. 2012; Jain, Taylor, and Peschiera 2012; Peschiera and Taylor 2012; Peschiera, Taylor, and Siegel 2010). Chen et al. (2012) sought to frame information in a way that would have a positive or negative emotional impact on users by representing energy consumption through an increased or decreased diversity of animal life forms. This example of information framing demonstrates the potential power of information to become more than just numbers, to go beyond the information deficit model, and to tap into the influence of emotion and the role it plays in behavior.

A problem encountered in studies which seek to quantify the effectiveness of these theories or features is that if a monitor's design affects the ability of users to understand and interpret the information, then one could assert that variation in designs could result in variation in findings even from studies that test the same aspects of a monitor. In designing these monitor studies not only used various behavioral theory and design methods, but also drew heavily on literature review to define which features and methods of information framing might be relevant. This seems to have raised some questions about how design may have affected the results of their research. For example Jain, Taylor, and Peschiera (2012) used a *disaggregated* information option, which Karjalainen's (2011) study had indicated users wanted, but their findings didn't support. Jain, Taylor, and Peschiera (2012) goes on to point out that in general:

> Furthermore, results for components that were not supported must be taken as inconclusive because usage data could have been impacted by the idiosyncratic design of these components in the eco-feedback interface studied. (15)

If it is true that results form unsuccessful components could be the result of design, could not also the successful results be from design impact? The findings of these studies should be considered in light of this information. The design of a monitor can affect the users ability to understand and interpret information, and this in turn could affect his or her ability or desire to utilize the monitor or change behavioral patterns.

These studies used measurement to collect data and statistical analysis to interpret that data and determine whether their treatments had been successful or not. In the case of Chen et al. (2012) a questionnaire was also used to gain user feedback. Primarily quantitative studies used measurement of electricity to assess savings and Jain, Taylor, and Peschiera (2012) also used click stream data to measure interaction. Studies then looked for a statistically significant correlation in data. Peschiera and Taylor (2012), Jain, Taylor, and Peschiera (2012), and Peschiera, Taylor, and Siegel (2010) all had a control group to compare data against, and both Chen et al. (2012) and Jain, Taylor, and Peschiera (2012) used an energy consumption baseline from a pre-study period. While these methods did yield statistically significant correlations of energy consumption reduction, they are not able to provide causal evidence or explain if occupants understood the information that was presented to them.

Study results showed that users who interacted more with the monitor and those who could view personalized normative information reduced their energy consumption, but this reduction was temporary, with the exception of Peschiera and Taylor (2012). In studying interaction Jain, Taylor, and Peschiera (2012) found that users who had increased their consumption over the study period had logged into the monitor only half as often as those who had reduced consumption. Chen et al. (2012) and Peschiera, Taylor, and Siegel (2010) both observed initial savings, but these were not sustained for the duration of the study. In the case of Chen et al. (2012) a falloff period happened mid-study where occupants returned to before study levels of usage with one study group, and the other group experienced an increased spike in usage the last week as well. Whereas Peschiera, Taylor, and Siegel (2010) found that:

> In every instance that a group showed significant improvement after receipt of an electricity consumption profile, three days later behavior would essentially relapse to pre-study utilization levels. (1336)

Peschiera and Taylor (2012) found that personalized network normative information was more effective in reducing energy consumption than impersonalized information. Peschiera and Taylor (2012) also point out that this verified the findings of Peschiera, Taylor, and Siegel (2010) over three weeks rather than three days. This time period could have followed the trajectory of Chen et al. (2012) though, and a longer study period is needed to verify that *user fatigue* will not occur. These findings show that while there is potential in certain monitor design information options and representations to help occupants reduce consumption, that potential unaided is not enough to produce sustained reductions.

The results of these studies have opened many areas of potential research, from learning about user understanding to addressing the problem of consistency in savings. Chen et al. (2012) suggested investigating user fatigue, and Peschiera, Taylor, and Siegel (2010) called for a better understanding of how external factors affected this condition. Peschiera, Taylor, and Siegel (2010) also suggested that future studies might instigate and examine and the impacts of monitors on social interaction and discussion. All of these suggestions point towards a better understanding of users, their interaction with these devices, and their context of use. The dependency of these studies on unmeasured factors beyond the display, and in most cases not well explained in depth, may be responsible for experienced *user fatigue* or monitor feature failures. As pointed out by Chen et al. (2012, 111) the spaces being tested are not “condition-controlled experimental environments” but rather are normal working school spaces with the behavioral influences of those contexts. In seeking to communicate information to occupants and influence behaviors more research needs to be conducted that takes into account the external factors of a non *condition-controlled experimental environments.* We need to understand energy consumption behaviors, as they exist in the context of building space usage.

2.2 Occupants As an Agent to Reduce Consumption

Studies that have sought a solution in user understanding and behavior have sought to design information for user understanding, assessing what users think, and how they behave. The studies of Bonino, Corno, and De Russis (2012) and Karjalainen (2011) both have monitor designs that were created, but the point of these studies is not to measure the efficiency of these designs, but to assess if users can understand the information communicated. Karjalainen (2011) studied which type of information display people wanted to see and understood. Hargreaves, Nye, and Burgess (2013) focused on gathering user feedback from those living with a commercial monitor for a year, specifically on what types of social dynamics developed around and from interaction with the monitor. These studies do not offer the same statistical evidence as those which sought a solution in monitor design, but instead offer empirical data about user understanding and behaviors. In seeking to communicate information to users and influence behaviors, it is logical that this cannot be done without a prior proper understanding of the users current state of understanding and behavior.

In the studies that focused on user understanding of information, user-centered design methods were adopted to guide the monitor design and to some degree persuasive behavioral models were used, though this is not explicitly stated. Karjalainen (2011) used *human-computer interaction guidelines* for developing prototypes of energy consumption with both graphical and numerical data. Bonino, Corno, and De Russis (2012) employed user-centered design in their survey that assesses user understanding and approval of an energy monitor shown in use. In a review of previous studies Bonino, Corno, and De Russis (2012, 385) notes that they found “Psychological implications of energy displays and interaction paradigms may also influence the effectiveness of IHD’s [In-home Displays]…” This approach is intended to gain understanding of what occupants understand and need from energy monitors. Since purpose of these monitors as a persuasive technology is to give users the motivation, abilities, and triggers to make behavioral changes, gaining an understanding of how those needs translate into monitor features from the users perspective is an important aspect of the design process.

The study done by Hargreaves, Nye, and Burgess (2013) explores this idea more in depth through its use of grounded theory of long term (12 months) user experience of monitors in a home environment to fill an existing research gap. Hargreaves, Nye, and Burgess (2013) also points out that many studies treat the context of use as a *black box* which obscures context conditions which might affect energy usage. This heuristic approach allows the black box to be lifted and the context of the experience of using an energy monitor to be revealed in a long-term setting. This type of research could be a powerful tool in combination with energy data and post occupancy evaluations to start explaining energy behaviors.

The user-based design studies used information options and representation, as the experimental studies had, as a medium of communication. Karjalainen (2011) utilized different combinations of historical, normative, disaggregation, or incentive options in the representation of charts, pictorials, tables, numbers and text using units of kWh, watts, monetary costs, or environmental damage (CO2). This wide range of options resulted in eight distinct interface prototypes. Bonino, Corno, and De Russis (2012) chose to create a prototype that was demonstrated in action through video simulation. The prototype catered to two types of information options, historical and goals. This was represented through a colored floor plan reflecting energy usage in each room's contribution to consumption, it was also shown numerically in kW and kWhs (Bonino, Corno, and De Russis 2012). While these studies used some of the same information options as the experimental studies, what they began to assess was not actual energy consumption, but occupant understanding of the displays.

What questionnaire and interview data from these two studies started to show was that there are several information options and units that people do not completely understand, but can sometimes use contextual clues to begin understanding. Karjalainen (2011) found that:

> The problems with understanding the prototypes mainly involved two issues: (1) many people are not familiar with scientific units and do not understand the difference between W and kWh and (2) many people do not understand how carbon dioxide emissions are related to electricity consumption. (464)

While this finding was from a very small sample size located in Finland, it was still used by Jain, Taylor and Peschiera (2012) to inform their decision to use a disaggregated feature, but they didn't find this feature to be statistically successful. The results of Karjalainen (2011) also matched those of Bonino, Corno, and De Russis (2012) finding that users liked the direct feedback of kWh, but didn't completely understand kWh. Despite this issue, users will still able to understand energy consumption based on color feedback and relate the units to use (Bonino, Corno, and De Russis 2012). These findings indicate that occupants could potentially relate units such as kWh with associated usage graphics, but that they do not completely understand these units.

Findings from the grounded theory approach used by Hargreaves, Nye, and Burgess (2013) were consistent with both these studies and the experimental studies. It was found that user fatigue occurred due to, amongst other reasons, the monitors continually portraying the same information (Hargreaves, Nye, and Burgess 2012) This is consistent with the findings of Jain, Taylor, and Peschiera (2012) and Chen et al. (2012), and offers the added insight of why this happened with occupant behavior. While they do not say occupants explicitly understand the units of display on these monitors, kWh in this case, they do explain that the monitors allowed users to understand their normal energy usage level, and to make informed adjustments if it went over. (Hargreaves, Nye, and Burgess 2012) This information is important because it reinforces some of the findings from the experimental and simulation test in a more typical real life context, and begins to explain why with user insight.

In addition to these findings Hargreaves, Nye, and Bur gess (2013) also shed light on the experience of living with energy monitors from the occupant's point of view, revealing that monitors actually have the potential to create new energy social interactions.

> In addition to these effects on levels of awareness and types of behavior, a key theme running throughout several of the follow-up interviews, much more strongly than in the initial set of interviews, was the ways in which the monitors had given rise to new forms of social interaction around energy use both within and beyond the household. Most commonly, interviewees stressed that the monitors had made it easier for them to communicate the impacts of energy use – either on their bills or on their carbon emissions – to other, less interested household members. (Hargreaves, Nye, and Burgess 2012, 131)

These findings also bring up a condition of energy usage not mentioned in other studies: energy consumption is the result of a household of individuals, all with different interests and behaviors. If one of the first steps in changing energy behavior is to give occupants the ability to understand their usage, then these monitors were successful in this aspect. The study also revealed that there are contextual constraints to savings. People were willing to make some changes initially, such as switching lamps, but didn't have as much flexibility in larger appliances, and were not willing to give up certain comforts such as television (Hargreaves, Nye, and Burgess 2012) In considering how occupants might change their energy usage behaviors these limits would be important to consider, as well as the complex social situations in which energy consumption occurs.

The strengths of these studies are their ability to start explaining why certain occupant understanding, behaviors, or interactions with monitors might occur. Their weakness is that none of these measure the actual reduction of energy consumption or lack there of. Karjalainen (2011) suggests that in the future the prototypes tested be put to use. This was done with Jain, Taylor, and Peschiera (2012), but the findings weren't consistent with Karjalainen (2011). This indicates that a comprehensive study that begins with user assessment, implementation of a design, and followed up on user point of view in combination with energy data might be very beneficial in better understanding the effect of energy monitors on user understanding, behaviors, and interactions.

3.0 Discussion

While theses studies show overlap, they appear to be divided between seeking a design solution and a user solution. The complexity of the problem of energy consumption though is such that one or the other will not yield a solution; design and user must engage each other to provide the most effective feedback and motivational means. Additionally the built environment must be considered in greater depth, and perhaps information about this should be factored into these monitors as well. In helping occupants understand their energy usage we much define what their understanding of energy information is. In helping them change their energy usage behaviors we must know what those existing behaviors are, and how environment and context affect them.

While there are many aspects of these studies that may not necessarily directly translate to future studies, what can be gleaned from reviewing them is a need for understanding of the occupant perspective. The behavioral models employed in the experimental studies address some aspects of users, but there aren't studies that test all models or combinations against each other, and it is possible to say that a model could have been compromised by ineffective design or information choices. The studies which focus on user understanding explain the user's point of view on some aspects of these monitors, such as information options and units, but don't begin to form a model of behavior that might inform design decisions that could translate in to an effective system of user and monitor. Since the changes made have to be behavioral, finding behavioral models that fit the variety of occupant types is of key importance.

In studying energy monitors, the context of behaviors should not be separated out as a detached element. Buildings and building systems are the mediums of energy consumption, and research studying energy consumption should take note of the impact that these context could have on results. Additionally the context of social interactions within space could be a major contributor to energy behaviors and social norms. Future studies might investigate energy cultures within a larger variety of context and the role that monitors could play in these environments, beyond simply being a monitor, but becoming part of the social or injunctive norm of energy consumption.

Studies that examine the consumer aspect of energy monitors have found similar results to these studies in terms of adoption of monitors and reactions, but also postulate about the ways that monitors might diffuse themselves into existing technologies. Wallenborn, Orsini, and Vanhaverbeke (2011) predicts:

> A probably future of these monitors is to be integrated into existing devices such as PC or mobile phones (152).

Indeed this has already started happening with a variety of applications available for smart phones and computer systems. As these types of monitors continue to develop research about what theories and features create the most successful technologies for user behavior will be useful to architects seeking to lower CO2 emissions as well as other disciplines involved in the development of these products.

CONCLUSION

In seeking an *optimal design* for energy monitors, one must consider, as Hargreaves, Nye, and Burgess (2013) points out, that there is not one solution for all users. The optimal design will differ for different countries, cultures, social contexts, and user desires. The best design will be one that adapts to each users needs and should not be based on an empirical comparison of features, but rather based on the most efficient behavioral and design models. This has yet to be researched in a comparable manner across studies, and it might be the case that a new model needs to be developed. Architects can begin to take part in this process by studying occupant behavior and energy cultures in buildings, and identify how persuasive technologies can start to become part of the archi tectural environment to address energy consumption behaviors.

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Cool Skins: Exploring the Cooling Potential of Lightweight, Ventilated Cladding Systems

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ABSTRACT: The heating of the exterior building skin by solar radiation is a significant problem with regards to cooling season thermal performance. Lightweight construction systems are particularly prone to problems under these conditions, yet often rely merely on insulation devised for the winter months to reject the heat of the summer months. In recent decades, ventilated roof systems have demonstrated their effectiveness at reducing cooling season loads by way of solar radiation-induced convection behind the roofing. It is evident from recent research that ventilated cladding systems can have similar benefits; yet the existing research on the subject focuses on massive cladding and does not address the lightweight cladding systems that correspond to lightweight construction methods. Of particular interest in this research is the role of open-joint versus continuous ventilated cladding with respect to solar radiation-induced convection. Physical mockups and computational fluid dynamics computer simulation were used to compare non-ventilated, open-joint ventilated, and continuous ventilated cladding with respect to heat rejection.

KEYWORDS: Rainscreens, cladding, cooling, building skins

INTRODUCTION

The conventional approach to controlling thermal transfer in the building skin focuses merely on insulation (resistance to conduction), largely ignoring the properties of cladding. Yet heat transfer from solar radiation originates on the exterior side of the building envelope, suggesting that cladding material and configuration play a critical role in heat transfer during the hot months. Modern building science has addressed heat gain in roofs by introducing natural ventilation behind roofing; these systems use solar-driven, heat-induced convection between roofing (often metal or tile) and the roof deck, rejecting heat that would otherwise add to the magnitude of heat that the insulation beyond must resist, resulting in substantial, measurable energy savings (Ciampi 2005).

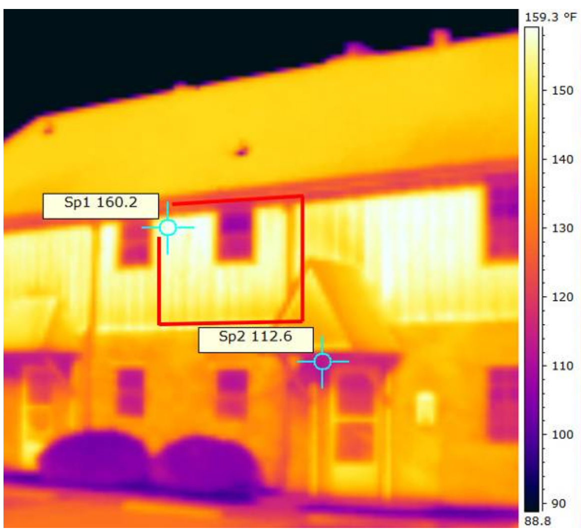
The key concept to ventilated roofs is that the *material layers* in the roof package can be manipulated to reduce heat gain. In their normal configurations, these layers would otherwise remain in contact with one another, transmitting heat by conduction – ventilating the layers interrupts this process, even though from the standpoint of thermal resistance (R-Value or U-Value), the assembly changes very little. This paper looks at a similar concept in light-weight ventilated cladding systems, where ventilation can be used between the cladding and the building envelope to reduce heat transmission driven primarily by solar radiation. Coincidentally, ventilated cladding systems have been common for many decades now and are known more familiarly to architects as 'rainscreen' cladding systems. While rainscreen cladding evolved originally to prevent moisture intrusion into wall cavities, it has the potential to benefit cooling season building performance through similar thermal behaviors as ventilated roofs.

1.0. BACKGROUND

1.1. Challenges of light-weight construction in hot conditions

In the U.S., a significant portion of contemporary building stock is built using light-weight construction – wood or light-gauge steel cavity walls serving either as primary structure or infill, sheathed and clad with similarly light-weight wood, plastic, metal, or cementitious cladding products. Lower building costs, increased material efficiency, and faster erection times were among the improvements realized by modern light-weight systems over their massive stone and masonry predecessors. Along with these improvements also came insulation – the use of low-conductance materials in the building envelope to slow down heat loss during the heating season. Heat loss during the heating season and heat gain during the cooling season are very different, however, as a result of solar radiation. In the winter time, heat loss is largely a steady state process in which conduction of heat through the envelope dominates and heat loss increases as the difference between interior and exterior temperatures increases. In the cooling seasons, conduction works in the opposite direction as heat from the exterior environment makes its way into the building interior. Yet the difference between interior and exterior temperatures is only part of the heat transfer picture; additionally, solar radiation impacts exposed parts of the exterior envelope, adding greatly to the heat gain passing into the interior of the building. In contemporary energy calculations, the effects of radiation and conductive transmission are combined using a value called the 'sol-air temperature' which combines radiation and conduction into an equivalent exterior temperature convenient for heat transfer calculations. Coincidentally these heat gain calculations are the same simplified calculations used to assess heat loss in the winter; thus the same measures to combat heat loss are perceived as the best to combat heat gain, even though these thermal processes are very different.

Traditional massive construction tempers heat transfer by way of its mass: heavier construction takes much longer to lose and gain heat to the external environment, and as a result, its performance during hot and cold periods is similar. Heat travels more quickly in light-weight envelopes, on the other hand, and the layers in these light weight envelopes respond differently in the heating and cooling months. In particular, the exterior cladding of light weight buildings lacks the thermal mass behind it to slow down heat gain from the sun – solar radiation can thus produce tremendous surface temperatures in the cladding itself. This "hot skin" condition subsequently passes heat back to the interior of buildings by combined effects of radiation, conduction, and convection, posing issues to thermal comfort and additional cooling loads; in Figure 2 it is the cladding's soaring temperature (71°C/160°F+) and not the exterior air temperature that impacts the interior wall beyond. Heat gain originating from solar radiation is a major factor for cooling loads even for relatively temperate locations. Often designers stop merely at protecting glazing; yet for many buildings opaque walls are subjected to a larger amount of solar radiation than windows and as buildings get taller, the radiation affecting walls approaches that affecting roofs. When windows are logically located, sol-air gains (radiation plus conduction) through the opaque envelope can markedly surpass direct solar gains occurring through windows. Thus solar radiation's effect on the opaque building envelope during the cooling season presents a significant challenge for energy efficiency in lightweight construction.



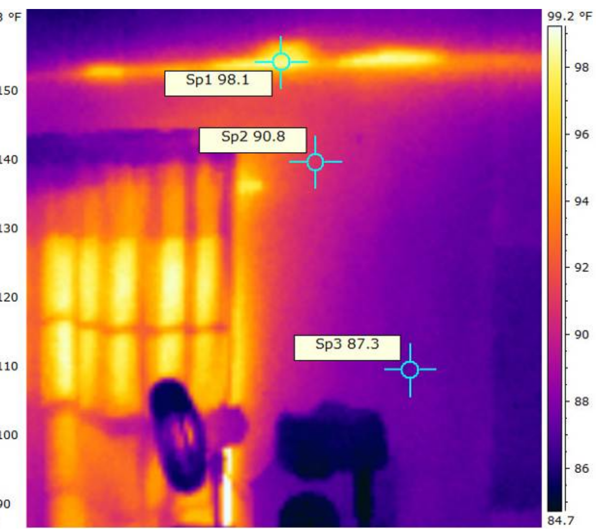


Figure 2: Thermal imagery[2] of a "stick frame" apartment building where solar heat gain impacting the wood exterior cladding is transmitted to the interior walls (and ultimately the interior space); re-radiation, conduction, and internal convection are at work simultaneously and the presence of hot spots suggest gaps in the insulation. Note the interior images were taken in a conditioned space with an ambient temperature of approximately 27°C (80°F) – because of the effects of MRT, the much warmer interior walls would produce an apparent temperature that could be several degrees higher, depending on the point of observation. Source: Author

1.2. Inquiry: ventilated cladding and cooling

Typical rainscreen systems have evolved to provide the following functions via their air cavities: prevent water intrusion by capillary break, provide a drainage space for moisture, allow air circulation to remove moisture, and most critically, to allow for pressure equalization of the cavity and the exterior air to prevent water infiltration by pressure (Salonvarra 2007). The function of pressure equalization is key here: with equalization of pressure, a combination of gravity and ventilation allows moisture to escape the backup cavity rather than be transmitted into the dry envelope assemblies beyond. One design factor that is somewhat ambiguous about ventilated rainscreens, however, is the degree of continuity in the outer cladding; manufacturers of panelized rainscreens often offer open joint and closed joint variations of their products, while the larger array of options for rainscreens include nearly continuous masonry veneers (very few joints) to wood screens (very large and frequent joints).

In ventilated roofs, the continuity and smoothness of the ventilation cavity is critical because heat evacuation is driven by thermal buoyancy – the movement of heated air by pressure differential (Salonvarra 2007). Thus a major 'what if' for understanding similar cooling potential in walls is the role continuity plays in the exterior skin. Although different rainscreen cladding materials and configurations may offer marginal performance differences in terms of moisture rejection, when heat rejection is considered certainly cladding material and configuration is critical. The stack effect – a more organized, idealized form of thermal buoyancy – requires that inlets and outlets be limited for a given air volume. Thus it may be inferred that a closed joint cladding system would provide the most organized thermal lift in the air cavity beyond, rejecting the most heat from convection. On the other hand, it may inferred that an open joint system would tend to move air more slowly under conditions that are more equalized with the exterior, rejecting less heat without the benefit of the stack effect.

Early in the research, the author visited a building with a light-weight rainscreen system with 1.3cm (1/2") joints and high-pressure laminate (HPL) cladding panels during a warm summer to collect data (Figure 4). It was expected that thermal buoyancy and the stack effect would be evident from the vertical temperature profile of the cladding (from heat gain rising to the upper cladding) and from the air velocity and direction within the cavity. The first observations were carried out on a day with light winds; air velocity[1] in the cavity was highly erratic and was attributed to the wind. The next observations were carried out on a day in which winds were calm – yet air velocity and direction in the cavity was still highly erratic. Clearly the open joints in the cladding were defeating the stack effect. During the same observations, thermal imagery[2] revealed very high cladding temperatures (about 11°C or 20°F above ambient) with little differentiation between lower and high panels. Was this rain screen assisting the building at all in terms of heat rejection?

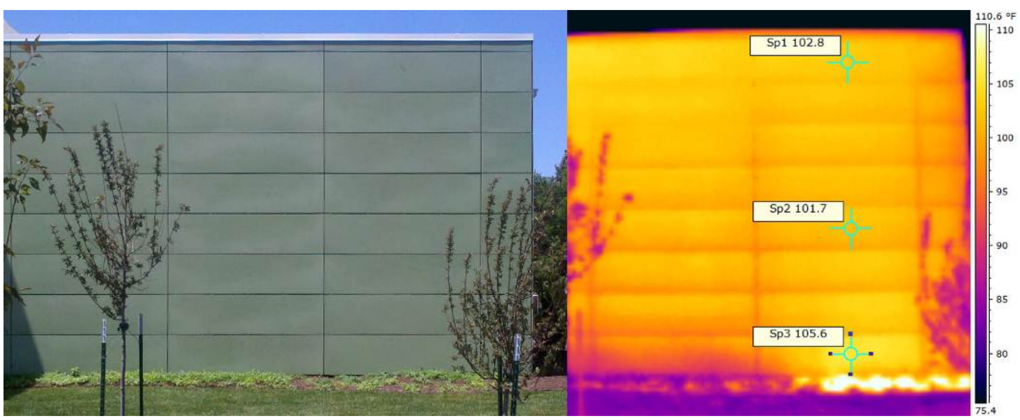


Figure 4: Thermal imagery from a local building that exhibits an HPL rainscreen cladding system. Field observations did not show clear thermal organization on the exterior surface (from cooler to warmer) as was expected from thermal buoyancy. Readings of the air velocity within the cavity did not show stable, upwards ventilation. In sum these initial observations indicated that light, ambient breezes were enough to disturb organized thermal flow and more examination of the benefit or detriment of the open joints was necessary to understand how, if at all, this light weight type of rainscreen could reject heat. Source: Author

1.3. Prior studies in thermal benefits of ventilated facades

The thermal benefits of ventilated cavities are still emerging in the discourse of building science. Enthusiastic interest on this subject has emerged in Mediterranean regions where researches using both experimental observation and numerical models show evidence that significant reductions in cooling loads can be realized by thermally-induced convection in air cavities (Ciampi 2003, Suarez 2011, Marinosci 2011, and Giancolaa 2012). Yet studies exist for less sunny and hot climates (like the German study of E. Jung as cited by Salonvarra 2007) that contradict the Mediterranean research in showing no improvement in thermal performance from ventilated cavities, even in the presence of significant ventilation rates. The cited studies from the Mediterranean are of note because they examine regionally-specific cladding methods using stone and masonry veneer (Marinosci 2011 and Giancolaa 2012) that are heavier and have tighter, less frequent joints than the light-weight systems of interest to this this paper.

Despite differences in cladding, a strong body of research exists that suggests the benefits of ventilated facades for hot, sunny climates. Rather than address the quantitative conclusions of each selected source, some key aspects from each source are summarized with their particular relevance to the research questions raised by the author in this paper. In Ciampi et al (2003), a numerical model identifies several factors in the wall assembly with respect to optimizing heat rejection, including the thermal characteristics of the cladding and back up materials as well as the ventilation cavity depth. This study underscores the importance of heat transfer by radiation within the cavity and interestingly, showed that materials like cementitious board can yield energy savings that are very close (within 18%) of heavier masonry claddings although the numerical model assumed the cladding system is continuous (i.e. no joints). A more recent numerical model developed by Suaréz et al (2011) examines heat transfer in the wall cavity more closely, using a more refined numerical model that describes a two-stage process of convection. In the first stage, lower buoyancy results in free convection where surface heat transfer is mostly responsible for convection. The second stage described is one with higher temperatures where laminar flow develops (effectively the stack effect) but where the stable moving air column is responsible for heat extraction much more so than the slower, less organized surface heat transfer that is characteristic of the first stage.

Two recent studies used full scale construction to test the influence of ventilated cladding to reduce the influence of incident solar radiation. In Marinosci et al (2011) a very large full scale mockup was used with fired stone panels (1.0 x 0.5m) with 1cm joints and a 25cm (10”) ventilation cavity. Another source consulted in the research was carried out in Spain by Giancolaa (2012) whose subject was a recently constructed building with a stone rainscreen system, this time with a shallower cavity (about 4cm) and somewhat tighter joints (0.5 cm). Both studies compared data from sensors against computer models; in Marinosci, a more conventional energy modeling software was used (ESP-r) and in Giancolaa a more sophisticated computational fluid dynamics (CFD) simulation was performed which fully simulated convection and air flow in the system. The main difference between these two studies was that in Marinosci, the computer model did not account for the open joints in the system. In that study, correlation between the model and the actual observations was rather wide until the cladding became very hot, suggesting that the joints in the cladding were a critical part of heat exchange at more moderate temperatures. In Giancolaa the CFD simulation integrated the joints and was able to demonstrate better correlation with the real observations, while also demonstrating that air moved in and out of the joints in a sort of gradient from bottom to top rather than in an organized stack.

What is significant in the research discussed above is that the role of joints and the property of cladding has a critical role in heat transfer and the success of the system in rejecting heat from solar radiation, although no research could be found that has tested the specific impact of joints (or lack of joints) on heat rejection. It also remained an open question as to whether generalized stack effect or more varied free convection was more successful in conveying heat out of the cavity.

2.0. INITIAL EXPERIMENT

2.1. Experiment: open or closed joints?

With regard to typical *light-weight construction*, several research questions emerged. How would light-weight facades (as opposed to stone or masonry facades) behave, and is there a measurable difference in performance between non-cavity cladding, open joint cladding, and closed joint cladding systems? Will this difference remain if the effect of wind is eliminated in a controlled experiment? Are there heat transfer behaviors that might suggest an optimal approach to light weight cladding, relative to gapping and/or material and assembly properties? An experiment was subsequently conceived to compare the cooling performance of light-weight, ventilated cladding in open joint or closed joint configurations. Part of the experiment was also design to compare both open joint and closed joint ventilated configurations against a non-ventilated configuration. Early research suggested that the closed joint configuration would yield the best heat rejection results because of the presumed optimization of the stack effect from the continuity of the closed-joint cavity. Certainly, it was expected, the substantial gaps of the open joint prototype would disrupt organization of air flow, limiting convection.

The experiment was designed to use mock ups scaled to reproduce the effects of heat transfer at full scale, yet be relatively portable for use in a test chamber. In order to eliminate interference from the wind, the prototypes were tested in a test chamber at the Institute for Environmental Research at Kansas State University, where a rack of high-powered heat lamps simulated insolation and a dedicated air handling unit maintained a relatively constant temperature. The light rack was constructed identical to the mockup height and width, and outfitted with fifteen 250W heat lamps in a regular pattern that, at the 0.45m (5ft) initial test distance produced a maximum heat flux density[3] of approximately 726W/m^2 (230 Btu/ft^2*h) at the center of the lamp beam, with heat flux density falling off to about 10% of maximum at +/-15° from the center of the beam.

The first battery of tests were conducted over a period of approximately 70 minutes with the test chamber set to maintain an ambient temperature of 80°F. Mockups with cavities had small test ports (at height = 81”, 61”, 45”, 27”, and 9”) drilled through the rear of the ventilation cavity to measure cavity ventilation rates and air temperature[1]. Ports were sealed with tape when not in use, and data collected from each port was collected in 2-minute durations and averaged. Ventilation was measured only in a vertical path, directed upwards, with the probe at the center of the cavity. At the end of the test, infrared thermography[2] was used to collect surface temperature data from both the cladding side and sheathing side of the mock ups. A vertical temperature profile was completed by capturing a series of five individual images in sequence and a post-analysis program was used to collect average values from each of the five images in the profile. The averaging of these values was critical to level out the hot spots that were created by the lamps.[4]

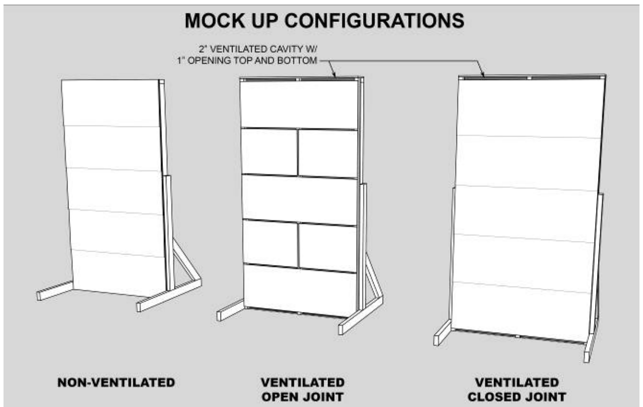


Figure 5: Schematic view of the mockups. Three mock ups were constructed measuring 2.3m high and 1.2m wide (90”H x48”W) using conventional wood framing with 11mm (7/16”) wood strand sheathing, covered by roofing paper (similar in properties to building paper). Hardboard (i.e. Masonite) of 5mm (3/16”) thickness was used for cladding to approximate HPL rainscreen cladding. One mockup was clad in lapped hardboard in direct contact with the sheathing and wrap (left – “non-ventilated”). Galvanized steel studs of 50.8mm (2”) depth were then introduced vertically over the sheathing and wrap of the remaining two mockups (middle and right) to represent the steel offset system used in common rainscreen applications. An EPDM weatherstripping tape was used between the steel studs and the sheathing to prevent thermal bridging from the cladding, as is typically used in rainscreens. One ventilated mockup used individual cladding panels spaced 12.7mm (1/2”) apart in an alternating pattern, leaving a larger 25.4mm (1”) gap at the top and bottom of the mockup (middle – “ventilated open joint). The final mockup (right – “ventilated closed joint) used a lapped cladding resulting in closed joints except for the top and bottom of the mockup, where a 25.4mm (1”) gap was left open for ventilation. Source: Author

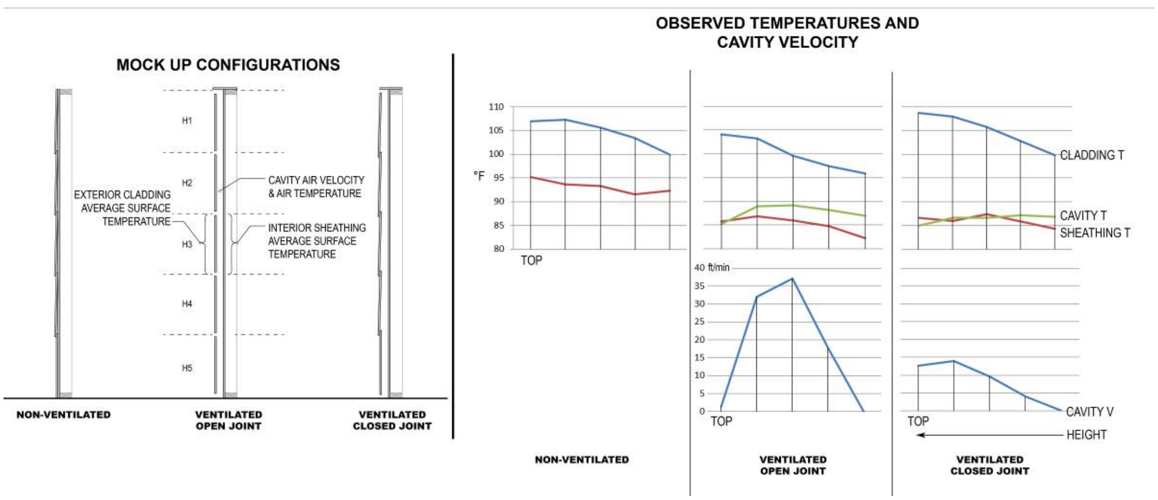


Figure 7: Observations from the initial experiment with the mock ups. Source: Author

2.2. Initial Observations and Interpretation

On one level, the initial experiments comparing the three prototypes confirmed the benefit of ventilation behind the cladding over the non-ventilated configuration. The air cavity clearly mitigates the transmission of radiation as conduction from cladding to sheathing – a characteristic that was seen readily in the thermal imagery. In the non-ventilated mock-up, the hot spots from the lights were transmitted directly to hot spots on the reverse side of the sheathing, producing a nearly identical thermal image; for the ventilated mock ups, the hot spots weren't visible on the sheathing side because this conductive transfer was broken by the cavity. The most telling comparison between ventilated and non-ventilated mock-ups were in the average sheathing surface temperatures, which were significantly lower for the ventilated cladding mockups (29.5°C/85.1°F for the open-joint prototype and 30°C/86.0°F for the closed-joint mock-up) than for the non-ventilated mock-up (34°C/93.2°F) (Figure 7). Lower sheathing temperatures indicate a reduction in heat transfer, confirming the benefit of a ventilated cavity over a non-ventilated cavity for cooling purposes, even with the rather arbitrary materials characteristics of a hardboard skin (i.e. brown, rough surface on the cavity side, etc.).

The comparison between the open-joint and closed-joint mockups yielded results that were unexpected. The first important distinction was from cladding surfaces temperatures, measured on the exterior face of the cladding. The open-joint mock-up ended the test with an average cladding surface temperature of 37.8°C (100°F), while the closed-joint mock-up ended at 40.6°C (105.0°F) – as hot as the cladding on the non-ventilated mock-up. The difference in cladding temperatures is likely associated with the small performance edge for the open-joint mock-up in sheathing heat transfer (29.5°C/85.1°F for open-joint vs. 30°C/86.0°F for closed-joint). Another surprising difference came in the observations of cavity air velocity and temperature. In the open-joint mockup, air velocities were much higher overall (0.19m/s or 37.2 ft/min max, measured at 45" height) than in the closed-joint mock-up (0.07m/s or 14.0 ft/min max, measured at 61" height). Air temperatures in the open-joint cavity were also slightly lower than in the closed-joint mockup.

Based on the experiment, it may be interpreted that both ventilated prototypes outperformed the non-ventilated prototype with regards to heat rejection. The differences between the two ventilated prototypes are more difficult to account for and let to a series of experimental follow-ups that looked at behavior in the air cavity more closely.

3.0. FOLLOW UP EXPERIMENTS

3.1 Observations at varying cavity depth and radiation intensities

After considering the results of the first experiments, the very low air flows and increase in heat transmission for the closed-joint mock-up became an important follow up question. In order to better understand what was happening in the air cavity, a second experiment was run with this mock-up. In this experiment, three velocity and air temperature readings were taken at different horizontal depths (1.5", 1", and 0.5") at each of the five test ports. What was expected from these readings was some picture of the laminar flow that was occurring in the mock-up during the test – would the air flow and temperature be different for these three depths? Preliminary research (Suaréz 2011) suggested that in this configuration, laminar flow would result in higher velocities in the middle of the air cavity, where its flow would tend to convect in a channel rather than from the cavity walls where heat extraction would be most beneficial.

A secondary question involved the intensity of radiation that the cladding was subjected too – would increasing radiation intensities increase or change the air flow in the cavity? To explore this question, the experiment using the closed-joint mockup and multiple depth readings was repeated with the light rack at (1.5m, 0.9m, and 0.45m (5', 3', and 18") distances (yielding approximately 1x, 2.8x, and 11.1x the heat flux in the initial experiments).

Results from this experiment (Figure 8) were interesting, in that some explanation for the poorer performance of the closed cell prototype materialized. With the lamps at the original 1.5m (5') distance, air temperatures across the cavity *increased* as the readings moved from the exterior to the interior side of the cavity. This trend intensified as the level of radiation impacting the cladding was increased. Thus while the exterior cladding was getting far hotter than the sheathing, a significantly warmer layer of air was in contact with the sheathing. Observations of air velocity were equally telling. At the original 1.5m (5') distance, air velocity in the cavity was greatest at the cladding surface and decreased almost to zero towards the sheathing. As the radiation level increased, the convection channel moved towards the center of the air cavity while the air closest to the sheathing remained relatively slow-moving. Also interesting was a small increase in general velocity readings when the lamps were moved to 0.9m (3'); yet when the lamps were closest and surface temperatures were soaring, velocity readings *dropped.*

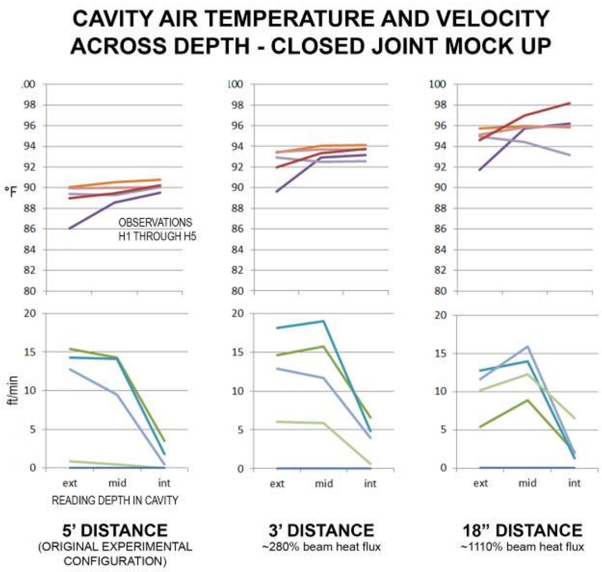


Figure 8: Follow up experiments involving the closed-joint mock up. Source: Author

3.2 Air flow studies using computational fluid dynamics simulation

With a better understanding of air flow across the depth of the air cavity in the closed-joint mock-up, a computational fluid dynamics (CFD) simulation was carried out to examine air velocity in the cavity in greater detail. The simulation was heated by a solar radiation source, configured to represent realistic, full solar intensity for Kansas City on April 1st. The sheathing and cladding were modelled as plywood and fiber hardboard respectively. The simulation was run in steady-state mode (i.e. no transient effects) for 200 iterations, resulting in approximate convergence (i.e. flows in the CFD model stabilized by the final iterations).

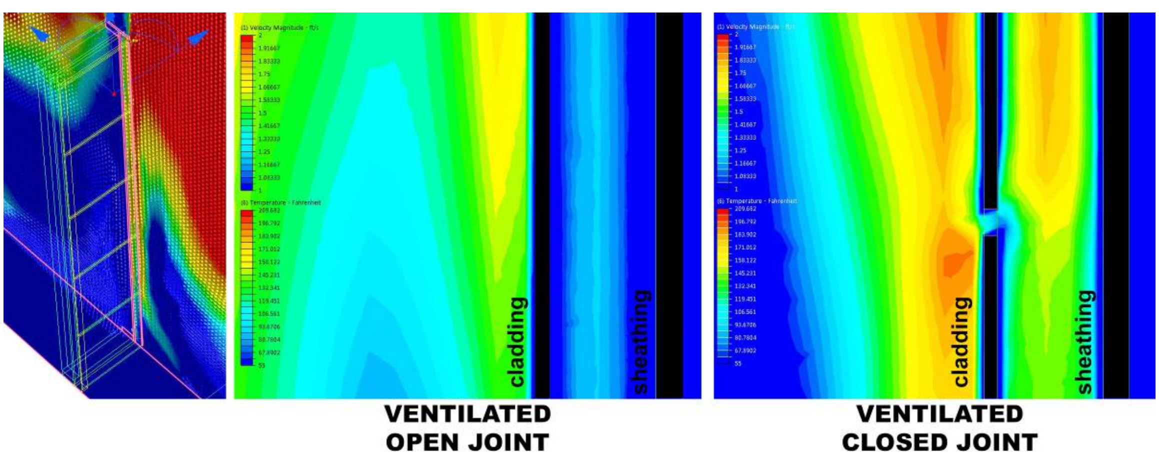


Figure 9: CFD analysis comparing internal air velocities between closed and open joint models. Source: Author

The results of the CFD simulation (Figure 9) reflected what was gleaned from initial research and from the empirical experiments. The closed-joint model exhibited slow, laminar air flow in the cavity and this flow was asymmetrically oriented towards the cladding versus the sheathing side of the cavity. Air flow on the exterior side of the cladding was also relatively slow. What is important is that this behaviour was exhibited from realistic conditions in the model – i.e. realistically hot temperatures from realistic radiant heat flux.

The open-joint model demonstrated very different performance in the CFD simulation (Figure 9). Air flow within the cavity was almost 50% higher than in the closed-joint model, and the overall area of convection within the cavity was much greater, showing increased convection at both the cladding and sheathing walls. Furthermore, air flow on the exterior faces of the cla dding was greater for the open-joint model. Flow for the open-joint model was certainly not as uniform as in the closed-joint model, but it was apparent that convection was more affective as a result of the open joints. Another benefit for the open-joint configuration (not shown in the figures) came with the cladding surface temperatures; around the edges of the panels, surface temperatures dropped greatly in response air circulation into and out of the cavity. Thus the interaction of air around the open joints seemed to both increase cavity convection and decrease overall cladding temperature. The sum of these effects, given the configuration of the models tested, seems to indicate that open joints result in greater heat rejection than closed joints.

CONCLUSION

The most direct suggestion from the research is that even when deploying light-weight materials, a ventilated rainscreen will perform better in the cooling season than non-ventilated cladding. A footnote to this conclusion is that conventional thermal resistance values (R-values and U-values) would recognize very little difference among the three configurations examined in this research. This emphasizes the importance of re-examining the thermal behavior of building assemblies in the cooling season versus the heating season, when simple measures against solar radiation, such as ventilated cladding, can be quite effective without changing envelope insulation or thickness. The second conclusion is that the research here suggests that significant (albeit at the time un-quantified) performance difference exists for open-joint rainscreens over those that have closed joints. While this claim is best directed at applications similar to those tested in the experiments (2" cavity, single floor wall height, fiber cladding product) it seems logical that the apparent benefits of open cladding systems may transfer to different configurations.

Returning to the original assumptions in this research, it appears that the stack effect does not occur as originally presumed. In the configuration tested, in a continuous cavity, the stack effect is actually less effective at transporting heat than free convection, because versus free convection, the convective column is slower and more isolated from the cavity walls. In contrast, when a cavity has open joints, free convection occurs with greater velocities and more heat is transported from the cavity walls. Reintroducing the factor of wind, the effectiveness of open-joint cladding seems to increase rather than decrease; on a breezy day, the admission of ambient temperature air directly into the cavity can only lower the cavity temperature in an open-joint rainscreen. While the stack-effect in ventilated cladding may be more useful in some scenarios (tall buildings, extremely hot conditions) it appears that more consistent benefits to cooling can be delivered by open-joint cladding.

Lastly, further research is planned upon the design of the cladding systems themselves. If a minor change such as the opening of joints can impact convection significantly, it is also promising to further optimize beneficial convection through the design of materials, cladding detailing, and cladding geometry. With most rainscreens still highly conventionalized to panels, assembly units, and boards it seems that increasing knowledge of ventilation behavior can inform a rethinking of the skin to improve heat rejection. Certainly this rethinking can integrate the multi-functional imperatives that rainscreens already promise across aesthetic, moisture mitigation, and thermal imperatives. As cooling performance becomes increasingly important for buildings, cool building skins may offer an important solution towards energy efficiency.

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ENDNOTES

1 Air velocity and temperature measurements were carried out with a CIH20DL General Tools hot wire anemometer with a handheld probe, logged at 5-second intervals and averaged.

2 Thermal imagery was captured with a Flir i7 infrared camera (thermal sensitivity of 0.1°C) with emissivity set at 0.95. Spot temperatures and area-averaged temperatures were determined using Flir software.

3 Solar radiation heat flux density was measured using a DBTU1300 General Tools solar power meter with readings averaged over 30-second intervals.

4 The intensity and lens type of the lamps used created hot spots in the infrared spectrum. Such light racks have a precedent in this type of research although the effect of the hot spots on the results is unknown. Averaging temperatures from thermography made it possible to mediate the hot spots in the observations.

The Development and Valuation of Intelligent and Adaptive Building Systems

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ABSTRACT: Energy consumption by buildings, especially high-rise buildings, has increased to the point that it has overtaken the industrial and transportation sectors (Perez-Lombard et al., 2008). This unsustainable phenomenon has prompted research into intelligent and adaptive building systems (IABS) for more energy-efficient buildings that current architectural practice and building operations overlook. IABS are bottom-up strategies that provide energy consumption and comfort solutions at any scale of the built environment. In addition to the benefit of reduced energy consumption, occupant physiological and psychological well-being can also be addressed through better control and feedback mechanisms. These improvements can be made through the widespread application of systems that blend many different and readily attainable components. This research seeks to address these issues through the development and study of IABS prototypes, virtual models, and material/component libraries that address the needs of all stakeholders (Table 1). Prototypes that form contextually aware and flexible agent networks will be presented, along with the results from those that have been completed Suggestions for design and interfacing are also discussed. Controlled environments are constructed in and around physical prototypes to carefully observe performance results. Also discussed is how high-rise buildings are ideal candidates for IABS integration.

Table 1: Building stakeholders and relative performance metrics

Stakeholder	Performance Metrics
Occupant	Indoor Air Quality, comfort, health (psychological & physiological)
Building Owner and/or Developer	Return on initial investment, building lifespan, operating costs, occupant satisfaction/rate of occupancy
Building Engineer	Efficient building control and management
Utility Companies	Energy consumption (especially during peak demand)

KEYWORDS: High-Rise, Adaptive, Facade, Building Systems, Intelligent Networks

INTRODUCTION

Architects currently utilize many technologies in practice. Rapid prototyping, BIM, parametric modelling, and information databases are all currently used in the development phase of a building's life cycle. Although these powerful tools have helped with project delivery in many ways, we fail to use them and other applicable technologies in a building's often cyclical maintenance & operations phase, which makes up roughly 85% of a typical 50 year life-cycle (Shabha 2003). Balance can be given to this cycle by identifying ways in which appropriate technologies can be integrated into the built environment (Figure 1). The goal of this research is to seek out technological solutions for the energy and occupant related issues that we currently face.

The degree to which viable IABS are deployed and used is important. Solutions for increasing energy efficiency and comfort within a building exist. However, it is difficult to integrate them into a large number of new and existing structures due to cost and over-customization. Owners and designers have indicated that they desire further progress with advanced facades. Furthermore, they have the ability to reliably predict performance and ensure that availability and cost matches their time and budgetary requirements (Beltran et al., 2003). To change prohibitive trends and convince all stakeholders that IABS can be a viable solution to excessive energy consumption, intelligent building systems should consist of technologies that are readily attainable, affordable, and adaptable thus allowing implementation at a global scale that leads to a tangible effect on energy consumption.

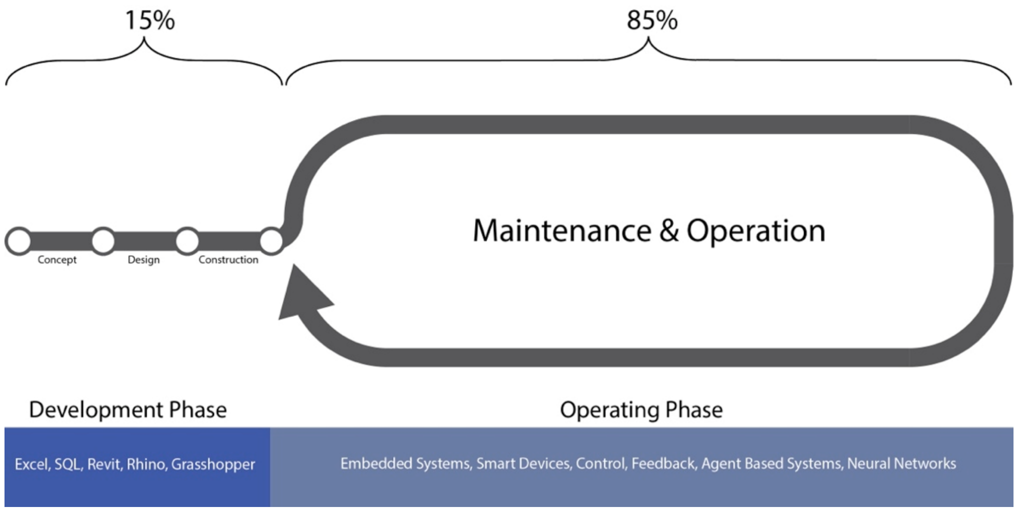

Figure 1: The distribution of technologies throughout the entire life-cycle of a building

Recent research indicates that building occupants value access to daylight and views, as well as the ability to locally control their environments (Beltran et al., 2003). As a bottom up granular system, IABS are able to provide these preferable conditions and create a more productive, as well as psychologically and physiologically healthier environment.

INTRODUCTION OF IABS TECHNOLOGIES

It is necessary to provide a brief introduction on the technologies being utilized in this research before moving forward. Artificial Neural Networks are computational models that are inspired by the structural and/or functional aspects of biological neural networks (e.g. central nervous system), and are adaptive systems that learn to change their structure based on the information that flows through them. Agent based systems are used as computational models for simulating the actions and interactions of autonomous agents to assess their affects on the system as a whole (Niazi and Hussain 2011). They are commonly used to simulate group behavior in financial and sociological studies. A connection exists between these two concepts, in which an interconnected group of agents could be viewed as neurons or groups of neurons. The feedback exchanges fostered by this relationship have the potential to give rise to increasingly intelligent and agile building control networks, providing management capabilities of the built environment at any scale.

Considering the density of the urban environment and the resources required to maintain a comfortable interior condition within a large building, this research makes the reasonable assumption that high-rise buildings are the ideal test vehicles for IABS. The following supposes how an IABS would be integrated within a 16 floor high rise, with a 70’ x 50’ footprint. This example building is arbitrary in nature and without site, program, or specific materials (Figure 2). The subsequent diagrams are meant to illustrate how the IABS network would be integrated with this building. Due to their dynamic nature, occupants have been excluded from these diagrams.

Figure 2: Example High Rise with glass curtain wall, concrete structure, and Agent Computing Mechanism (ACM) distribution

This example illustrates two major and potentially adaptive high-rise components: artificial lighting and curtain wall. Hubs connect to both interior light sensors and controls with other building systems, such as the adaptive facade or HVAC (Figure 3). Each floor is broken up into regions, with a lighting hub in each.

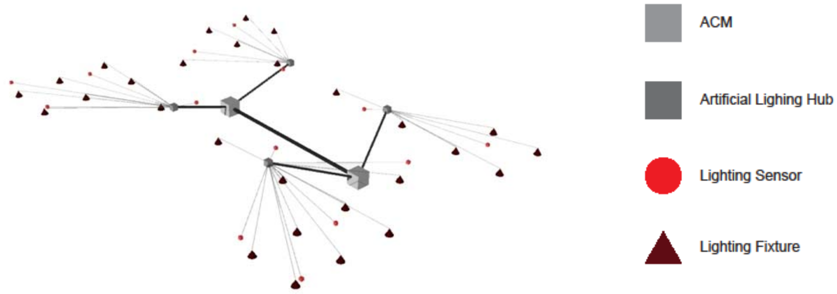

Figure 3: Artificial lighting network and ACM's per floor

Facade modules each represent an adaptive curtain wall panel in this example. There are no specific metrics or adaptive components considered here. However, each module consists of a networked microcontroller, actuator, and sensing components (Figure 4).

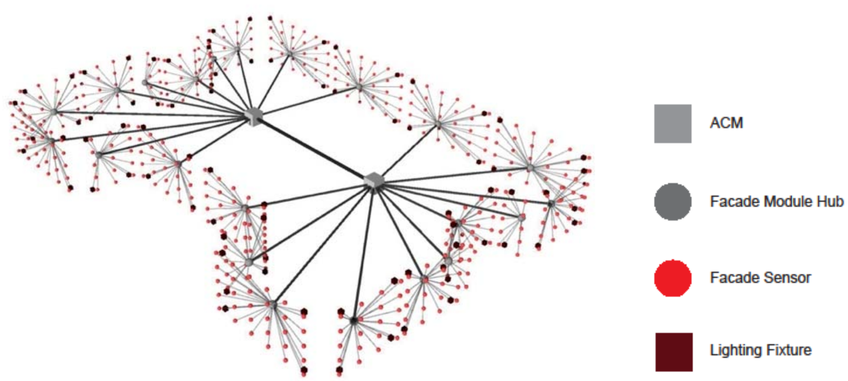

Figure 4: Facade Module Network and ACM's per floor

Agent networks should be considered the foundation layer upon which is laid the Artificial Neural Network. In this example, this is done horizontally floor-to-floor (Figure 5), and vertically from top to bottom (Figure 6). With this arrangement, each individual agent is capable of communicating with any number of others. A goal of this project is to determine if this arrangement is capable of performing better than contemporary systems.

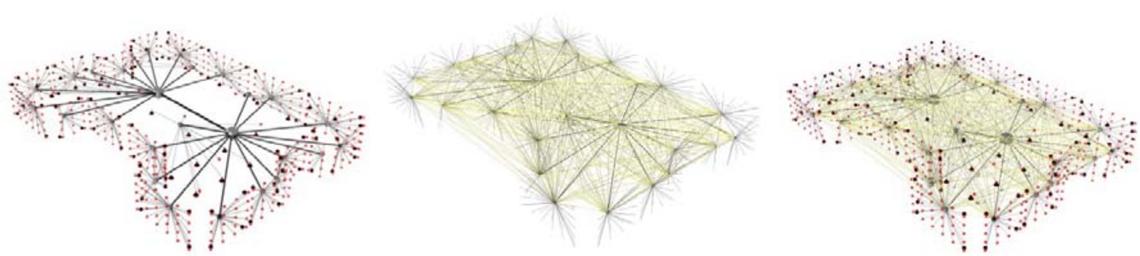

Figure 5: Floor-to-floor agent and neural network integration

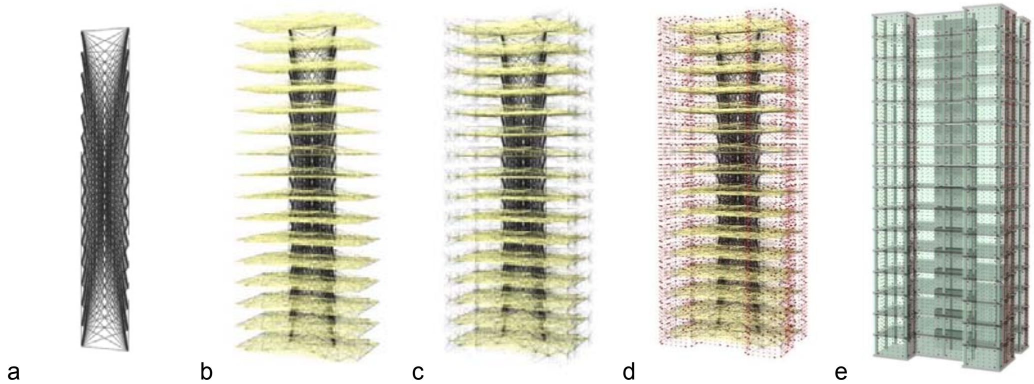

Figure 6: Example high-rise with IABS: a. Interconnected ACM's, b. Floor-to-floor agent neural net, c. Floor-to-floor agent network, d. Sensing and dynamic components, e. Complete IABS enabled building

That agent systems and artificial neural networks can provide superior building automation and management is not a new concept. In fact, numerous research papers have been written on the subject. However, no literature could be found on the development of physical prototypes created to identify component makeups and how they might work. This research attempts to build upon theoretical precedents by developing working IABS prototypes, then examining them qualitatively and quantitatively.

1.0 FACADE AND BUILDING SYSTEM PROTOTYPES

1.1. Facade prototype 1

In the course of this research, two prototypes have been fully developed. The first (Figure 7) served largely as a learning tool, setting the foundation for subsequent versions by necessitating a working knowledge of physical computing and computer programming. Its sole function was to sense the ambient light on one side of the fritted glass module and then actuate a sliding pattern to block or permit light to meet the predetermined requirements. However, the rudimentary nature of the prototype limited its adaptive qualities and the subsequent version would need a more refined mechanical composition.

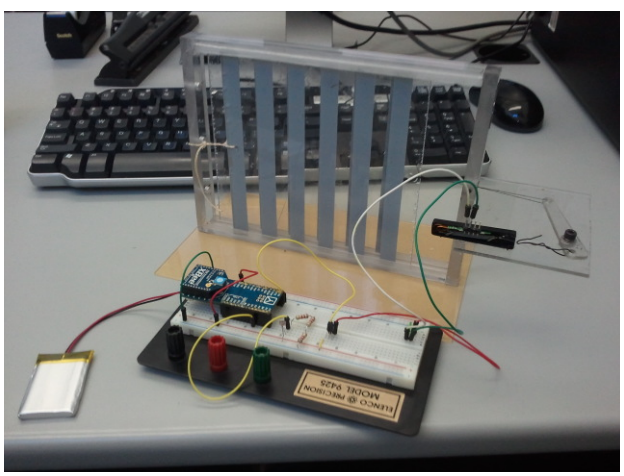

Figure 7: Adaptive Facade Prototype 1

1.2. Micro-enclosure and intelligent building network prototype 1

A second-generation prototype (Figure 8) furthered insight into the same lessons and led to discoveries related to the potential of specific actuators and sensors, device networking, and agent based networks. In an IABS, individual agents are capable of observing behavior, environmental conditions, exchanging data, assuming commands, and acting independently from the rest of the network to provide a more granular approach to the control and monitoring of the many spaces within a building. Observations and commands are transmitted through the wireless or hard-wired building networks where appropriate. Table 2 lists the agents that make up this prototype.

Table 2: Second prototype agent inventory

Agent	Purpose
Agent Computing Mechanism	Acts as a data hub and higher decision making component
Data Base Agent	Stores environmental data and dynamic responses for later access
Cloud Agent	Consists of web based data sources, feedback interfaces, and storage
Micro-Enclosure Agent	Consists of microcontroller, sensors and adaptive components (dynamic frit & vent dampeners) that physically sense and respond to internal and external building environments

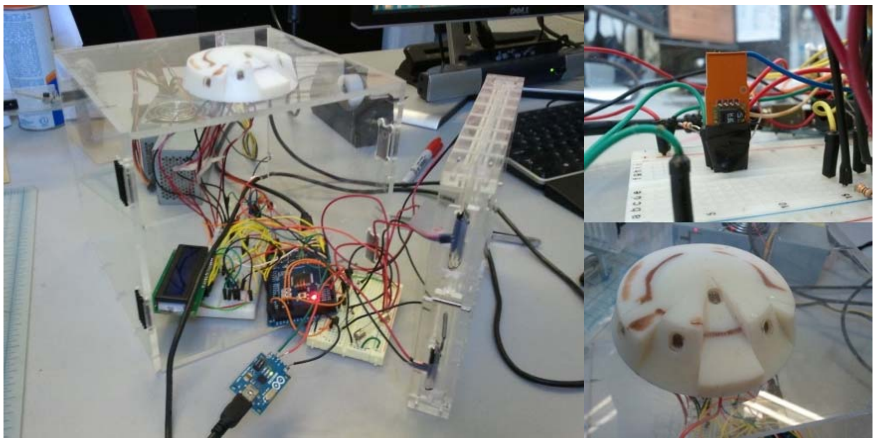

Figure 8: Adaptive Facade Agent with Shape Memory Alloy Frit Actuators; Temperature & Humidity Sensor; Solar Position Array

Every agent in this prototype functioned as hoped, with the exception of the frit and dampener actuators. Although attention was given to how the unidirectional actuators would be counter-balanced to return them to their relaxed state, inconsistent strength through the full stroke limited movement. This translated to a limited stroke and lack of dynamic functionality. Despite this, the prototype yielded a great deal of useful data, and served as a sound proof of concept.

2.0. PROTOTYPES UNDER DEVELOPMENT

With the lessons learned from the initial prototypes, it is necessary to develop a third generation of prototypes that will establish groundwork for choosing effective and sustainable choices in component makeup and functionality for IABS. By developing a series of prototypes, rather than one, the opportunity to draw comparisons between each one becomes available. Moving forward, this paper will focus on five prototypes, and what can be learned from them. Four make up a unique series of prototypes, and will share the same physical construction. However, each will incorporate increasing levels of technological complexity to learn what, if any, ideal makeups exists. An evaluation of performance characteristics will be made, and then compared. The metrics for which include energy consumption, solar control, effective adaptation, maintenance, lifespan, and first/total costs.

Listed from least complex to most, these four prototypes will have the following component makeups:

1. Mock IGU as a control model
2. One non-networked stand-alone microprocessor (Arduino Uno or TI LaunchPad MSP430)
3. One networked Raspberry Pi as the agent control mechanism(ACM), and one microprocessor connected as a slave via Serial Peripheral Interface (SPI)
4. One networked Raspberry Pi as ACM, and two microprocessors. Each

Simple enclosures will be built around each prototype to maintain an agreeable amount of separation between the environment in which the prototypes will be housed and their immediate environment. This ensures that metrics can be accurately measured. Prototypes will be stationed side-by-side along a large south-facing glass curtain wall for testing and observation. To track performance and record data, cameras and appropriate sensors will be placed on and within the enclosure. Energy use/production, temperature, humidity, and light measurements will be monitored and evaluated in each case.

A fifth prototype will consist of an interactive digital model of a high-rise building, working in conjunction with a mobile device application from which the model's components will be controlled and behavioral/environmental data viewed.

2.0.1 Prototype physical makeup

Each facade prototype will consist of the same physical components to eliminate performance data variations. Actuation is performed by black latex balloons inflated with a commercial grade aquarium pump that is activated with a relay switch attached to the microcontroller. Photo-resistors sense the ambient light levels and the balloon inflates in response. In its deflated state, the diameter of the flattened balloon is equal to that of the spacing between glazing panes. Any subsequent increase in volume would result in an outward expansion within the IGU only (Figure 9). Arrayed, equally spaced bulbs would form a loose frit-like pattern. As the balloons expand, they form an increasingly dense pattern, blocking out most solar gain (Figure 10). Each will have a light sensor assigned to it and would be capable of expanding or contracting independent of the others.

Figure 9: Latex balloon show inflated within the mock IGU

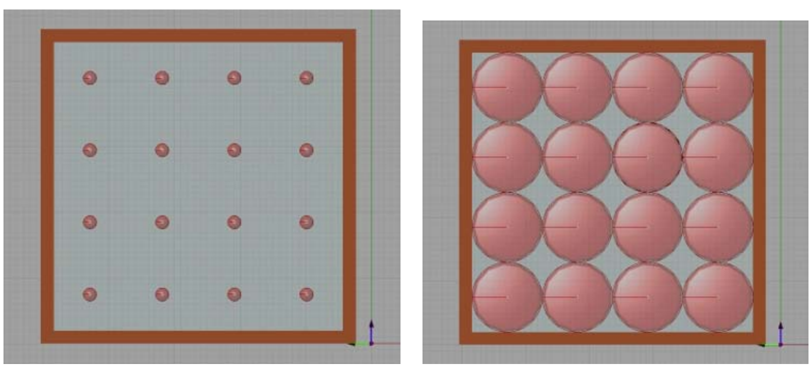

Figure 10: Rubber bulbs shown deflated, then fully inflated

To ensure that the proper amount of air volume is given to the balloon, an analog sensor constantly monitors the air pressure within the balloon. The pneumatic system is capable of recognizing when the balloon needs to be inflated, sealed, or vented to respond to the changing light levels. Electrical consumption, mechanical maintenance, and component life-cycle will also be recorded.

In following tests, special attention should be paid to the color of the balloons used and from where the air to inflate them is sourced. These choices could significantly affect how the prototype performs in terms of heat absorption and redistribution. Here, black balloons have been chosen to provide greater absorption of solar energy, preventing it from reaching the interior. Air will be sourced from outside of the enclosure to reduce heat building up. While in the balloons, the air will be heated. Air is vented outside of the enclosure to reduce heat gains.

2.1 PHYSICAL PROTOTYPES

2.1.1 Prototype 1

The first and simplest system will consist of only the mock I GU and serve as an experimental control. Sensors will be embedded within the enclosure and facade to monitor conditions.

2.1.2 Prototype 2

The second will consist of only one microcontroller, and the I/O devices essential for basic sensing and actuation. The microcontroller of choice is the Texas Instruments LaunchPad MSP430. This microcontroller is the first choice due to its cost ($5). To prove that IABS can be affordable, component costs will be kept to a minimum in each prototype. However, the more developer-friendly Arduino may be substituted if required/desired.

2.1.3 Prototype 3

The third prototype will consist of an agent computing mechanism (ACM), the Raspberry Pi Model B ($35), microcontroller, and peripherals. The Raspberry Pi will communicate with the microcontroller via asynchronous serial communications. This method of interfacing ensures that both can act as independent agents and allows prototype 3 to extract results specific to an agent based system.

2.1.4 Prototype 4

The final prototype has two microprocessors: one to interface with sensors and actuators and the other to act as a physical interface. The interface will be used to manually control and override certain behaviors as well as provide feedback on environmental conditions. The agent computing mechanism will be capable of monitoring and overriding the behavior of either microprocessor. As an agent with more powerful functionality, the ACM will be able to make higher level decisions and communicate them to the microprocessors should their preprogrammed behaviors not suffice. This also means that the ACM can potential lock-out specific control features associated with the interface agent should it be deemed necessary.

Table 3: Third generation prototype series and makeup

Mrk	Microprocessor	Sensors & Actuators	ACM	Network Agents	Agent System	ANN
1	None	None	None	None	No	No
2	One Arduino or TI LaunchPad MSP430	Yes	None	None	No	No
3	One Arduino or TI LaunchPad MSP430	Yes	One Raspberry Pi computer	Database and cloud agents	Yes	No
4	Two Arduinos or TI LaunchPad MSP430's	Yes	One Raspberry Pi computer	Database and cloud agents	Yes	Yes

2.2. Additional agents

Architects have long understood that it is possible to change the way that users interact with the spaces and objects that surround them by integrating logical devices into the built environment, but only recently have such devices become cheap, powerful, and small enough to be economically used in this way (Sterk 2006). This research seeks to add two more agents to this prototype series: human interface and end-user (Diagram 1). Statistics state that almost half of U.S. mobile phone subscribers now own smart phones (The Nielsen Company 2012). Due in part to this trend, there is a vast and readily available network of human interface devices that can be folded into an agent network. Desktop PC's, laptops, and ambient information devices are other examples of suitable interface devices. A dense and familiar network of interface devices delivers the added benefit of improved psychological wellbeing for occupants via the democratization of energy monitoring and limited environmental control (WGDB 2011). Important occupant biometrics (Table 4) can also be monitored from many of these devices, and used to further improve the environmental conditions.

Table 4: Occupant related metrics used to intelligently adjust environmental control

Occupant Metric	Definitions and Examples
Biometrics	Body temperature, heart rate, etc.
Personal Sentiments	Data on personal sentiments regarding the conditions in a building can be mined from social networks, blogs, etc.
Direct Commentary	Provided through explicit communication from occupant to interface

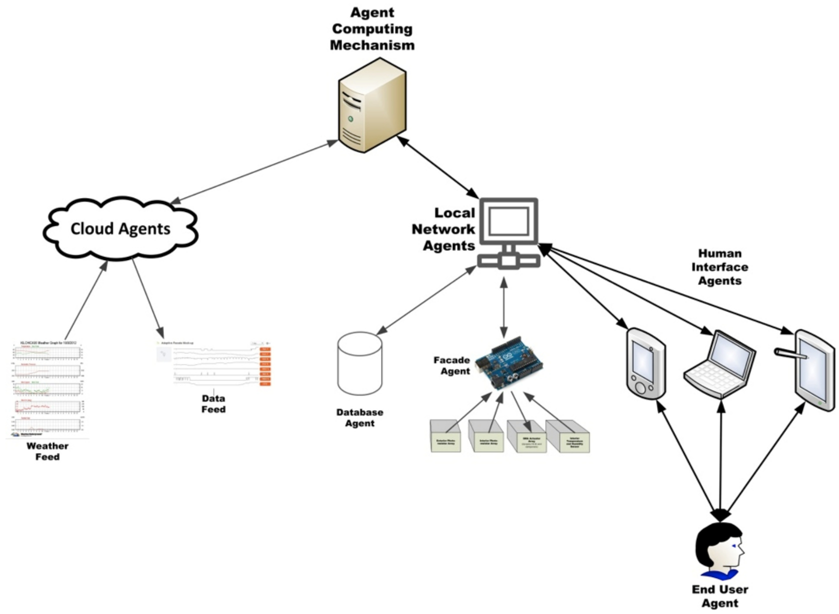

Diagram 1: Representation of functionality and data flow between the primary agents in 3rd generation prototypes

2.3. Virtual high-rise

In addition to the other prototypes already discussed, a virtual model of a prominent downtown Chicago mixed-use high-rise will be produced for the purpose of illustrating the capabilities of IABS. The high-rise to be chosen will be approximately 30 stories tall. This floor count is to ensure that a complete building can be modeled given the project time frame. The building's mixed-use program provides a diverse cross-section of space usage. In addition to the structure, the model will also consist of artificial lighting, HVAC, and adaptive components.

A mobile device application currently in development (Figure 11) will work as an interface for stockholders. With this prototype, model and components can be monitored and/or controlled in ways that are specific to each end-user. The application will run on an iOS 6 platform. Interfaces will differ for each stakeholder, and will allow varying levels of access to data and control. This interface will work as a tool for illustrating IABS capabilities and studying user interaction. User-centered design methodology will be utilized throughout development and testing. The study of subsequent results will be applied to future versions of both interface and IABS systems.

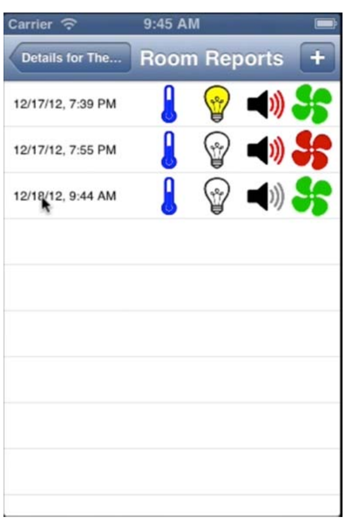

Figure 11: Mobile device application for environmental feedback and adaptive systems control

3.0. IMPLICATIONS

It should be noted that the proposed system's flexibility allows it to be applied to both new and existing high-rise structures. Since sustainability is a major component of this research, it should be noted that retrofitting existing high-rises could potentially save mor e in resources than starting anew in some cases.

IABS are capable of delivering feedback and control to occupants from any location. It follows that this characteristic can be exploited to function beyond the scope of the building, and into the urban environment as well. If applied at this scale, singular buildings would not just operate independent of others, but also be part of a larger network connected by urban infrastructure. This network would be capable of reallocating a building's resources through an exchange network to support reasonable indoor conditions throughout.

CONCLUSION

Architectural design practices already utilize a vast array of technologies when delivering projects. However, this technological advantage is not seen in the maintenance and operation phase of a buildings life-cycle. Intelligent and adaptive building systems have the potential to fill this gap through the marriage of various established and emergent technologies. Widespread use of these systems is important when trying to make a significant impact on the sustainability of building. They should therefore be as attainable and flexible as possible. Given the relative scale of high-rise buildings, they are a suitable vehicle for determining the technological make-up required to ensure widespread deployment of these systems. To date, this research has produced two prototypes to inform future research, and a 3rd series is in development to satisfy the goals discussed here. This series of prototypes will build upon the previous two by incorporating a more rigid process by which components and materials are chosen and analyzed. It is expected that the addition of the interface and end-user agents to a virtual high-rise model will strengthen for future system developments.

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Beyond Green: Growing Algae Facade

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ABSTRACT: As the popularity of glass façades in buildings continue to rise, the environmental impact of using glass façade systems is of increasing concern. Due to their high energy consumption through heat loss and unwanted heat gain, there needs to be a growing effort to promote an environmentally sustainable façade system. As a sustainable facade alternative, an innovative algae façade system was explored in this paper. The primary goal of this research is to demonstrate the design and development of the algae façade system and describe its preliminary structural and thermal performance using a FEA (finite element analysis) software and experimentation. The system details were explored throughout the prototyping of an algae façade panel. The research findings have demonstrated the viable application and improved performance characteristics of the algae façade system compared to a conventional glass façade system. The paper highlights areas of ongoing research activities and challenges associated with the algae façade system.

KEYWORDS: sustainable façade system, algae façade system, thermal performance, structural performance

INTRODUCTION

The construction and operation of a building significantly contributes to resource depletion and greenhouse gas emissions. A challenge for the building design, construction industries and building owners is to provide healthy indoor environments without depleting non-renewable energy resources and contributing to air pollution and global warming. According to DOE/EIA Annual Energy Outlook, buildings in the residential and commercial sectors in the US consume 40% of total energy, 72% of total electricity, and 40% of raw materials while generating 39% of the country's CO_2 emissions. For the transportation sector, transportation consumes 210 billion gallons per year and produces approximately 2.1 billion tons of CO_2 per year. Biofuels such as starch-based, biomass-based and cellulosic biofuels reduce our dependence on petroleum fuel and emerging technologies lead to the development of advanced biofuels using algae. A considerable amount of research on algae as a biofuel has been conducted and it has been reported that there are several advantages in using algae. First of all, due to their high growth rate, algae require less land and offer a high production rate for biomass and fuel. Further, they absorb CO_2 and do not require the use of fresh water. Figure 1 shows the algae production rate compared to other biofuels and its land use requirement. Corn, for example, requires twice the size of the USA to harvest biofuel of 210B gallons while algae need a state the size of North Carolina (around 50,000 sq. miles) to grow equivalent biofuel.

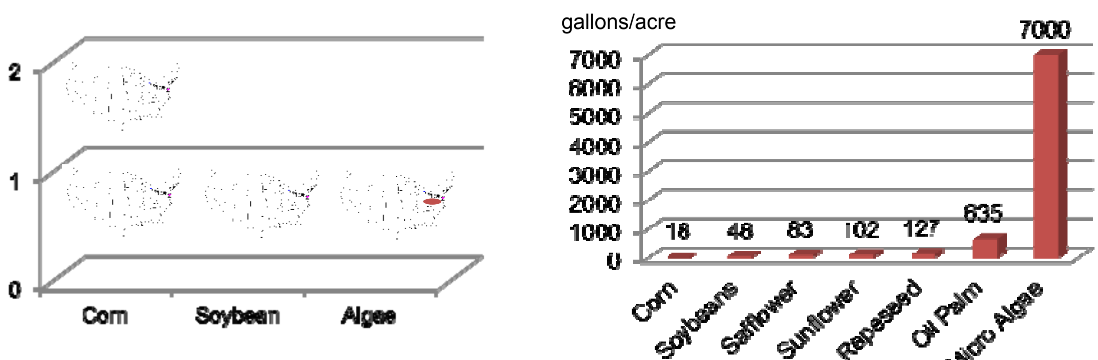


Figure 1: Algae production rate and required land compared to other biofuel alternatives. Image source: (Author 2013). Data source: (DOE, 2012)

A variety of state-of-the-art transparent facade technologies are available: low-e coated IGU, inert gas integrated IGU, and shading device (such as stretched metal, frit, suspended film) integrated IGU. These technologies particularly reduce building energy consumption by improving the heat transmission (U-factor), SHGC (solar heat gain coefficient), and VLT (visible light transmittance). Managing heat flows through building facades alone, however, is not sufficient to give rise to a high performance façade system. Photovoltaic and solar thermal systems are examples of accomplishing both energy management and energy generation currently applied in buildings. As a high performance facade alternative, an innovative algae facade system has been investigated.

The primary objective of this research is therefore to carry out a feasibility study of an algae façade system by exploring its performance attributes, façade system details and fabrication challenges. This paper discusses the preliminary performance assessment in the areas of structural and thermal performance. This effort includes FEA computer simulation and experimentation. More comprehensive study on optimal design configurations for the algae façade system is under development.

1.0 ALGAE FAÇADE SYSTEM

Environmental concerns and resource depletion are issues that we currently face. Algae integrated building envelopes are not a new concept in the architecture field. Several architects and designers have used algae in their conceptual buildings or art installations. The HOK's first place winning scheme for the 2011 IDEAS competition showed an algae photobioreactor tube attached to the top surface of the opaque building envelopes of the GSA federal building in LA. In addition to this project, their recent concept design of the net energy zero Battery Park project in San Francisco incorporated algae photobioreactor panels to grow algae and reduce CO_2. The world's first algae façade integrated building, the BIQ house in Hamburg, Germany is enclosed with an algae panel as a shading device. The algae façade system explored in this paper acts as a building facade system that fulfils various functional requirements such as airtight, watertight, structure, energy, daylighting, occupant's comfort and aesthetic. Further, it creates an optimum environment that maximizes algae growth, thus reducing the amount of atmospheric CO_2 and, as an added benefit, produces O_2.

The algae façade system consists of an algae panel, aluminum framing and algae growing apparatus. The algae facade system is insulated and thermally broken and is designed to be spanning between slab edges. The algae façade system is sized to be 5ft wide by 12ft tall or taller depending on building conditions and consists of vision zone and algae zone. Unobstructed vision zone in the algae façade system has been introduced for viewing, daylighting and ventilation where necessary. The remaining area called algae zone is assigned for growing algae. The algae façade system is simply supported on four sides of aluminum framings and is mechanically restrained with sufficient clearances for thermal expansion and contraction. A demountable single-piece metal cover is a part of the system to conceal algae growing apparatus. The algae growing apparatus is comprised of intake systems for supplying CO_2, and growing algae (e.g. algae, nutrients, medium etc) and discharging systems for emitting O2 and collecting grown algae. Figure 2 illustrates a schematic detail of the algae facade system and its generic application into a building facade.

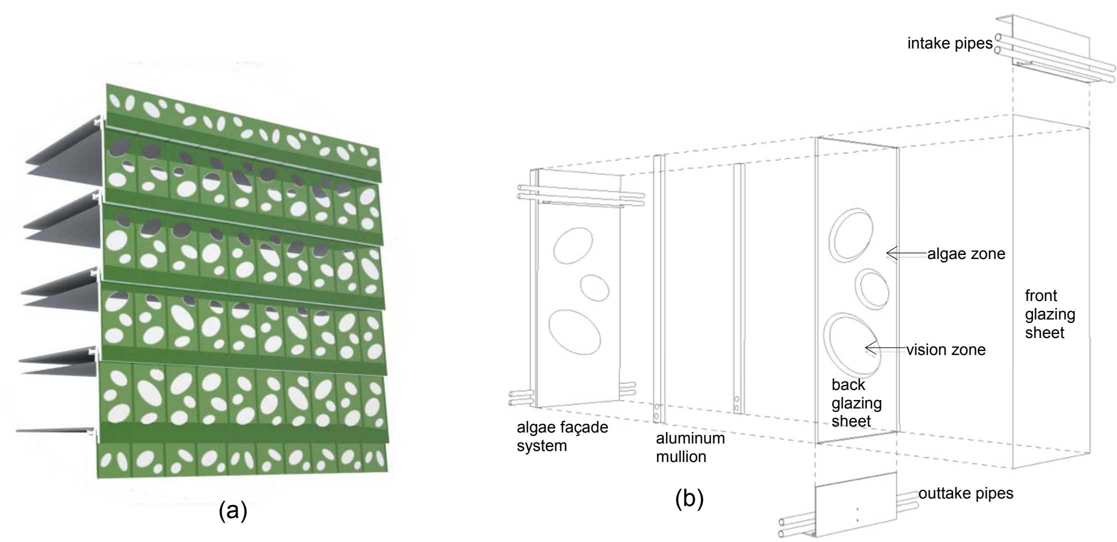


Figure 2: Algae façade application in office building (a) and exploded system details (b). Source: (Author 2013)

The short-term research goal is to identify the feasibility of the algae façade system through schematic design and prototyping. The development work of the algae façade system is currently being carried out at the School of Architecture, University of North Carolina Charlotte working with faculties and students across a range of disciplines, under an EPA/NSF funded grant P3 (People, Prosperity and the Planet) project. A visual mock-up was fabricated to facilitate decisions on fabricability, aesthetics and performance (Figure 3). Acrylic was considered for the algae façade material due to its higher impact resistance, lightweight, optical clarity and ease of fabrication compared to glass. Given that it is important to consider scratch and UV resistance of the acrylic surface, there are coating or surface treatment technologies available that offer good UV and scratch protection.

(a) (b) (c)

Figure 3: Algae façade panels[1] with different surface treatment; transparent (a), 50% sandblast (b) and 100% sand blast (c) at the algae zone. Source: (Author 2013)

The current research being carried out by the author includes geometrical variations of the vision zone and different surface conditions of the algae zone. One of the performance issues to consider was to block or minimize the green light transmission from the algae zone. As a result, the interior surface of the algae zone was sandblasted or covered with different colors. Figure 3 shows an algae panel with different levels of translucency at the algae zone. These prototyping algae façade panels revealed fabrication challenges associated with making a watertight assembly, especially at the interface between vision and algae zone. The kinds of adhesives and connection method are currently being researched.

2.0 PRELIMINARY PERFORMANCE ASSESSMENT

2.1. Preliminary Structural Analysis

One of the primary goals of this research was to understand the general structural behaviors of the algae façade under various loadings. Prior to the lab testing, the stress and stiffness levels of the algae panel were investigated using a FEA software tool, Strand7. The size of the algae panel is 5ft x 12ft x 2in, and the acrylic is 5/16in thick. The algae panel was modeled with plate elements in Strand7, and the mesh was sized to approximately 4in x 4in. The edge supporting conditions were a pin support and a roller support, simulating a typical curtainwall attachment condition and accommodating thermal expansion and contraction. The material properties (E-modulus, density, Poisson's ratio) of the acrylic were obtained from the product data of Acrylite FF provided by Cyro Industries. The shear modulus was calculated using the equation: $G = E/2(1+ v)$. The loading condition applied in this study included self-weight of the algae panel, wind load and water pressure. The weight of the panel is approximately 230lbs without water in the cavity and 650lbs with water. The design wind load for the algae panel is assumed to be 20 psf. It is assumed that the wind load is transferred by the finite volumes of water in the cavity without loss. The water pressure from the water in the cavity is assumed to be a distributed load that is increasing uniformly to the bottom of the algae panel. Additionally the internal temperature of the water in the cavity is assumed to be in the range of 68°F ~ 86°F and any internal cavity pressure from the external isobaric pressure is assumed to be zero. Deflection of a façade system controls the façade design of a curtainwall system.

The FEA simulation results showed that the current design deflects 0.62” under wind and 1.5” under water pressure. Deflection of L/90 or 1” is generally regarded as an upper bound on acceptable glass deflection. The current deflection exceeds maximum allowable deflection, which requires design alteration. Deflection can be reduced by increasing the thickness of the acrylic or adding vision zone where the greatest deflection occurs. The maximum principal stress occurs mostly at the panel edges and perimeter of the vision zone. The maximum stress is around 5ksi under combined loading condition. Special attention is required at the adhesion between vision and algae zone. Figure 4 shows the output of Strand7 simulation, indicating deflection and stress levels under self-weight, wind load, and water pressure, respectively. Long-term performance such as creep deformation under water pressure needs to be investigated. The results of a more comprehensive study on both analytical and experimental assessment of the structural performance are expected to be presented at the conference.

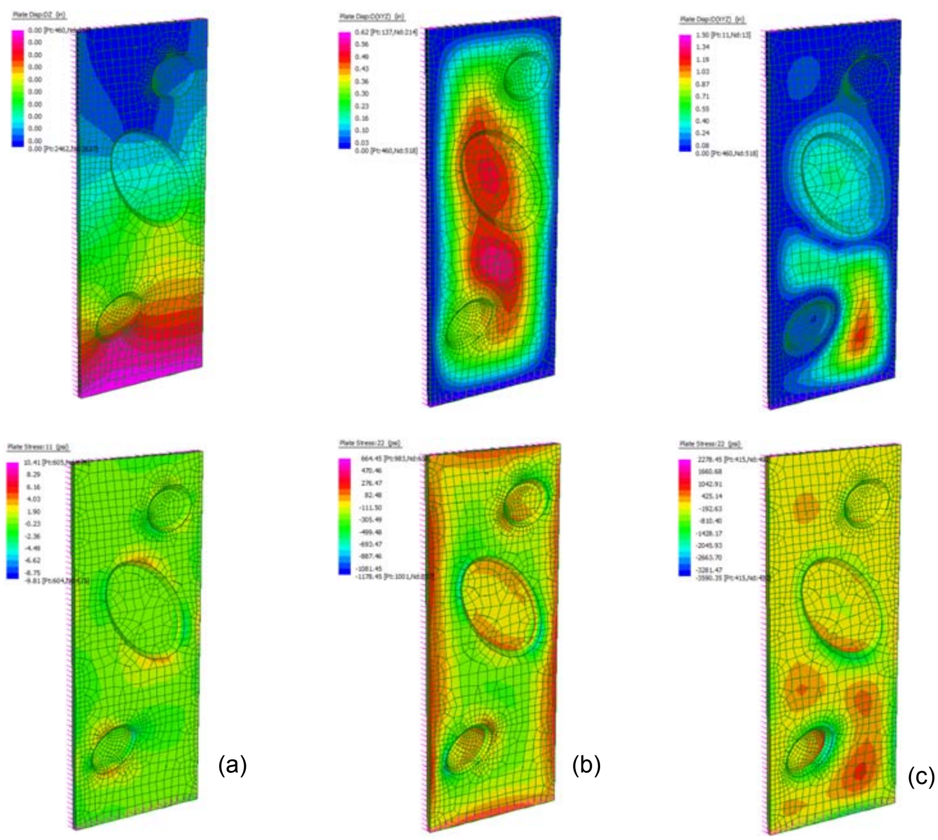


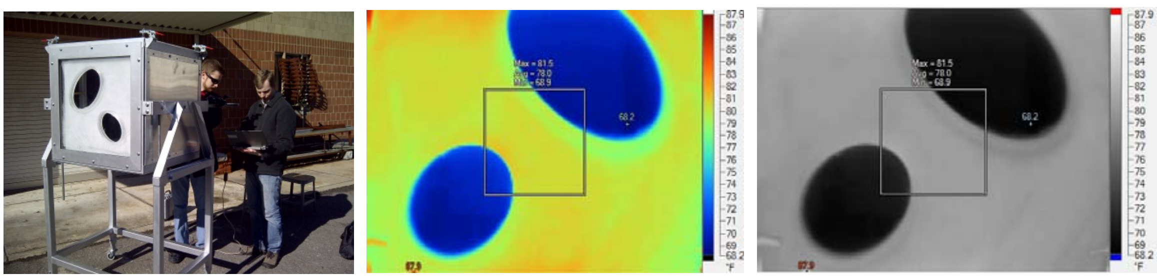
Figure 4: Preliminary structural analysis results of algae façade; stress (top) and deflection (bottom) output under self-weight (a), wind load (b) and water pressure (c). Source: (Author 2013)

2.2. Preliminary Thermal Performance Analysis

In the building industry, thermography technique is often used to detect air infiltrations, cold bridges, moisture creation, and heat loss through windows. An understanding of the surface temperature distribution over a building envelope is important, as the thermal variations affect cooling and heating loads of a building, as well as the occupant’s thermal comfort. Ambient temperature and solar radiation are the primary factors affecting the thermal distribution on the exterior building envelope. Infrared cameras convert the thermal energy (i.e. the infrared band of the electromagnetic spectrum) radiated from an object into a visible image where each thermal energy level is represented by a color or grey scale. The thermal energy is dependent on the emissivity of a material surface and a fraction of the thermal energy can be added or absorbed by the atmosphere between the surface and the camera.

In practice, the thermal performance of a facade system is determined in accordance with various standards such as ASTM (American Society of Testing and Materials), NFRC (National Fenestration Rating Council) and AAMA (American Architectural Manufacturing Association). These standards require a specific apparatus and testing procedure and evaluate a final assembly of a building façade system. Since the algae facade system in this paper continues to evolve and develop, the thermography technique proved to be an efficient tool to assess the preliminary thermal performance. The thermography technique is an image based analysis tool that offers a user friendly and time efficient assessment. It allows evaluating preliminary energy performance of a façade system and facilitates design evolutions from the fast performance feedback.

An algae panel was set up to test the thermal distribution of the interior surface temperature. Tests were conducted in a sunny winter noon in outdoor environment using the FLUKE thermography system with its software package. The testing algae panel was 2ft by 2ft and the interior surface of the algae zone was sandblasted with 100% translucency. In order to minimize energy flow between the material and the atmosphere, the interior surface of the testing chamber was covered with black painted plywood. The preliminary thermography data showed that the temperature difference between the vision and algae zone during winter time is approximately 13°F (the vision zone is 69°F while the algae zone is 82°F), indicating that the vision zone is subject to higher heat transmission (U-factor) compared to the algae zone (Figure 5). A simple mouse click of the thermal image shows a surface temperature of the algae panel where dark blue (black in grey scale) represents the minimum temperature and red (light grey in grey scale) represents the maximum temperature.



(a) (b)

Figure 5: Preliminary thermal performance of algae façade; test set-up (a) and temperature distribution (b). Source: (Author 2013)

In the next step, it is intended to conduct the same experimentation of an insulated glass unit (IGU) in order to understand how much the algae façade outperforms in U-factor relative to an IGU. The temperature data obtained from the thermography testing will be used in a CFD analysis tool to verify interior temperatures of a building enclosed with algae panels. The interior temperature will be used in DesignBuilder to run a whole building energy simulation. By carrying out the whole building energy simulation, energy saving from algae façades can be determined. Since this is an ongoing process, the results of energy performance of algae facades will be presented at the conference.

CONCLUSION

This paper shows the development of the algae façade system and its preliminary structural and thermal performance. The research demonstrated that the algae façade system has the future potential for sustainable façade alternatives and energy generation possibilities. The computer simulation on structural behaviors provided alternative design solutions to meet stress and stiffness criteria under various loadings. The IR experiments involved determining the thermal characteristics of the vision and algae zone of the algae façade. The prototyping of an algae façade panel reveals fabrication challenges associated with watertight interfaces between the vision zone and the algae zone. Additional façade system details need to be explored, incorporating algae growing apparatus and artificial lighting to grow algae at night time. The future direction of this research is to investigate long-term performances such as weatherability under outdoor use, durability from periodical maintenance of the algae zone, and creep deformation behaviors under water pressure.

ACKNOWLEDGEMENTS

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ENDNOTES

[1] Algae façade system© is fully copyrighted and patent pending by Kyoung-Hee Kim in its entirety.

Lessons from Visualizing the Functions of the Building Enclosure

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ABSTRACT: A study completed in 2012, by the author, surveyed designers and builders about their use and understanding of the air barrier system in residential construction. Results show that a larger percentage of builders than designers reported *always* performing blower door tests on their projects. The study also showed that a larger percentage of builders than designers believe that an air barrier system must be continuous to be effective. It is well known that an air barrier system must be continuous to be completely effective and it is hypothesized that more builders believe this because they have first hand, visual experience of air infiltration. Blower door tests depressurize a building to expose air leaks through the enclosure. If visualization of air infiltration has convinced more builders of the importance of the air barrier system, what other visual and experiential tests of the building enclosure could be devised for building professionals to reinforce the importance of other enclosure components?

This paper explores possibilities for new experiential tests for a highly misunderstood layer of the enclosure, the vapor retarder. Reasons for its misunderstanding are numerous: placement is climate based, it is sometimes only millimeters thick, it is made of many parts, information on the topic is often unreliable and it is generally a confusing topic. For these reasons, the vapor retarder is often misused within the enclosure creating potential problems for structural rot and mold within walls. Is there an onsite testing option for this layer that would provide the same visual feedback that the blower door test gives for the air barrier system? This paper seeks to identify possible methods to teach building professionals using hands on experience and visualization about the function of the vapor retarder.

KEYWORDS: Building Enclosure, Experiential Learning Theory, Vapor Retarder, Air Barrier System

INTRODUCTION

I know the difficulty of understanding the invisible functions of the building enclosure. Without understanding these invisible functions, intelligent design decisions about the composition of the enclosure are difficult to make. I based my graduate thesis on this issue. As a design professional, I often wondered if I was correctly positioning the vapor retarder and what constitutes an air barrier system. Clear answers to my questions were almost impossible to find in books and on the internet, and other designers seemed to be just as confused. Although these parts of the enclosure are thin and difficult to see, they are important to a properly functioning enclosure.

It is commonly known that a correctly designed air barrier system prevents air infiltration which preserves heating and cooling and stops vapor transmission. A correctly placed vapor retarder reduces interstitial condensation which prevents mold and rot within wall cavities. Both are essential to an efficient and healthy building. Although it is obvious they are needed, the use and placement of these parts are often confused because they are challenging to draw and communicate between designers and builders, they are usually only millimeters thick, and the scientific nature of their function is difficult to understand. For instance, an air barrier system is the combination of many parts of the enclosure – not just a layer of house wrap. Air barrier systems are three dimensional, therefore include the caulked joint from the window to house wrap and taped joint between each layer of house wrap. Insulation, drywall, sheathing, and other building materials, at times, serve as parts of the air barrier system. Vapor retarders sometimes serve as part of the air barrier system.

Vapor retarder placement is determined by climate and differs depending on wall type. The air barrier system must be completely continuous to be effective whereas the vapor retarder does not (Lstiburek 2001.) Because of their sometimes shared functions and sometimes very different placement requirements, it can be a confusing task to design and install these systems. An intimate understanding of both is necessary for effective use.

My graduate thesis completed at the University of Oregon in 2012, titled *A Comparative Study of Climate Based Design of Building Enclosures*, concentrated on common use and understanding of the vapor retarder and the air barrier system in residential construction. I attempted, through research, to determine if the contradicting information and confused terminology I discovered in practice had a negative effect on the performance of buildings. Through a national on-line survey, I asked building professionals where they learn about vapor retarders and air barrier systems and if they find the information confusing. I wanted to know what resources others were using for answers and what practices for design they used. I also asked specific questions about their understanding of and where they place vapor retarders and air barrier systems. This information could help me to determine if what is being built is flawed. I hypothesized that common practice of enclosure design differed from best practice. This paper uses two interesting points of data derived from my thesis and applies them to ideas about better ways to teach building professionals about the building enclosure.

The results of the survey revealed that a large percentage of builders “strongly agree” that an air barrier system must be continuous to be effective; whereas, a significantly smaller number of designers believe this statement to be true. Why do more builders believe in the importance of a continuous air barrier system? Could it be because more builders report always performing blower door tests on their projects (McGlohn 2012?) Is it possible that builders understand the importance of a continuous air barrier system because they have visually experienced the effects of a discontinuous system and had to fix the problem? Can it be concluded that hands-on experiential learning methods like blower door testing are better for teaching building professionals about the functions of the building enclosure? This paper considers alternative ways to learn using Experiential Learning Theory as a vehicle for teaching design professionals about the invisible functions of the building enclosure.

Section one gives a short overview of my master’s thesis including the problem, methodology and conclusions gathered. The information this paper focuses on is discussed in section two. Section three introduces Kolb and Kolb’s Experiential Learning Theory (ELT) and relates this theory to the results of my thesis’ survey. Section four explores the possibly of applying ELT to other lessons about the building enclosure such as vapor retarder function.

1.0 A COMPARATIVE STUDY OF CLIMATE BASED DESIGN OF BUILDING ENCLOSURES

The thesis referred to in this paper was completed in March of 2012 in partial fulfillment for the degree of Master of Architecture awarded by the University of Oregon. An online survey approved by the Institutional Review Board (IRB) was issued to designers and builders of residential construction in 4 states from October 07, 2011 to November 04, 2011. In this thesis designers are defined as “. . . an architect, an architectural intern, or designer/builder (McGlohn 2012, 71.)” Builders are defined as “someone directly related to the construction of a house in a decision making role (McGlohn 2012, 71.)” From the results two interesting points related to teaching methods are highlighted for this paper and considered for future research.

1.1 Problem statement and hypothesis

As mentioned in the introduction, air barrier systems and vapor retarders are often confusing to building professionals. This is supported by the following quote from building science experts, Straube and Burnett in their text book *Building Science for Building Enclosures*.

> . . . much of the older literature (and a remarkable proportion of current documentation) confuses or combines the function of the air barrier system and vapor barriers, and the difference between the two is still one of the most commonly discussed building science issues (Straube and Burnett 2005.)

Considering this, the first objective of my research was to determine if common practice of residential design and construction was negatively affected by the documented confusion. Do designers and builders detail their enclosures so that air can infiltrate and water vapor can condense within the wall? Other objectives were to find out where building professionals learn about the vapor retarder and air barrier system and if the resources they use are reliable.

I hypothesized that building professionals do not follow best practice and make mistakes in detailing. I also hypothesized that the internet is the first place building professionals go when they have a question pertaining to the building enclosure.

1.2 Methodology

To answer these questions I designed a 17 question on-line survey that was approved by the University of Oregon’s Human Subjects Office. Many aspects of enclosure design are climate based; therefore, 4 states in 4 different climate zones were selected for the survey. States were selected based on their use of shared and mandated International Residential Code and International Energy Conservation Code. Through the use of the American Institute of Architects (AIA) and the National Association of Homebuilders online databases of members, I randomly selected 80 architecture firms and 80 homebuilders to contact and ask to take the survey. One hundred sixty phone calls and emails were sent to potential respondents across the country. Personal contacts in the selected states were also used to distribute the survey. Two hundred twenty responses were collected but after cleaning the data only 152 were used.

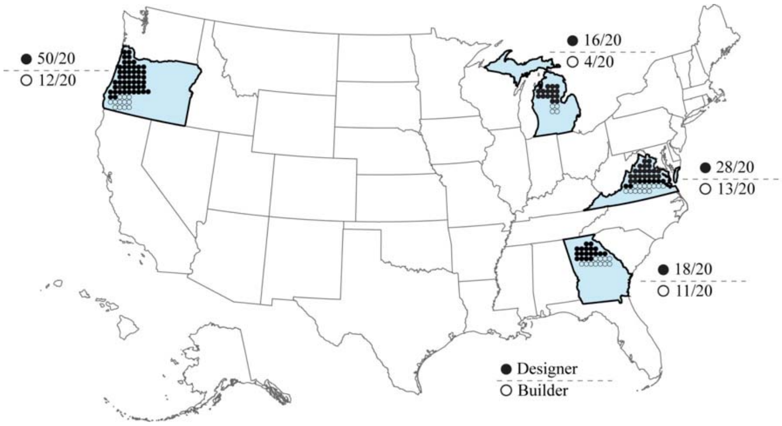

Figure 1: State selection and response numbers from each.

Above, Figure 1 illustrates the states selected for the survey and how many responses were received. Oregon represents a marine climate, Michigan a cold climate, Georgia a hot-humid climate, and Virginia a mixed climate.

1.2 Results pertinent to this paper

The complete results of the referenced thesis will not be discussed; however, two interesting points from the results make the basis for this paper. A question was included in the survey that was designed to help determine if building professionals understand the importance of a continuous air barrier system. They were asked to respond to the statement "A continuous air barrier system is essential for proper function of the building enclosure" by selecting one of the following: "strongly disagree," "disagree," "neither agree nor disagree," "agree," "strongly agree," or "not sure." The results showed that, alarmingly, only 65% of designers "strongly agree" that an air barrier system must be continuous to be effective (McGlohn 2012.) This is a surprisingly low percentage because it is a well-known fact that an air barrier system must be completely continuous to be effective. On the other hand, 83% of builders "strongly agree" with this statement (McGlohn 2012.) Why do more builders believe in the importance of a continuous air barrier system? A follow-up question asked "how often is a blower door test performed on your buildings?" with the choices of "never," "rarely," "sometimes," "always," and "not sure." A blower door test identifies areas of air infiltration. Twenty-five percent of builders reported they "always" perform blower door tests (McGlohn 2012.) Designers report "always" performing blower door tests only 6% of the time (McGlohn 2012.) Figure 2 graphically depicts these results. Is it possible that more builders believe in the importance of continuity of the air barrier system because they more often perform blower door tests?

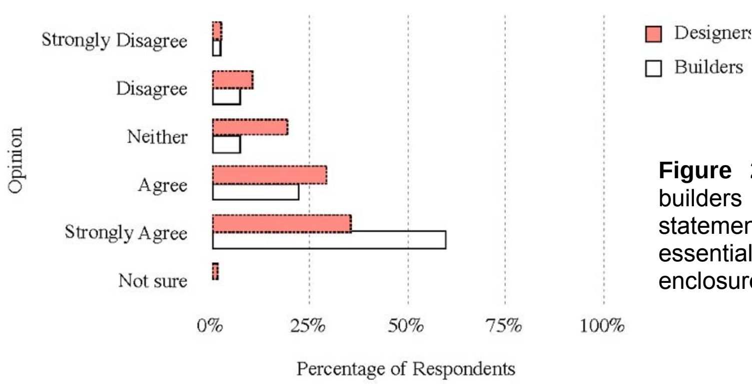

Figure 2: Percentages of designers and builders who responded to the following statement: A continuous air barrier system is essential for proper function of the building enclosure" (McGlohn 44.)

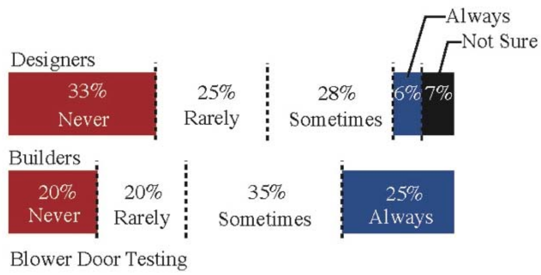

Figure 3: Percentages of designers and builders reporting how often they perform blower door tests on their projects (McGlohn 44.)

These two points from the results are the basis for this paper. One conclusion that can be made from the information presented above is that more builders believe an air barrier system must be continuous to be effective because more builders preform blower door tests. Blower door tests depressurize a house in order to measure the air infiltration through the enclosure. Air changes per hour (ACH) are then calculated with the results. A house with a low ACH number has low air infiltration. Conversely, a high ACH indicates many cracks and crevices that air is able to pass through the enclosure. Often builders use blower door tests during construction to insure a tightly sealed and energy efficient house. Air leaks are identified with smoke sticks or infrared cameras so they can be sealed. Does this process of testing air tightness, identifying the problem, and fixing the problem teach builders about air barrier system functionality? If this is the case, it can be concluded that design professionals' understanding of the building enclosure can be improved with the use of other experiential based testing methods.

2.0 Experiential Learning Theory

One well known theory presented by Kolb and Kolb that supports the learning process identified above is the Experiential Learning Theory. This theory defines learning as "the process whereby knowledge is created through the transformation of experience. Knowledge results from the combination of grasping and transforming experience" (as cited in Kolb and Kolb 2005.) This theory supports that learning is enhanced by having a "concrete experience" that can be thought about and then used to draw conclusions on the event (Kolb and Kolb 2005.) The conclusions are then used to adjust future attempts to learn in order to improve a second "concrete experience" (Kolb and Kolb 2005.)

2.1 Experiential Learning Theory applied to air infiltration

Builders report testing the performance of the enclosures they build with blower door tests more often than dsigners and more builders also believe in the importance of a continuous air barrier system. My conclusion for these results is that builders, unknowingly, participated in experiential learning. They constructed an enclosure, tested its effectiveness through depressurization which identified their mistakes, assessed the leaky situation, fixed the mistakes and probably tested the enclosure again. The following chart (figure 4) adapted from Kolb and Kolb's journal article *The Learning Way: Meta-cognitive Aspects of Experiential Learning,* diagrams the process.

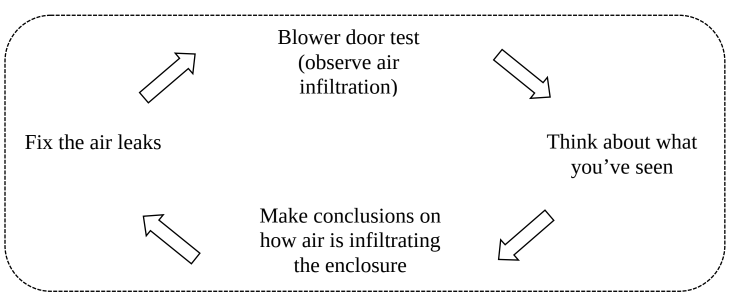

Figure 4: Experiential Learning Theory applied to testing air infiltration in a house (Kolb and Kolb 2009.) Through each cycle, knowledge is increased because the end result is experienced, adjusted, and refined.

2.1 How Experiential Learning Theory can be applied to vapor diffusion

Many builders, carpenters, architects and designers learn their trades through first hand experiences. “On the job” was ranked number 1 when building professionals were asked “where did you first learn about vapor retarders and air barrier systems?” (McGlohn 35.) Experiential Learning Theory is discussed in earlier sections and highlighted by the relationship between blower door testing and comprehension of the continuity of an air barrier system. Through on-site testing and adjusting, builders teach themselves about air infiltration and how to fix problems. This is significant because preventing air infiltration is important to energy efficient and healthy homes. Another invisible action within the enclosure is vapor diffusion. Generally, more water vapor is held in warm air; therefore, buildings in hot-humid climates have more water vapor on the exterior most of the year and buildings in cold climates have more water vapor on the interior most of the year. The higher concentration of water vapor seeks to balance with the air in the lower concentration of water vapor. This happens by vapor diffusion through the enclosure and this process will cause problems if the water vapor collides with a surface below the dew point within the wall cavity. Vapor retarders are placed within the enclosure at climate specific locations to slow down water vapor diffusion which prevents interstitial condensation.

The function of a vapor retarder is invisible. Is there a mechanism that can be devised, similar to a blower door test that can visually demonstrate how a vapor retarder works to builders and designers? Can the Experiential Learning Theory be applied to learning about vapor retarder function?

2.2 WUFI-ORNL/IBP

One method of learning about vapor diffusion thorough the material of an enclosure is a software program developed by the Oak Ridge National Laboratory (ORNL) called WUFI-ORNL/IBP or WUFI for short. WUFI is creates a “realistic calculation of the transient hygrothermal behaviour of multi-layer building components exposed to natural climate conditions” as stated on the ORNL Building Technology Center’s website. This program allows a user to define the composition of a building’s wall, apply climate specific conditions to the exterior and interior of the wall, and simulate climate conditions for a two year period. The results show if the wall, over time, will accumulate moisture or if the wall will dry over time. Although this is a relatively simple program and one version is free, most people in the field will never be exposed to this way of demonstrating vapor movement. My research has shown that an on-site demonstration that shows measurable water vapor movement would be more beneficial.

2.3 ORNL Rotatable Guarded Hotbox

Another testing method the Oak Ridge National Laboratory’s Building Technology Center has developed is the Rotatable Guarded Hotbox. Wall assemblies are tested according to ASTM C1363 – 11 Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus (“Oak Ridge.”) This dual chamber system controls temperature on two sides of a wall assembly sample and measures levels of thermal resistance through the sample. One side of the chamber is warm and one is cold. Although measuring vapor diffusion is not a goal of this research it is an aspect. Relative humidity is controllable in the Large Scale Climate Simulator, the roof and attic assembly testing simulator (“Oak Ridge.”) A system similar to this is one possibility for demonstrating the use of vapor retarders. The Rotatable Guarded Hotbox and the Large Scale Climate Simulator are huge, stationary, and not appropriate for on-site demonstrations to carpenters, builders, designers, and architects.

3.0 The vapor diffusion experience

This paper is the beginning of a larger and more in-depth research effort. The broadest question that arises from the discussion above is, “can vapor diffusion be measured through a building’s enclosure?” Unlike air infiltration, there are few onsite tests that exist to measure how much water vapor passes through an enclosure and identifies problematic areas of condensation. Because interstitial condensation is the major concern, access to the inner layers of the enclosure would be necessary to measure moisture accumulation. Also, because interstitial condensation is dependent on the climate conditions of the exterior and interior of the building, temperature control would be necessary to accurately identify the consequences of a misplaced vapor retarder. Furthermore, the amount of water vapor in the air, relative humidity, would also need a control mechanism. These obstacles present a few major problems with testing an entire building’s vapor retarder function. But is testing the entire building necessary? The continuity and the quality of installation of the vapor retarder is not as important and the continuity and quality of installation of the air barrier system. From the book *Builder’s Guide: Mixed-Humid Climates*, Lstiburek explains that a vapor retarder that is 90% complete, blocks 90% of vapor diffusion (109.) I believe understanding the basic function and climatic placement of a vapor retarder can be taught with an on-site module that contains all the controls necessary to simulate climatic conditions necessary to affect vapor diffusion.

3.1 Proposed on-site vapor diffusion demonstrations

Below, in Table 1, the components a vapor diffusion teaching module would need are listed.

Table 1: Components needed for dual chamber vapor diffusion simulator

Component	Function
Sealed, dual chamber container	An air tight chamber is needed to isolate climate specific simulations. Air infiltration must be avoided to prevent water vapor from entering through air infiltration.
Mechanism to control heat and relative humidity on side 1 of dual chamber container.	Simulate winter conditions on the interior of a cold-climate wall assembly and summer conditions on the exterior of a hot-humid wall assembly.
Mechanism to control air conditioning and relative humidity of side 2 of dual chamber container.	Simulate winter conditions on the exterior of a cold-climate wall assembly and summer conditions on the interior of a hot-humid wall assembly.
Desiccant	Moisture absorbing material that allows water vapor to be measured as it diffuses from one side of the chamber to the other.
Visual indicator	A visual component that allows the user to see water vapor move through the wall assembly would be ideal. Although, at this time I am unsure what this mechanism is.
Wall assembly divider	The two chambers must be divided by the wall assembly in question.
Data loggers	Data logger sensors are needed within the wall assembly to measure temperature, relative humidity, and dew point. It is necessary to determine if condensation has formed within the wall.

Although there are simulation methods that exist for testing vapor diffusion, I believe that to improve education of the installers and designers, a traveling simulator is necessary. Ideally, it would be simple to use for on-site experimentation. Temperature and relative humidity set points can be specified, the sample wall assembly can be inserted, and water vapor diffusion can be measured. Admittedly, this is a simplification of the proposed machine. Technically, I am proposing a complicated module; however, I believe that an experience such as this would be beneficial to those designing the location and installing vapor retarders.

CONCLUSION

My research has highlighted a practical fact that most educators already know, having hands-on learning experiences solidifies the lesson for a student. As building technologies change and become more complicated, we must find ways to continue to educate ourselves and the people hired to build what is designed. The quality and functionality of our buildings depends on it. Learning environments are different for individuals involved with the design and construction of buildings. A classroom setting is not always available and arguably not the best learning environment for these subjects. Most lessons for these trades are learned on-site, through hands-on experiences. The blower door test is one example of how builders and designers are learning about air infiltration and energy efficiency. This exemplifies the Experiential Learning Theory. Air infiltration is only one of many invisible and important subjects within the building enclosure. Vapor diffusion is also problematic when it is not properly controlled with a good understanding of how to use vapor retarders. Is there an on-site method for teaching about vapor diffusion that would provide installers and designers with an experience that teaches them how a vapor retarder works? With on-site experiential learning simulations, building technology education can be enhanced, building performance can be improved, and lasting impressions can be made on builders and designers. Confusion on this topic can be reduced; therefore, more efficient and healthier homes will be designed and constructed.

There is much more to do to make this idea a reality. More research is necessary to determine what components are needed for an on-site vapor diffusion chamber. I have only proposed general elements. Consultation with other researchers involved in similar research will be helpful to determine where overlap may occur and where joint efforts can take place. A feasibly study that outlines costs, time line, educational curriculum, and documented interest from the industry will also be necessary. A final product is in the distant future but the need for improving on-site building enclosure education is immediate.

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Parametric Design of Photo-catalytic Concrete Cladding Panels

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ABSTRACT: The paper documents the research conclusions, design methodology, and development of a prototype for an exterior wall paneling system which utilizes proprietary self-cleaning photocatalytic cement panels. The developed method of design is performatively modeled utilizing data from site conditions as a means of customizing each particular cladding panel variation to its location.
Buildings' energy demands are closely related to the building envelope, and can be decreased with efficient envelope design. As the building industry continues to be among the main accessories to the looming energy crisis, sensible envelope design and choice of exterior cladding are imperative. .

KEYWORDS: photo-catalytic concrete environmental design

INTRODUCTION
Today, environmental issues and political pressures for our industry to contribute more to sustainable development continue to intensify. While the architectural profession sees its future in the interplay and balance between the natural and built environments, it is increasingly poised to establish a functional interface between them. Influenced by the wide use and dependency on software and numerically-controlled fabrication technologies, complex forms are often evaluated through performance criteria that put an emphasis on the environmental and structural parameters that shape them.

Research into photocatalytic cements has been progressing for over ten years and this emerging technology offers building professionals a renewed opportunity to contribute toward sustainable goals while improving value. Photocatalytic cement uses daylight to react with and neutralize common air pollutants such as nitrogen and sulfur oxides, carbon monoxide, and VOC's – the reaction takes place on the surface of the concrete and the resulting inert nitrates can be washed off manually or by rain[1].

The environmental benefits of using photocatalytic cement are many – in addition to eliminating air-pollutants and its self-cleaning properties, reduced clinker content, comparable strength to Type I early-strength cements, and relatively high reflectivity make the use of this new admixture to concrete a sensible contribution to environmental protection and rehabilitation.

By pairing environment-based algorithmic design and innovative materials, the paper's bias is also that the mitigation of the adverse effects of energy transfer through the building envelope starts with the earliest possible incorporation of model data from site conditions into envelope design.

1.0. APPROACH
The developed method of design is performatively modeled utilizing data from site conditions as a means of customizing each particular cladding panel variation to its location. One type of data used comes from the site's longitude and latitude, which in turn is linked to data describing predominant wind directions, and hours of daylight. Another type of data describes the preferred orientation at a chosen site, which also corresponds with a predominant/desired view. As the parametric model is subjected to various data sets, such as geographic position and orientation and data linked to those two parameters, such as yearly solar stress, incident solar radiation[2], absorbed and transmitted solar energy[3] (based on the applied surface and material properties) and photosynthetically active radiation[4],a range of possible performative possibilities and optimized solutions arise.

Once the panel geometry is derived it is compared to a flat vertical panel of identical material and orientation and, lastly, a possible incorporation into a small building structure on the chosen site is illustrated.

1.1. Site

For the purposes of testing our design approach we have selected a medium density suburban location at latitude 40°39'50"N (40.66°), longitude 75°22'0"W (-75.37°), and altitude 116m (380’). The climate during the hot summer months form mid-June until mid-August is classified as warm humid and the weather station is less than a mile away, which makes the available weather data highly pertinent. The values are gathered from weather data available from U.S. Department of Energy[5] and formatted in Weather Tool 2011[6].

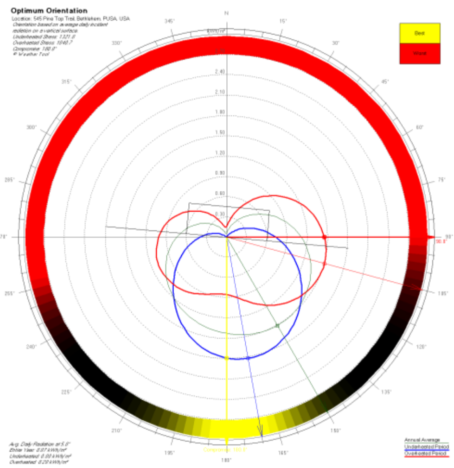

Figure 9: Optimum orientation, Weather Tool 2011, Autodesk Inc.

The most undesirable orientation for glazing is towards those portions of the sky in which the sun is low in its daily path, usually towards the East and West. The best orientation for a vertical surface is when there is the most solar radiation during the under-heated period (Fig. 1, blue line) and least during the overheated period (Fig.1, red line). An analysis of the case study location leads to the conclusion that the worst case scenario is for east-facing glazing at 15 degrees from the East, based on average daily incident radiation on a vertical surface. A façade 80.25° degrees from the East is identified it as most exposed to solar radiation and as such an obvious choice for use of photocatalytic cement products.

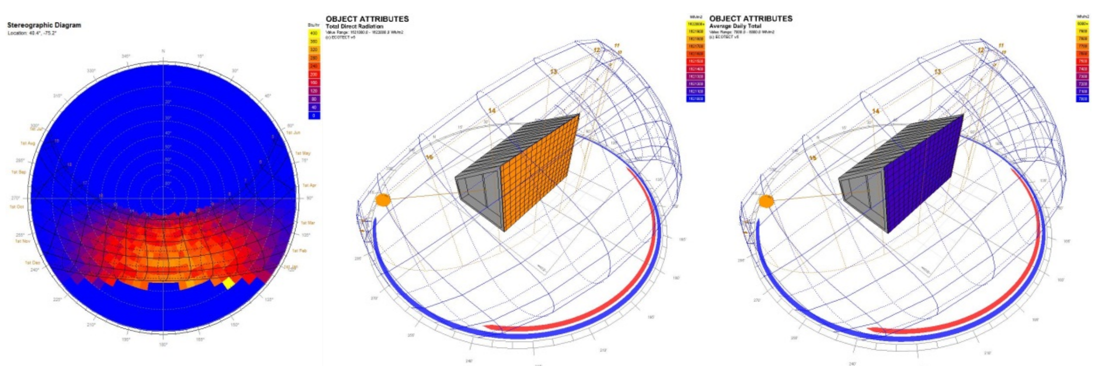

Figure 10: Left: total monthly stress south-facing façade (sun-path diagram); Middle: annual cumulative incident solar radiation (direct only); Right: annual cumulative photosynthetically active radiation (direct only). Source: (Author 2013).

The annual cumulative incident solar radiation (direct only), annual cumulative photosynthetically active radiation (direct only), and total monthly stress south-facing façade (sun-path diagram), provide a good insight about what time of year is most critical for a vertical facade with southern orientation and how inefficient a vertical flat façade is in capturing the available photosynthetically active radiation (Fig. 2).

1.2. Cumulative solar radiation

For the purpose of maximum exposure to solar radiation a plane needs to be in perpendicular orientation to the direction of the sun[7]. Over the movement of the sun such a plane will continually revolve like the head of a sunflower, continually inscribing a spherical polyhedron (the size of its side can be thought of as either infinitely small to approximate a sphere or of a given dimension to reflect available solar radiation data). Using a modified code ported into vb.net and integrated into a Grasshopper[8] by Ted Ngai[9] we visualize the yearly incident solar radiation[10]. We determine that over the year[11], 90% of annual accumulated amount of solar radiation[12] occurs at Azimuths ranging between 121.73° and 235.94° and Solar Altitude angles ranging between 8.72° and 57.41° (Fig. 3).

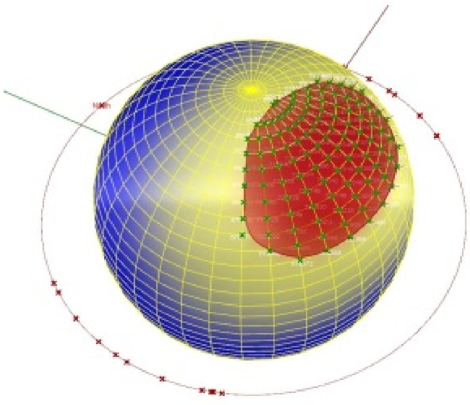

Figure 11: Incident Solar Radiation on a sphere, area of 90% of total annual radiation amount shown in red. Source: (Author 2013)

The further design is based on the premise that the spherical surface from Figure 3, in red, represents the collection of all normals parallel to the sun position within the above mentioned range and, more importantly, its constant curvature (being spherical) enables even distribution of solar stress. This surface optimally faces the sun year-round and represents the geometry with maximum exposure to 90% of the solar radiation. Its inverse clone, made by polar symmetry, is equally suitable. We have two reciprocal surfaces which can serve as the basis for surface generation as long as their curvature and range of normals are maintained.

2.0. Panel design

Developed in grasshopper surface is comprised of developable surfaces with horizontal inclination between 121.73° and 235.94° and vertical inclination between 8.72° and 57.41°. This corresponds to the previously identified limits for solar elevation and azimuth. Having all surface normal within these ranges of inclination ensures that for any given sun position from the design orientation there is fully performing portion of the surface (Fig.4). Each surface has an equal amount of normal oriented within the above range in both concave and convex position - the produced pattern is mirrored relative to a central horizontal axis to generate a surface which is topologically equivalent in both short and long axes.

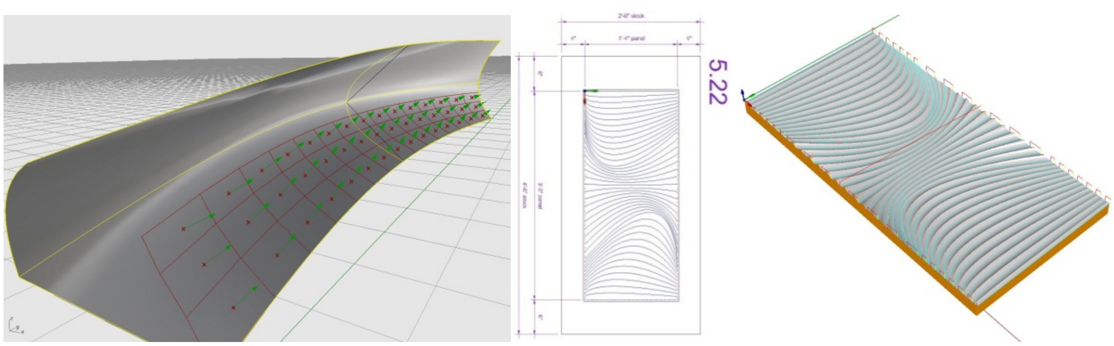

Figure 12: Left: Developable surface constrained by face normal angles, modeled in Rhinoceros; Middle: tool paths exported for use by RhinoCam; Right: Simulation of panel surface stock for CNC routing. Source: (Author 2013)

2.1 Comparison to a generic flat concrete vertical panel

A new concrete panel with the above surface is simulated in Grasshoper and compared against a vertical flat surface of equal overall height, width, and depth, and in identical south orientation. The comparison shows an 11.26% increase of surface area of the proposed panel compared to that of the flat panel, which leads to an overall increase of total surface available for photocatalysis. In addition, 55.28% of surface area of proposed panel has higher exposure to radiation than the flat panel. 9.99% of proposed surface is exposed to 90% of total accumulated annual radiation[13] (Fig. 5).

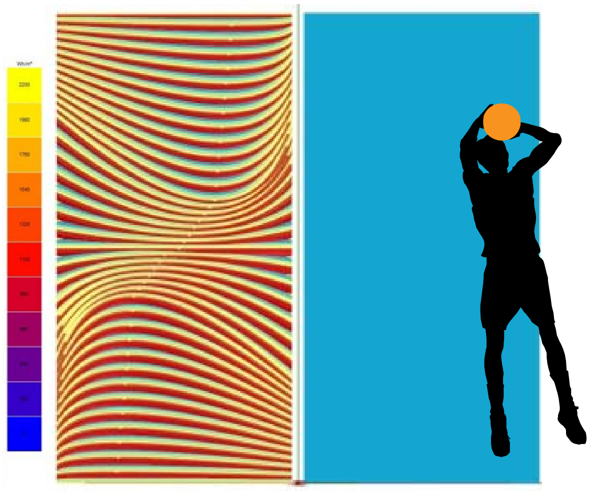

Figure 13: Color-coded comparison of amount of total annual incident radiation of proposed panel (left) to a flat panel (right). Source: (Author 2013)

2.1. Scales

An interesting observation can be made that the panel's performance is not related to its scale. Comparisons of a number of different scales produce density patterns with varying aesthetic readings and fabrication implications. Most importantly, all of them result in identical total areas of surface available for photocatalysis and with same large amount of surface area with higher exposure to radiation than that of a flat panel. The final size and scale of the panel is derived from typical construction material dimensional module of 120cm x 240cm (4'x8'), (Fig. 6).

Figure 14: Close-up of proposed photocatalytic concrete panel. Source: (Author 2013)

3.1. Building design

The building design follows the general rules of environmental design: the footprint is a rectangle with the long sided facing North-South and short sides facing East-West. The east- and west-facing facades are glazed and set back with 120cm (4') overhangs. The west roof rake is pitched at 25.9° to the South toward the lowest solar altitude at 12pm on December 23 to minimize incident radiation exposure on the roof. For similar reasons, the North eave is pitched 9° toward the highest Sun position to the West (Fig. 7). The roof pitch values are taken from tabulated daily solar tables formatted in Solar Tool 2011, (Fig. 8).

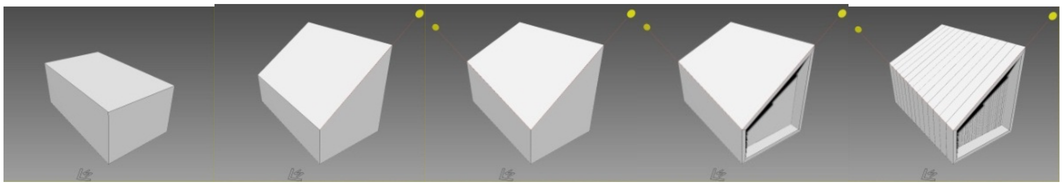

Figure 15: Design Development, Parti model. Source: (Author 2013)

Tabulated Daily Solar Data

Latitude: 40.6°
Longitude: -75.4°
Timezone: -75.0° [-5.0hrs]
Orientation: 0.0°

Date: 23rd December
Julian Date: 357
Sunrise: 07:27
Sunset: 16:33

Local Correction: -0.5 mins
Equation of Time: 1.1 mins
Declination: -23.5°

Local	(Solar)	Aziumuth	Altitude	HSA	VSA	Shading
07:30	(07:29)	122.0°	0.3°	122.0°	179.4°	[Behind]
08:00	(07:59)	127.0°	5.0°	127.0°	171.7°	[Behind]
08:30	(08:29)	132.4°	9.4°	132.4°	166.2°	[Behind]
09:00	(08:59)	138.1°	13.4°	138.1°	162.2°	[Behind]
09:30	(09:29)	144.2°	17.0°	144.2°	159.3°	[Behind]
10:00	(09:59)	150.7°	20.1°	150.7°	157.3°	[Behind]
10:30	(10:29)	157.5°	22.5°	157.5°	155.8°	[Behind]
11:00	(10:59)	164.8°	24.4°	164.8°	154.8°	[Behind]
11:30	(11:29)	172.3°	25.5°	172.3°	154.3°	[Behind]
12:00	(11:59)	179.9°	25.9°	179.9°	154.1°	[Behind]
12:30	(12:29)	-172.5°	25.5°	-172.5°	154.3°	[Behind]
13:00	(12:59)	-165.0°	24.4°	-165.0°	154.8°	[Behind]
13:30	(13:29)	-157.8°	22.6°	-157.8°	155.8°	[Behind]
14:00	(13:59)	-150.9°	20.2°	-150.9°	157.2°	[Behind]
14:30	(14:29)	-144.4°	17.1°	-144.4°	159.3°	[Behind]
15:00	(14:59)	-138.3°	13.5°	-138.3°	162.1°	[Behind]
15:30	(15:29)	-132.6°	9.5°	-132.6°	166.0°	[Behind]
16:00	(15:59)	-127.2°	5.2°	-127.2°	171.5°	[Behind]
16:30	(16:29)	-122.2°	0.5°	-122.2°	179.1°	[Behind]

Tabulated Daily Solar Data

Latitude: 40.6°
Longitude: -75.4°
Timezone: -75.0° [-5.0hrs]
Orientation: 0.0°

Date: 23rd June
Julian Date: 174
Sunrise: 04:36
Sunset: 19:30

Local Correction: -3.6 mins
Equation of Time: -2.0 mins
Declination: 23.4°

Local	(Solar)	Aziumuth	Altitude	HSA	VSA	Shading
05:00	(04:56)	62.2°	3.9°	62.2°	8.3°	0%
05:30	(05:26)	66.8°	9.0°	66.8°	22.0°	6%
06:00	(05:56)	71.2°	14.4°	71.2°	38.5°	15%
06:30	(06:26)	75.6°	19.8°	75.6°	55.4°	27%
07:00	(06:56)	80.0°	25.4°	80.0°	69.9°	48%
07:30	(07:26)	84.5°	31.0°	84.5°	80.9°	61%
08:00	(07:56)	89.2°	36.7°	89.2°	88.9°	66%
08:30	(08:26)	94.2°	42.4°	94.2°	94.6°	[Behind]
09:00	(08:56)	99.8°	48.0°	99.8°	98.7°	[Behind]
09:30	(09:26)	106.2°	53.6°	106.2°	101.6°	[Behind]
10:00	(09:56)	114.1°	58.9°	114.1°	103.8°	[Behind]
10:30	(10:26)	124.0°	63.9°	124.0°	105.3°	[Behind]
11:00	(10:56)	137.3°	68.3°	137.3°	106.3°	[Behind]
11:30	(11:26)	155.1°	71.4°	155.1°	106.9°	[Behind]
12:00	(11:56)	177.2°	72.8°	177.2°	107.2°	[Behind]
12:30	(12:26)	-160.1°	72.0°	-160.1°	107.0°	[Behind]
13:00	(12:56)	-141.1°	69.1°	-141.1°	106.5°	[Behind]
13:30	(13:26)	-126.9°	65.0°	-126.9°	105.6°	[Behind]
14:00	(13:56)	-116.2°	60.2°	-116.2°	104.2°	[Behind]
14:30	(14:26)	-108.0°	54.9°	-108.0°	102.2°	[Behind]
15:00	(14:56)	-101.2°	49.4°	-101.2°	99.5°	[Behind]
15:30	(15:26)	-95.5°	43.8°	-95.5°	95.7°	[Behind]
16:00	(15:56)	-90.3°	38.1°	-90.3°	90.4°	[Behind]
16:30	(16:26)	-85.6°	32.4°	-85.6°	83.1°	58%
17:00	(16:56)	-81.1°	26.7°	-81.1°	72.9°	48%
17:30	(17:26)	-76.7°	21.1°	-76.7°	59.2°	39%
18:00	(17:56)	-72.3°	15.7°	-72.3°	42.7°	27%
18:30	(18:26)	-67.9°	10.3°	-67.9°	25.8°	16%
19:00	(18:56)	-63.3°	5.1°	-63.3°	11.3°	8%
19:30	(19:26)	-58.5°	0.1°	-58.5°	0.3°	0%

Figure 16: Tabulated Daily Solar Data for Dec23 and June 23. Solar Tool 2011, Autodesk, Inc. 2010

The building utilizes a standard light-wood balloon construction with 5x20 (2x8) wall studs, 5x35 (2x14) floor joists, 2x30 (2x12) roof joists, plywood floor and roof deck, plywood sheathing at north and south wall, let-in braces and translucent polycarbonate panels at east and west walls, standing seam metal roof and flashing, photocatalytic concrete panels adhered to structural substrate (Fig. 9).

Figure 17: South-West, Bird's Eye, and North-West Exterior Views. Source: (Author 2013)

CONCLUSION

Buildings can consume up to 40% of primary energy and 72% of electricity consumption - each of building's energy demands is closely related to the building envelope and can be decreased with efficient envelope design. In climates where the exterior temperatures exceed the desired indoor temperature for extended periods of time, the sensible envelope design and choice of exterior cladding is imperative.

The proposed panel design is intended to augment existing building materials and technology and their interface with any particular construction method is generic. In addition to linking environmental parameters to formal design criteria applicable to an innovative material, this research project so far has led to the interesting discovery that the increase or decrease in the surface area of the panels does not affect their performance. In order to go beyond the critique of functionalist parametricism the author's indent is to test through both mockups and simulations panels of varying scales for aesthetic and stylistic interpretations as well as empirically verify the proposed panels' effect on the performance of the façade system.

ENDNOTES

[1] The cement contains titanium dioxide, which is a photocatalyst activated by daylight. The photocatalytic reaction results in oxidizing reagents converting hazardous NOx into harmless NO3- . On a bright and clear day the process can eliminate up to 90% of nitrogen oxides, aldehydes, benzenes and chlorinated aromatic compounds. When the sun is not directly shining and the UV radiation is low up to 70% of the pollutants can still be eliminated. The photocatalytic reaction does not consume the photocatalyst. Source: "TioCem® – High Tech Cement for the reduction of air pollutants." Accessed January 18, 2013. http://www.heidelbergcement.com/de/de/country/zement/lieferprogramm/spezialzemente/tiocem_en.htm

[2] A process by which electromagnetic radiation is propagated through space. This process is to be distinguished from other forms of energy transfer such as conduction and convection.Source: Glossary of Meteorology. Accessed January 19, 2013. http://amsglossary.allenpress.com/glossary/search?id=radiation1

[3] Absorption is the process by which solar energy is captured by a building material, reducing its available amount. Transmittance is the fraction or percent of a particular frequency or wavelength of electromagnetic radiation that passes through a building material without being absorbed or reflected. Source: Glossary of Solar Radiation Resource Terms. Accessed January 13, 2013. http://rredc.nrel.gov/solar/glossary/

[4] Photosynthetically active radiation designates the spectral range of solar radiation that photosynthetic organisms are able to use in the process of photosynthesis, mostly overlapping with the spectrum of light visible to the human eye. Photons at shorter wavelengths tend to be damaging to cells while photons at longer wavelengths do not carry enough energy to initiate photosynthesis.

[5] http://apps1.eere.energy.gov/buildings/energyplus/weatherdata_about.cfm

[6] Weather Tool ™ 2011, © 2010 Autodesk, Inc.

[7] The sun imparts more of its energy on a surface when it strikes it directly front-on than if the radiation strikes at an angle. Source:" Shading: Solar Incidence". Accessed December 22, 2012. http://wiki.naturalfrequency.com/wiki/Solar_Incidence

[8] Grasshopper™ is a graphical algorithm editor integrated with Rhinoceros' 3-D modeling tools. Rhinoceros, also known as Rhino, is a 3-D modeling software.

[9] Ted Ngai, "incident solar | analemma." Posted on February 1, 2009. Accessed June 22, 2012. www.tedngai.net

[10] The algorithm is based on National Oceanic and Atmospheric Administration's Solar Position Calculator. http://www.srrb.noaa.gov/highlights/sunrise/azel.html

[11] at the time of writing 2011 data was used

[12] direct light only, not accounting for ground reflections

[13] This solar irradiance is calculated using code ported into vb.net and integrated into Grasshopper by Ted Ngai Jan 30, 2009 http://www.tedngai.net/experiments/incident-solar-analemma.html . In it, he states that the calculation of solar irradiance is based on algorithm by University of Oregon Solar Radiation Monitoring Laboratory http://solardat.uoregon.edu/SolarPositionCalculator.html, and does not account for radiation reduction through various kinds of scattering (vapor, particle, ozone...etc).

Vital: Bringing Buildings and Sustainable Practices to Life

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ABSTRACT: This work addresses two common shortcomings in building design:

1. many of the indoor spaces where most people in the industrialized world spend the majority of their time inadvertently deprive them of contact with two important requirements for their long-term well-being: nature and change.

2. many simple sustainable practices that could significantly reduce the global environmental and economic running costs of buildings if more widely applied are largely invisible to the public.

In response, the authors have been examining the potential of using the natural movements of the weather to improve the habitability of indoor spaces and increase the visibility of passive environmental control and rainwater harvesting in buildings. A survey of existing architecture was first conducted to identify design strategies that could effectively bring the movements of the sun, wind and rain indoors without undermining the weather-protecting role of buildings. Three simple methods of achieving this were identified: *enclosure* of weather-generated movement in internal courtyards, sunlight *projection* onto interior surfaces, and *back-projection* onto translucent external materials. A series of design studios was then used to determine if these approaches were compatible with passive environmental control and rainwater harvesting techniques involving the same natural elements, and it was found that most could be effectively animated without compromising their environmental performance. The human effects of one of the combinations identified—wind-animated daylighting—were then tested in controlled experiments, which showed it to be both calming and distracting. In light of these findings, it was postulated that weather-generated indoor animation could be of particular value in low concentration/high stress situations, such as waiting or convalescence, where positive distractions have been shown to be beneficial. In order to test this thesis, wind-animated water light shelves were installed in a medical waiting room, where patient responses appeared to confirm their calming effect.

KEYWORDS: Natural Indoor Animation, Well-Being, Sustainability

INTRODUCTION

1.1 Nature, change and human well-being

Over the past thirty years evidence from a range of disciplines has suggested that contact with nature has important physical and psychological benefits for people in buildings. Well-known studies by the health-care environments researcher Roger Ulrich and others, for example, have linked views of outdoor nature with relief of stress (Ulrich 1984), and the presence of indoor planting to improved productivity (Bringslimark 2009). The link between human alertness and perceptible change has likewise been consistently confirmed since first being proposed by Donald Hebb's pioneering work on sensory deprivation in the 1950s and his resulting Arousal Theory, which suggested that unchanging environments lead to a rapid fall off in alertness, and eventually to fatigue and stress when we attempt to maintain concentration over long periods in under-stimulating conditions (Hebb 1955).

The Attention Restoration Theory developed three decades later by Rachel and Stephen Kaplan effectively linked these two areas of inquiry by proposing that contact with nature serves to restore attention and stave off stress due to under-stimulation (Kaplan and Kaplan 1989, S. Kaplan 1995). The Kaplans suggested that many familiar patterns in nature, such as the movement of clouds and water, for instance, stimulate the senses without demanding our active attention, and one of the apparent implications of their work we wanted to test was that these kinds of familiar natural movement might be able to help people in indoor environments remain alert without being distracted.

1.2 Static indoor spaces

Evolutionary psychology attributes our needs for nature and sensory variation to the fact that early human physiology developed largely outside in response to a constantly changing natural world. Many of us now spend the majority of our lives indoors, however, and as the environmental psychologist Judith Heerwagen has pointed out, one of the consequences of our pursuit of 'optimal' indoor climatic conditions over the last fifty years has been that the natural variation our still bodies require is largely absent from many of the places where we now spend the majority of our lives:

> Access to sensory diversity—change, ... is a basic characteristic of the natural world. Sensory change is fundamental to perception…. Our indoor environments are largely devoid of sensory change, and deliberately so. Buildings are kept at constant temperatures and ventilation rates, the light from overhead fluorescent lights is the same day in and day out…. Although many designers and researchers are beginning to express serious doubts about this state of affairs … there have been relatively few attempts to provide indoor environments that deliberately mimic sensory change as it exists in the natural world (Heerwagen 1990, 270).

The work reported here is aimed at remedying that situation. Rather than attempting to recreate natural change artificially, however, since the real thing is still freely available in the atmosphere around us, we investigated whether there might be practical ways of bringing that change indoors.

1.3 Invisible sustainability

Concern for the natural environment has fundamentally altered the professional criteria for measuring the success of building design over the last decade, yet ultimately the project that is sustainability will only succeed if the population at large is involved in its implementation. All too often the only visible sign of the sustainable design of many admirably Green buildings today is a LEED plaque. In response, several commentators have suggested that it is no longer sufficient for sustainable buildings simply to ‘do no harm,’ rather, they argue that in order to have any meaningful impact on the daunting environmental problems we now face buildings need to actively demonstrate ways of living in harmony with nature (Kellert 2005, Wines 2000). With this in mind, we set out to investigate whether the natural movements of the sun, wind and rain could not only be used to improve the habitability of indoor spaces, but also to raise the public visibility of underused passive environmental control and rainwater harvesting techniques in buildings, which involve the same three natural elements.

METHODOLOGY

A survey of existing architecture was first conducted in order to identify design strategies that could effectively bring the natural movements of the sun, wind and rain indoors without undermining the essential weather-protecting role of a building. A series of design studios was then used to determine whether the three methods identified—*enclosure*, *projection* and *back projection*—were compatible with established passive environmental control and rainwater harvesting techniques. The human effects of one of the successful combinations identified—wind-animated daylighting—were then examined in a series of controlled experiments, and based on those results, a wind-animated water light shelf was field tested in the waiting room of a working medical clinic.

2.1 Bringing the natural animation of the weather indoors

We first had to establish that there were practical ways of effectively bringing the movements of the weather indoors without undermining the primary role of buildings in providing shelter from the elements. Through a survey of existing buildings three simple strategies were identified for achieving this: *enclosure* of weather-generated outdoor movement in internal courtyards; sunlight *projection* onto internal surfaces; and *back projection* onto translucent external materials. Each of these methods allows visible weather-induced outdoor movement to be perceived as effectively part of an interior space without compromising the weather-proof envelope of a building. The three strategies are illustrated in Figure 1 using the example of wind-animated foliage.

Figure 1: Three methods of effectively bringing weather-generated outdoor movement indoors without compromising the weather-roof envelope of a building. From the left: *enclosure* in an internal court; sunlight *projection* onto an interior surface; and *back projection* onto a translucent external cladding material.

2.2 Synergies with passive environmental control and rainwater harvesting

Having established that it was possible to bring the natural animation of the weather indoors while maintaining shelter, a series of design studios at the University of Oregon was then used to test the feasibility of transmitting that movement using established passive environmental control and rainwater harvesting techniques involving the same natural elements. The following combinations were found to successfully transfer weather-generated outdoor movement to an interior space without compromising the environmental performance of the sustainable strategies involved: [1]

Direct Animations
Sun-animated Daylighting
Sun-animated Shading
Sun-animated Solar Heating
Wind-animated Natural Ventilation
Rain-animated Rainwater Collection

Indirect Animations
Wind-animated Daylighting
Wind-animated Shading

Independent Animations
Wind-animated Rainwater Collection
Rain-animated Daylighting
Rain-animated Shading

The successful combinations fell into three broad categories reflecting direct, indirect and independent animations of sustainable practices. The first consists of combinations in which naturally generated movement visibly discloses the primary mechanism underlying a sustainable practice. Visible convection current shadows can serve as a direct indicator of passive solar heating for example. The second group comprises natural animations that can effectively draw attention to a sustainable practice, but without necessarily revealing how it works. Wind-animated indoor shadows, for instance, can make building occupants more aware of shading and solar gain, but their movement is not inherent to either. The final group consists of natural animations that are compatible with but unrelated to the primary environmental purpose of a passive device. A reflecting pool or light court, for example, can effectively bring the sights or sounds of the wind and rain indoors without drawing attention to their daylighting role.

2.3 Water light shelf case study

One of the most effective combinations identified in the design studios was wind-animated daylighting. This led to the development of a water light shelf that combines energy saving and naturally moving indoor sunlight. Conventional light shelves reduce glare and save energy by redistributing excess daylight from immediately inside a window to the darker rear of a room, reducing the imbalance in light levels and the need for artificial lighting and cooling of a space during the day. The water light shelf does the same, but the sunlight it reflects is animated by outdoor air movement disturbing its water surface (Figure 2).

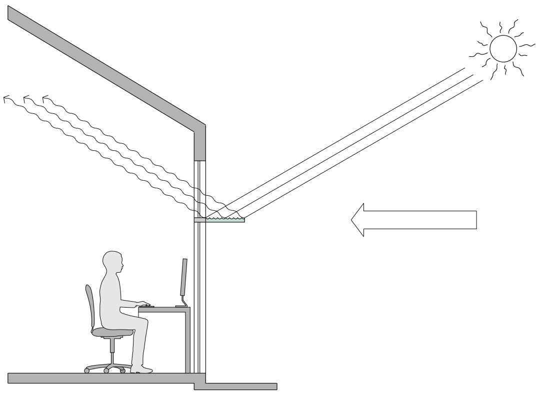


Figure 2: Section through a water light shelf, which diverts excess light from near a window to the rear of a room while introducing wind-generated movement into a space.

Before testing the effects of the wind-animated light from the water light shelf on building occupants, we wanted to confirm that introducing movement had not compromised its environmental performance. This was tested using a scale model and artificial sky to compare the water light shelf's indoor daylight distribution to an equivalent static light shelf. The daylight distribution of the wind-animated water lightshelf was found to be almost the same as its static equivalent, confirming that there was no significant environmental trade off as a result of introducing movement to the reflected light (Figure 3).

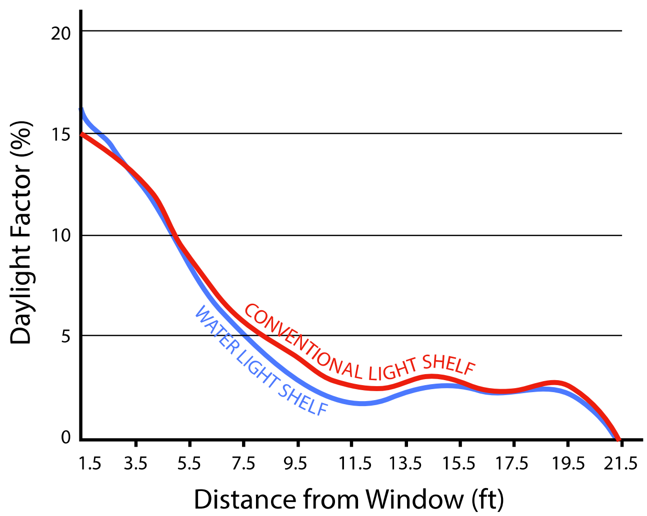


Figure 3: The indoor daylight distribution of a wind-animated water light shelf compared to an equivalent static light shelf.

2.4 Human effects of fan-animated artificial light

Having confirmed that the wind-animated water light shelf was as effective as a static light shelf in redistributing indoor daylight, we proceeded to test the effects of its moving light on people. This was initially done through a series of controlled experiments in the test room arrangement illustrated in Figure 4. In order to maintain the consistency of the light patterns experienced, the effects of the sun and wind on a water surface were represented by a theater lamp and a fan respectively. These generated less intense and variable reflected light patterns than natural sunlight and wind do, but we wanted to see whether this reduced version of the lighting effect had any potential benefits before deciding whether to conduct field tests in working buildings.

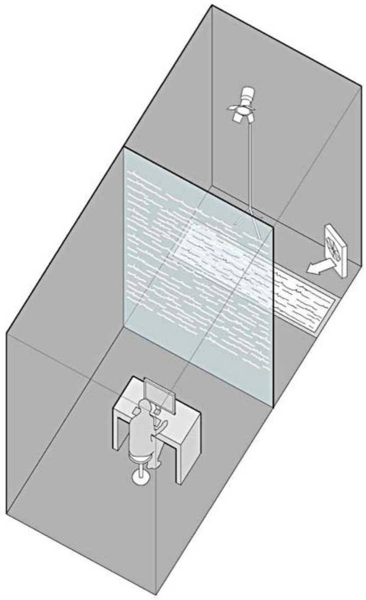


Figure 4: Test room arrangement for measuring the effects of wind-animated indoor light on building occupants' stress and attention. Moving light patterns reflected from a fan-disturbed water surface were projected onto the back of a translucent screen in front of the subject. In stress tests, subjects waited inactively with the illuminated background screen static and animated. In attentional tests, subjects performed a computer-based vigilance task against the same static and animated backdrops.

2 Effects of fan-animated artificial light on heart rate

This experiment was intended to simulate waiting, a common source of stress in everyday life similar to the inactive conditions in Roger Ulrich's well-known studies on the effects of natural views on recovering hospital patients (Ulrich 1984). The heart rates of twenty-five student subjects were recorded with a chest monitor as they waited inactively in the test room with fan-animated light patterns back-projected onto the screen in front of them and with the screen illuminated to the same brightness with static light.[2] Average heart rates were found to be slightly lower in the animated room than the static condition, but the difference was not statistically significant (Figure 5).

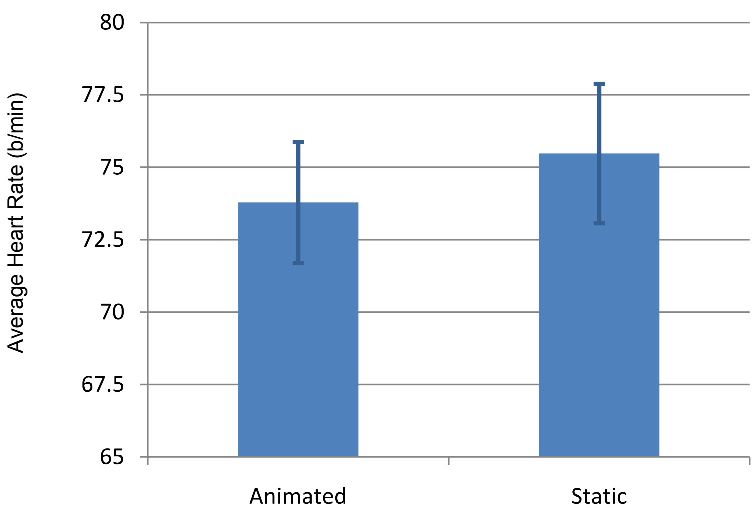


Figure 5: Subjects' average heart rates while waiting inactively in a room with fan-animated and static light (with standard errors).

2.6 Effects of fan-animated artificial light on recovery from stress

This test was intended to determine whether natural animation in a room could hasten recovery from already heightened stress. A different group of twenty-five student subjects was intentionally stressed by being asked to perform a series of timed mental math problems. Their subsequent recovery as they waited inactively in the same test room was then recorded under static and animated lighting conditions. Average heart rates compared at the same points during their recovery were again lower in the animated light, this time significantly so (Figure 6).

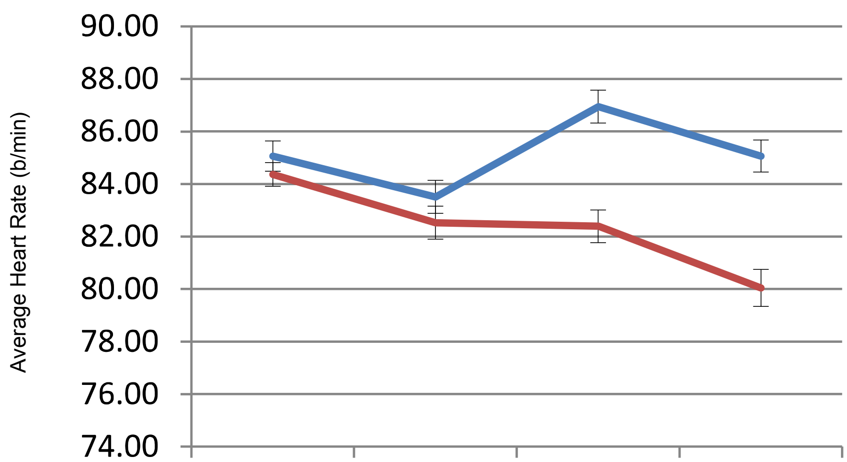


Figure 6: Subjects' average heart rates measured at the same four times during recovery from induced stress in a static room (red line) and fan-animated room (blue line).

The main differences between the moving light used in these controlled experiments and that created by natural wind and sunlight were lower variability and intensity, both of which tended to reduce the visibility of the moving patterns. This suggested that any stress-reducing effects could be expected to be at least as great with natural wind and sunlight, which prompted us to proceed with field testing of the water light shelf in a working building, the results of which are reported later in this paper.

2.7 Effects of prior exposure to fan-animated artificial light on task performance

This experiment was intended to determine whether exposure to animated indoor light increased subsequent alertness in the way that walks in outdoor nature have been found to do in other studies (Kaplan and Kaplan 2002, Hartig 2003).[3] Subjects' performance on a standard computer-based letter recognition task was first tested in a static room, and again after a thirty-minute rest period spent in a static room or in a room with fan-animated light.[4] While there was no significant difference in the accuracy of responses following these different rest conditions, the average speed of response was noticeably slower following exposure to the animated light, suggesting that—in contrast to prior exposure to outdoor nature—natural indoor animation was apparently acting to *reduce* subsequent alertness (Figure 7).

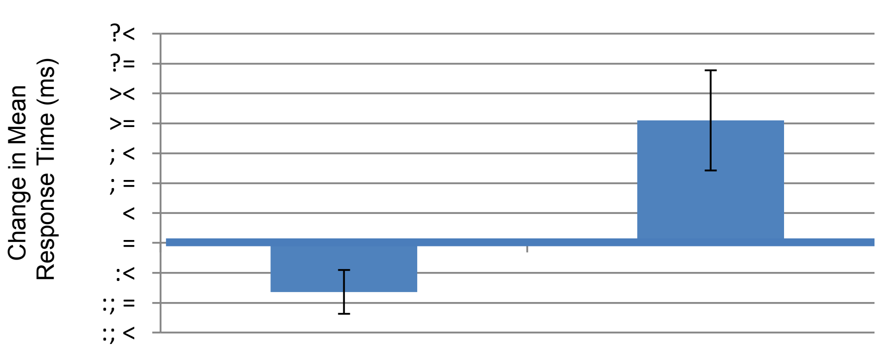
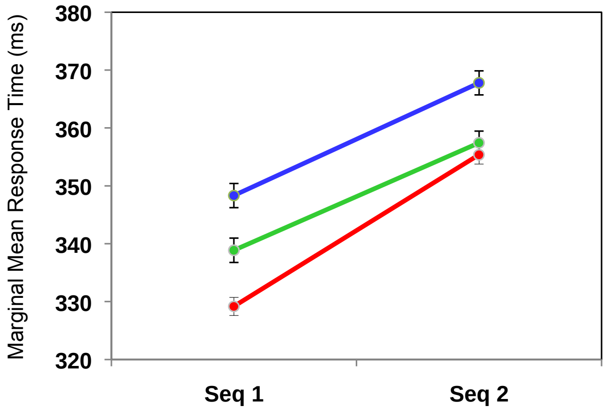


Figure 7: Changes in subjects' mean response times to a computer-based vigilance task following rest periods in a static room (left), and fan-animated room (right).

2.8 Effects of simultaneous exposure to wind-animated sunlight on task performance

In this study a video recording of a moving sunlight pattern reflected from a natural wind-disturbed water surface was played on a computer screen as the background to the same letter-recognition task. Subjects' performance with the naturally-animated screen was then compared to that with a similarly moving digitally-generated background, and with a static screen, each of the same brightness and contrast. Both the natural and the digitally-generated moving backgrounds were found to slow subject response times in comparison to a static background, but the distraction was noticeably less with the natural movement (Figure 8).



Sequence 1: No Movement, Natural Movement, Artificial Movement
Sequence 2: Natural Movement, Artificial Movement, No Movement

Figure 8: Computer-based vigilance task response times recorded against a static background (red line), naturally animated background (green line), and artificially animated background (blue line).

2.9 Responses to wind-animated sunlight in a health-care clinic waiting room

The controlled experiments seemed to show that while wind-animated light reduced stress, it could also be distracting. This suggested that it might of value in low concentration/high stress situations, such as waiting or convalescence, for example, where positive distractions have previously been found to be beneficial. In order to test this thesis, water light shelves were installed outside the waiting room windows of a medical clinic, and over a six-month period patients were asked to complete a voluntary questionnaire seeking their responses to the shelves' wind-animated sunlight patterns reflected on the ceiling of the space (Figures 9 and 10).

Figures 9 and 10: Left: water light shelves installed outside the windows of a Women's clinic waiting room in Eugene, OR. Right: wind-animated sunlight patterns reflected from the water surfaces of the light shelves onto the ceiling of the waiting room.

Patient responses were generally positive, and seemed to confirm the calming effect observed in the controlled experiments (Figure 11). Significantly more respondents described being 'fascinated' rather than negatively distracted by the moving light, suggesting that it was generally seen as a welcome diversion. The predominantly female subject pool and the small proportion of patients who responded however (less than 2%) limit how much can safely be read into this particular result.[5]

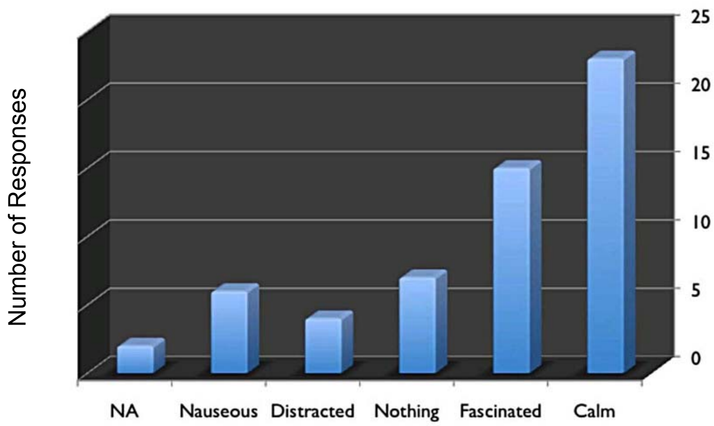


Figure 11: Patient responses to the question: "which of the following terms best describes how the moving sunlight patterns make you feel?"

CONCLUSION

Three design strategies were identified for effectively bringing the natural movements of the sun, wind and rain into indoor environments while maintaining physical shelter from the weather. These were found to be compatible with a range of established passive environmental control and rainwater harvesting techniques, offering a potentially simple means of raising the public visibility of these important but underused sustainable practices.

In controlled experiments and live field tests one such combination—wind-animated daylighting—was found to have a calming effect on inactive subjects, but also seemed to distract attention from a visual task. While improved attention with naturally-animated movement patterns compared to digitally-generated ones appeared to support the Kaplans' theory that familiar, naturally-generated movement is less distracting than artificially-generated change, but both slowed task responses compared to a static background, seemingly disproving the notion that natural movement patterns might not be distracting at all. The distraction we observed may have been exaggerated, however, by placing visible movement in direct competition with a task requiring unusually intense visual concentration.[6] Most everyday work allows people to momentarily glance elsewhere as a way of renewing concentration, and *choice* as to whether or not we look at movement could well be critical to its perception as either welcome or distracting.

Reduced alertness following rest periods in a naturally-animated room compared to a static room was the reverse of what has previously been found with prior exposure to outdoor nature (Hartig 2003). This would seem to have two possibly significant implications. The most obvious is that outdoor nature has attention-restoring attributes that are absent from weather-generated indoor movement. A key characteristic of restorative environments identified by the Kaplans, for example, was the feeling of 'being away,' and it would make sense if this were somehow lost in the process of bringing nature to us indoors (Kaplan and Kaplan 1989). The fact that subjects' responses were slower following rest periods in a naturally animated room, however, also raises the possibility that this kind of movement may be *so* relaxing that it acts to reduce alertness.

These initial findings suggest that the animation of the weather could offer a more widely accessible means of reducing stress in building occupants than external views of nature (Ulrich 1984), which are not available from many indoor spaces, and that they could be of most particular value in situations that combine inactivity and heightened stress, such as waiting and health care spaces.[7]

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ENDNOTES

[1] Each of the naturally-animated passive techniques listed was quantitatively tested in comparison to its static equivalent in order to confirm that introducing movement had not compromised environmental performance.

[2] The subjects of the controlled experiments were University of Oregon students between the ages of 19 and 24 with an approximately even balance of genders.

[3] The Kaplans' original self-reported findings on the benefits of walks in nature on subsequent alertness were later confirmed quantitatively using a computer-based vigilance task similar to the one we employed. See T. Hartig, *et al*, "Tracking Restoration in Natural and Urban Field Settings," *Journal of Environmental Psychology* 23 (June 2003): 109-23.

[4] The vigilance task involved clicking a computer mouse when a randomly generated letter that was *not* the designated target letter appeared momentarily on the computer, and refraining from doing so when the target letter appeared. Attention was measured in terms of both the accuracy and speed of responses.

[5] The voluntary questionnaire was left at the reception desk and consisted of preliminary questions intended to confirm that respondents had seen the moving lighting patterns. The spike in respondents who felt the movement made them feel nauseous might have been related to the high proportion of patients who would have been either pregnant or receiving hormone therapy at this particular clinic, although we were not able to quantify this.

[6] Work by Shibata and Suzuki has indicated that while creative work is aided by the presence of indoor plants, for example, those requiring concentration are not. See S. Shibata and N. Suzuki, "Effects of the Foliage Plant on Task Performance and Mood," *Journal of Environmental Psychol*ogy 22 (2002): 265–72.

[7] These findings also raise the possibility that wind-induced movement may play some role in the stress-reducing effects of external natural views. Studies have shown that indoor planting is significantly less effective than outdoor views of nature in reducing stress. See for example, C. Chang and P. Chen, "Human Responses to Window Views and Indoor Plants in the Workplace," *Horticultural Science* 40 (2005): 1354–59. This might be due simply to a perception of indoor plants as 'less natural' than their outdoor equivalent, but one of the most obvious visible differences is that they tend to be static in comparison.

Performance of Natural Ventilation in Deep-plan Educational Buildings: Case Study

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ABSTRACT: This paper discusses the applicability, use and performance of natural ventilation and natural daylight in two educational buildings on two continents. It discusses actual measured data in the building compared with simulations made by the ASHRAE Thermal Comfort Model that was developed by the American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE). The buildings were the Harm A. Weber Academic Centre completed in July 2007 on the campus of Judson University in suburban Chicago, IL, and, Lanchester Library completed in August 2000 on the campus of Coventry University in Coventry, UK. Three sets of scenarios were used in the building measurements: summer, winter and mixed-mode-season. Both use significant amounts of natural ventilation and high thermal mass. The study had students carrying out their normal activities in studio while wearing regular clothes. A questionnaire and instrumentation were administered to record data on thermal sensation and preferences of the occupants. Both buildings have significant applications and use of passive design strategies that include natural ventilation, natural daylight and thermal mass. The strategies tackle the limitations of traditional natural ventilation and daylighting strategies and suggest directions for design in complex urban contexts. Computer modeling was used to assess the performance of the strategies in other types of buildings and building forms.

KEYWORDS: natural ventilation, dry-bulb temperature, humidity, energy-efficiency

INTRODUCTION

The American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE) defines "ventilation as the intentional introduction of air from the outside into ma building and it can be done either as (1) ***natural ventilation*** through open windows, doors, grilles, and other planned building envelope penetrations, and/or (2) ***mechanically or forced ventilation***" (ASHRAE, 2009, p. 16.1). Natural ventilation is driven naturally by pressure differentials. In the past fifty years, the use of natural ventilation in modern buildings has declined significantly because of the technological advancements in mechanical heating, ventilating and air-conditioning (HVAC) systems. The use of outdoor air flow into buildings to provide ventilation and space cooling has been in existence since time immemorial in different climates. Comfort and healthy indoor quality (IAQ) requires a careful balance between control of pollutants, supply of fresh air, exhaustion of unacceptable air and maintenance systems. Outside air must dilute and remove contaminated indoor air. Natural ventilation in primitive buildings traditionally relied on wind and thermal buoyancy of heated/cooled air. It was observed that "the thermal storage capabilities inherent in the mass of a building structure can have significant effect on the space temperature as well as on HVAC system performance and operation" (ASHRAE, 2012, p. 51.18). Night-time ventilation of thermal mass can dampen and delay transfer of heat and temperatures in building envelopes. Correct ventilation strategies can moderate indoor temperatures (Brandemuehl, Lepore, & Kreider, 1990; Wilcox, 1985) and reduce energy consumption in active and passive solar buildings (Newell & Snyder, 1990; Balcomb, 1983).

People in different cultures around the world have used these driving forces to modulate and transform indoor conditions to the desired thermal environment and to extract undesired indoor air contaminants (Rapoport, 1969). A fireplace in the center of a room provided fire for cooking, light for visibility and higher air temperature that accelerated buoyant indoor air. In most of the United States of America, residential buildings have historically relied on infiltration and natural ventilation (ASHRAE, 2012, p. 16.2). This technique was used to adjust indoor climate but has now grown to become highly sophisticated and mechanized in terms of energy estimating and modeling methods (ASHRAE, 2009, p. 19.1). First costs and maintenance costs have grown significantly recently. Annually, the demand and growth of heating and air-conditioning equipment is putting major demands on space for equipment rooms in buildings. "Of the total energy used in buildings in the US, 7% is for cooling and 3.2% is for ventilation" (Brown, Kline, Livingston, Northcutt, & Wright, 2004, p. 12). The total space required for mechanical, electrical, plumbing and fire

protection for life-safety ranges “between 4 and 9% of gross building area, with most buildings in the 6 to 9% range” (ASHRAE, 2012, p. 1.6). Mechanical technologies have become highly complex and expensive, needing large floor space area. Indoor air-quality and other health-related issues require greater concerns of indoor climate for occupants of all building types. Concerns are also growing concerning the need to reduce CO_2 emissions. Kyoto protocol bound highly industrialized and developed countries to reduce greenhouse gases at least 5% by 2012, improve energy-efficiency and promote the use of renewable energy (United Nations, 1998). Natural ventilation contributes to Kyoto requirements by promoting the use of renewable energy, reduction of the cooling load and promotion of thermal comfort (De Dear & Brager, 1998). Natural ventilation saves energy (Ogoli, 2006; Givoni, 1998) but it is only energy-based HVAC systems that have established standards (ASHRAE Standard 55, 2010; ASHRAE Standard 62, 2007) for prescriptive ratings.
The two deep plan buildings discussed herein are defined by a wall to floor height ratio of 8:1, i.e., horizontal distance on the shortest external wall to the floor to floor height. Deep plan buildings are efficient users of a given site. Deep plan multi-story buildings have special challenges for the applicability, use and performance of natural daylight and natural ventilation, a problem that usually necessitates the use of expensive large HVAC systems and artificial lights ((Bordass, 2001).

EXPERIMENTAL METHOD

This study examines two buildings, the Harm A. Weber Academic Centre (HAWAC) at Judson University (USA) and Fredrick Lanchester Library (FLL) at Coventry University (UK). Both buildings are educational and have significant application of passive solar design strategies that include natural ventilation, natural daylight and building thermal mass. HAWAC was completed in 2007 with a library, classrooms and offices in suburban Chicago, IL. The building has three broad modes of operation for three distinct annual seasonal changes: (1) mechanical heating and humidification primarily in winter, (2) mechanical cooling and de-humidification particularly in summer, and, (3) fully integrated hybrid passive solar heating and natural ventilation for the mid-season. It also uses a photo-voltaic system integrated into the southern façade. Using the taxonomy for stack-effect ventilated buildings proposed in a recent paper (Lomas & Cook, 2005), HAWAC uses center-in edge-out (C-E) approach in the library block with localized edge-in edge-out (E-E) ventilation of perimeter offices. The Fredrick Lanchester Library (FLL) uses both center-in edge-out (C-E) and center-in center-out (C-C) strategies. Both buildings have very deep floor plans with ventilation air-flow controlled by demand through automated controls in each zone.

Data-logging instruments were used to collect temperature, humidity and air-flow data from various locations of the buildings. Simultaneously, questionnaires were administered to determine thermal sensations from occupants of the buildings. The study utilized two most common ways of quantitatively expressing thermal comfort and thermal sensation in the terms of Predicted Mean Vote (PMV) and Predicted Percent Dissatisfied (PPD) as developed in 1970 (Fanger, 1970) and then revised in 1975 (Humphreys, 1975).

OBSERVATIONS

3.1 Climate

HAWAC in suburban Chicago, IL (USA) is located at latitude 42.04°N and longitude 87.9°W. FLL is in Coventry (UK), at latitude 52.25°N and longitude 01.28°W. Both locations have semi-urban characteristics. In January, Chicago IL records a minimum temperature of -21.0°F (-5.8°C) and average maximum temperature of 45.32° F (7.4°C), and correspondingly in July, it experiences a minimum temperature of 53.42°F (11.9°C) and maximum temperature of 90.86°F (32.7°C). On the other hand, Coventry UK in January records a minimum temperature of 28.22°F (-2.1°C) and average maximum temperature of 50.72°F (10.4°C), and correspondingly in July, it experiences a minimum temperature of 43.52°F (6.4°C) and maximum temperature of 75.74°F (24.3°C). The local climate in Coventry is moderately cold during the winter months with 5448 heating degree days (base 65°F) and 48 cooling degree days (base 65°F), a ratio of 113:1. The local climate in Chicago is severely cold during the winter months with 6498 heating degree days (base 65°F) and 830 cooling degree days (base 65°F), a ratio of 8:1. See Table 1.

Table 1: Dry-bulb temperatures and degree-days base 65°F – compared

	Chicago, IL				Coventry, UK			
	Maximum Temperature		Minimum Temperature		Maximum Temperature		Minimum Temperature	
	°F	°C	°F	°C	°F	°C	°F	°C
Jan	45.3	7.4	50.7	10.4	28.2	-2.1	-5.8	-21
Jul	90.9	32.7	75.7	24.3	43.5	6.4	53.4	11.9
HDD65	6498				5448			
CDD65	830				48			

Both locations have semi-urban characteristics. In Chicago, the average maximum temperature swing between winter and summer is about 96.66°F (35.9°C) and correspondingly in Coventry the average maximum temperature swing between winter and summer is about 47.52°F (8.6°C). It appears from these data that Coventry has more opportunities for the applicability and use of natural ventilation. However, because Chicago has a higher mean diurnal range in air temperature of 9°C (16°F) in the spring and fall, it has better opportunities for night-time ventilation for thermal mass. The key features of the two buildings are summarized here below. Both buildings were designed by Short & Associates and completed in August 2000 (FLL) and July 2007 (HAWAC). They both have four main floor levels each.

3.2 Fredrick Lancaster Library (FLL) in Coventry, UK

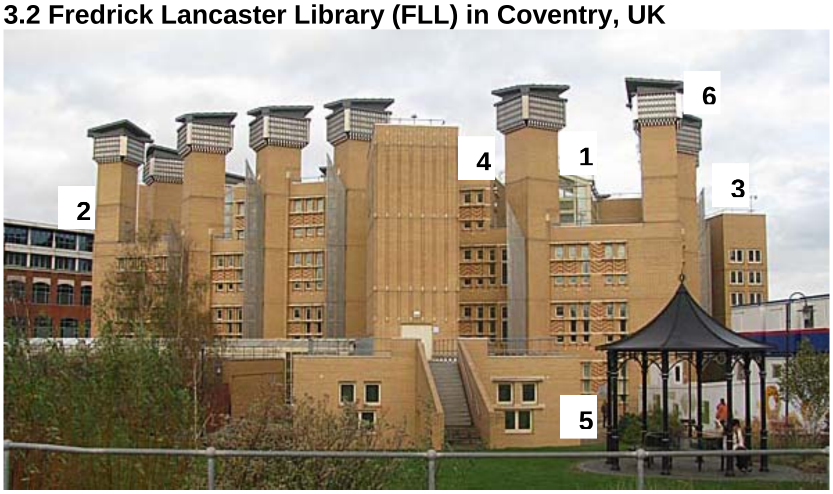


Figure 1: Main View of Fredrick Lanchester Library in Coventry University, England

The view of ventilation stacks (Figure 1) provide an indication for the air flow patterns for FLL. The corner light wells are the major areas for fresh air supply (1) with central light wells provide a means to exhaust air (2). Perimeter stacks (3) are also used to exhaust air. Air intakes to plenum around perimeter (4) joins directly to rooms for air supply (5) and exhaust (6). Air transfer ducts are acoustically treated to minimize noise. The larger rooms are arranged to span from the light well to the perimeter. The light wells provide natural ventilation and natural daylight into the interior spaces. The building has offices, library and teaching areas which for security reasons has the building façade sealed. The windows are clear low-emissivity double glazing and are shaded by the stacks, stair towers and vertical metal fins. The perimeter has radiators with thermostats, and exhaust dampers at high level. Solar shaded light-well for natural ventilation introduces into the interior spaces so that stack-effect natural ventilation and natural daylight. The floor plate measures 50 m x 50 m (164 feet x 164 feet).

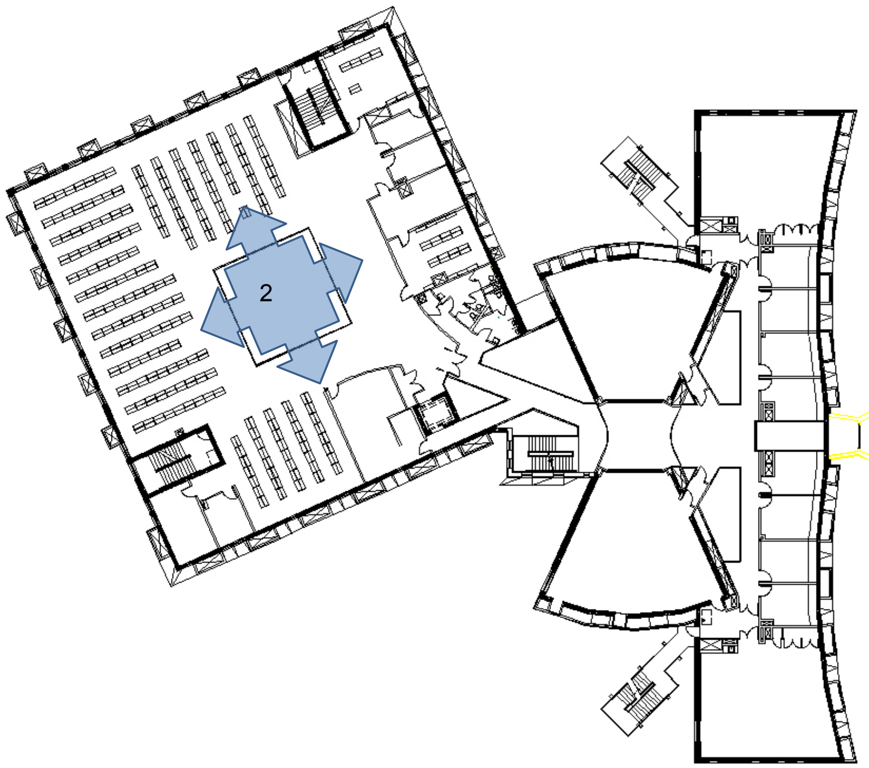
3.3 Harm A. Weber Academic Centre (HAWAC) in Elgin, IL

HAWAC integrates natural ventilation with standard HVAC system. It has an extensive landscape area with on-site storm water management and native prairie area on the south-side. HAWAC is designed to utilize night time ventilation, coupled with exposed thermal mass and sun-shading devices. The building is constructed with slightly higher insulation levels than standard buildings in this climate in order to reduce the mid-winter (December to February) heating energy loads. However, during spring period (March to April) and fall period (October to November) the building demands more heating energy because the window shading devices (needed for thermal control in the summer) excludes useful solar gain. The schedule of net floor areas is shown in Table 2. The building has twenty exterior exhausts for airflow paths. The dominant building material for both wall and floor/ceiling elements is thermal mass (12” thick concrete) to levels higher than commonly found in local buildings. In the mixed hybrid mode, the air-handling unit is shut-off. Air flow is driven mainly by natural buoyancy of warm air due to internal heat gains so that indoor temperatures remain between 68°F (20.0°C) and 80.6°F (27°C) for comfort. Figure 2 and 2 illustrate the supply air ducts embedded in the façade (1), exhaust air ducts embedded in the façade (2), return air duct from the roof plenum (3), riser ducts supplying the classrooms (4), exhaust ducts connected to roof-level plenum (5) and central supply to the library (2). The floor plate with a light well measures 35.5 x 35.5 m (116 feet x 116 feet).

Table 2: Schedule of floor areas in Harm A. Weber Academic Centre (square feet)

	Level1	Level 2	Level 3	Level 4	**Total**	Net Ratio
Library "Block"	6350	10585	10645	10330	**37910**	47%
Bowtie "East"	785	1320	1312	1315	**4732**	6%
Bowtie "West"	1020	1300	1315	1300	**4935**	6%
Office Bar	4014	3595	3725	3850	**15184**	19%
Hall	2924	3090	2281	2350	**10645**	13%
WC	1007	288	315	409	**2019**	2%
Mechanical Room	5216	100	68	85	**5469**	7%
TOTAL	**21316**	**20278**	**19661**	**19639**	**80894**	
[Light well]		[805]*	[805]*	[805]*		

Figure 2: Cladding (arrows) indicates location of stacks for natural ventilation in HAWAC

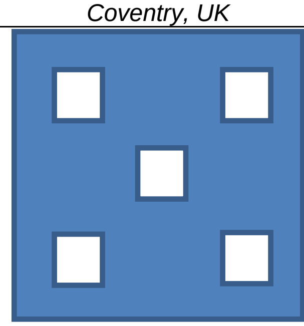
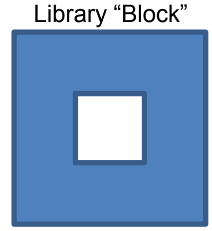


The building has three air-handling units on level one for a fully functioning HVAC system. Return air ducts connecting the exhaust air plenum to the air-handling plant and mechanical supply to the air inlet plenum are also on level one. The building has several air intake locations to the mechanical rooms and fresh air for natural ventilation for cellular office each with an acoustic attenuator box, damper and reheat coils.

Figure 3: Floor plan indicating location of vertical stacks for natural ventilation in Harm A. Weber Academic Centre

3.4 Comparison of key features of the two natural ventilated buildings

Table 7: Comparison of key features

	Fredrick Lancaster Library (FLL) in Coventry, UK	*Harm A. Weber Academic Centre (HAWAC) in Elgin, IL*
Footprint	 50 m x 50 m (164 feet x 164 feet)	Library "Block"  35.5 m x 35.5 m (116 feet x 116 feet)
Gross floor area	9103 m^2 (97,984 ft^2)	4660 m^2 (50,160 ft^2)
Floor to ceiling height	3.9 m (12.9 feet)	4.0 m (13.1 feet)
U-values (Roof) U-values (Wall) U-values (Windows)	0.18 W/m^{2}K (0.0317 BTU/h ft^2 F) 0.26 W/m^{2}K (0.045789 BTU/h ft^2 F) 2.00 W/m^{2}K (0.35222 BTU/h ft^2 F)	0.25 W/m^{2}K (0.044028 BTU/h ft^2 F) 0.25 W/m^{2}K (0.044028 BTU/h ft^2 F) 2.60 W/m^{2}K (0.457887 BTU/h ft^2 F)
Window shading	Perimeter stacks, metal fins	External window reveals
Air supply light wells Advanced Natural Ventilation (type)	4 light wells Centre in edge out (C-E) and Centre in centre out (C-C)	1 light well Centre in edge out (C-E) and Edge in Edge out (E-E)
Heating and Cooling Method	Natural	Hybrid Natural and HVAC
Air supply light-wells	Square shape, glazed at the top with moveable blind shading, clear single glazing sides and dampers for air outlets	Square shape, glazed at the top with moveable blind shading, clear single glazing sides and top-hung windows for air outlets

ANALYSIS AND DISCUSSION

4.1 General Observations

The ASHRAE winter design dry-bulb temperature for Chicago is -4°F (-20°C). The design goal is to provide appropriate levels of insulation and a tight building envelope. Thermal mass is passively cooled by night-time ventilation by the concept of “balancing of time” so that temperature swings are created to shift night-time coolness to daytime moments when cooling is needed. The roof plenum is used to exhaust air from lower floors to minimize gaining too much heat energy content. In summer mode, the building switches into the mechanical cooling and de-humidification modes of operation to ensure it does not exceed the upper limit of ASHRAE *Standard 55* comfort zone. Dampers at the inlet to the plenum and in exhaust outlets in the roof are closed so that return air ducts from room plenums remain open.

A parametric analysis of the data shows how the outputs change when they are varied one at a time. The responses to the questionnaires appear to suggest that occupants are generally comfortable in the building in summer and also in the winter. PMV is calculated using the formulation published in ISO-7730. The building is occupied daily between the hours 6:00 AM and 2:00 AM. In summer, most students are away on vacation but evidence appears to indicate that indoor air temperatures are slightly higher than thermal comfort limits. In the winter period, the building utilizes a conventional heating system but it may be observed that 73% people voted for no change, 18% voted for a warmer indoor environment while 9% voted for a cooler indoor environment.

4.2 Stack-effect ventilation analysis

The observed supply air temperature at the air-handling unit is 11 °C (52 °F) with a target of entering the occupied space at 16 °C (60 °F). Measured air indoor and outdoor dry-bulb temperatures with some stratified temperatures are shown in Figure 4. It shows that in the summer (June 25) indoor temperatures are well within the comfort zone. The average outdoor modulation is about 10 degrees lower than indoor temperature at 5:00 AM and about 7 degrees higher than the indoor condition at 3:00 PM. For this reason, the set-point temperatures for the two buildings are 68 °F (20.0 °C) in winter and 78 °F (25.5 °C) in the summer. This wide range implies that the buildings extend their passive solar capabilities before starting heating, ventilating and air-conditioning (HVAC) systems. It appears that the adaptive model of thermal comfort in which cross-ventilation and giving the occupants personal control of their own environment helped to increase their thermal comfort sensation to adapt better to indoor temperatures. A person’s experience of a place is a multi-variate phenomena and the adaptive model shows that thermal perception is affected by circumstances beyond the physics of the body’s heat-balance, such as climate setting, social conditioning, economic considerations and other contextual factors. Observations of the data on thermal comfort in the Harm A. Weber Academic Centre appear to suggest that when people have a wide range of adaptive factors, their sense of comfort increases.

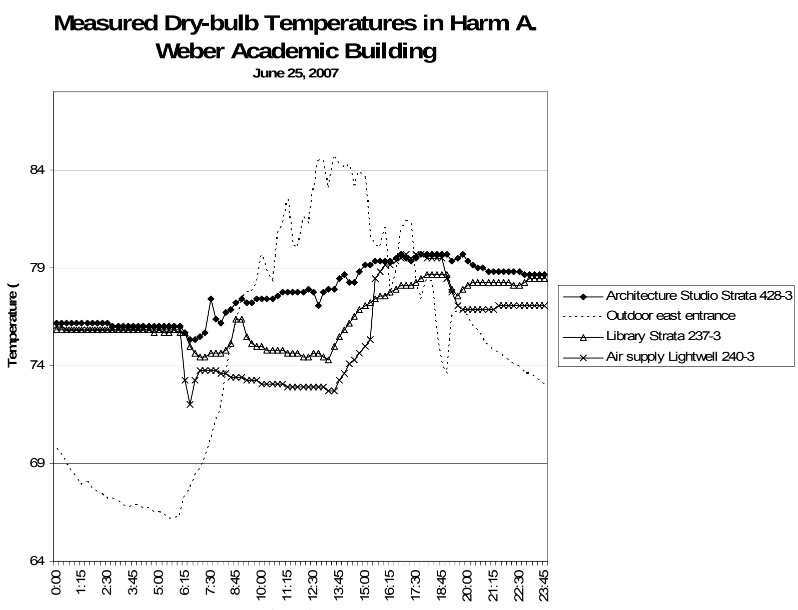


Figure 4: Measured dry-bulb temperatures in various areas

Some students’ comments:

“Studio gets cold at night. It seems that fresh air is not sufficiently conditioned before entering the space (too hot in summer, too cold in winter).”

“The building is too cold at night. The air is fresh and clean, but often noticeably uneven throughout the building.”

“The building whines like a ‘banshee’ due to night time air ventilation, usually after 10pm and early opening morning hours”.

Lomas discussed the sizing equations for a simple stack-effect ventilation system whereby a low level inlet supplies a given space to be cooled alongside a high level outlet into a stack and mass rate are given by the following equations (Lomas K. J., 2007):

$$m = \frac{QA_1}{C_c \Delta T} \ (m^3/s) \qquad \text{and} \qquad A_2 = \frac{m}{v} \ (m^2) \qquad (1)$$

Where m is volume flow of air (m^3/s), Q is heat gain (W/m^2) , A_1 (m^2) is total floor area, ΔT (K) is temperature difference, C_c is volumetric heat capacity of air (1200 J/m^3 K), A_2 is area of the ventilation opening, and v (m/s) is air speed. Combining the equations above yields the following relationship:

$$\frac{A_2}{A_1} = \frac{Q}{v C_c \Delta T} \times 100\% \qquad (2)$$

Using values of v=0.5 m/s, C_c=1200 J/m^3 K, ΔT=5 K and several suggested values of heat gains (Lomas K. J., 2007, p. 174), the ratio of measured and compared area of light-well to total floor area is given in Table 3.

Table 8: Ratio of area of light-well to total floor area in HAWAC

Q (W/m^2) Total Heat Gains	V (m/s)	C_c (J/m^3 K	ΔT (K)	Observed Ratio (occupied) (A_2/A_1)	Calculated (design stage) ratio (A_2/A_1)
20	0.7	1200	5	0.48%	
30	0.7	1200	5	0.71%	0.7%
40	0.7	1200	5	0.95%	
50	0.7	1200	5	1.19%	1.2%

Table 3 shows a comparison of the ratio of the area of light-well to total floor area. A previous study (Lomas K. J., 2007) was made to compare as-built and target design open areas that appear to suggest that the target areas may be somewhat larger than needed. Air flow speeds have been observed in the actual building as being between 0.3 m/s (60 FPM) and 0.7 m/s (137 FPM) which yield values slightly lower than anticipated.

4.3 Thermal Comfort Analysis

The comfort standard for the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE), is ASHRAE *Standard 55-2010* entitled "Thermal Environmental Conditions for Human Occupancy". The standard is mainly a prescriptive standard intended for occupants with primarily sedentary activity. It specifies the combinations of indoor space environment and personal factors that will produce thermal environmental conditions acceptable to 80% or more of the occupants in a variety of building types.
In winter, temperatures ranging from 20 to 23.5°C (68 to 74°F) at 60% relative humidity (RH) and 20.5 to 24.5°C (69 to 76°F) at 2°C (36°F) dew point are considered comfortable. In summer these ranges are 22.5 to 26°C (73 to 79°F) at 60% relative humidity (RH) and 23.5 to 27°C (74 to 81°F) at 2°C (36°F) dew point.

Air temperature and humidity are two most dominant environmental factors in thermal comfort. For most of the year, the building has medium relative humidity (30% to 60%) implying that it does not have high impact on human discomfort. The human body has an in-built mechanism to regulate itself through metabolic processes. When heat output is less than heat input, then adaptive factors like a change of clothing insulation, activity and change of room location become important control mechanisms. When the building can control its own indoor climate through passive solar heating passive cooling strategies, it saves overall building energy and enhances human comfort.

The preferred method of study for thermal comfort in the Harm A., Weber Academic Centre and the Fredrick Lancaster Library was the adaptive model since it allows occupants a large control of their ambient environment. Adaptive models include the variations in outdoor climate for determining thermal preferences indoors. Adaptive models have been developed that fit sensation to data based on field investigations to thermal comfort in different climates. The adaptive model is the most effective way of assessing passive solar buildings, or what is sometimes called “free-running” buildings. The adaptive model allows people to make adjustments to their clothing, activity, posture, eating or drinking, shifting position in a room, operating a window or shading device, or other “adaptive opportunity” in order to achieve or maintain thermal comfort. Many studies (Givoni, 1998) (De Dear & Brager, 1998) (Ogoli, ARCC Research Conference Spring 2007) demonstrate that when people are allowed greater adjustment and control over their own indoor environment, it extends the comfort zone. The adaptive model acknowledges that the occupant is not just a passive recipient of the environment but an active member. See observed results shown in Figure 5 and 6.

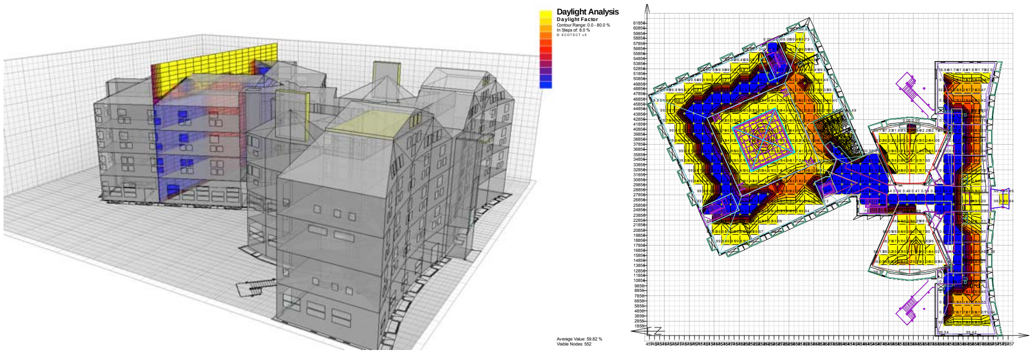


Figure 5: Air-flow, natural daylighting, thermal comfort and energy-efficiency analysis in Harm A. Weber Academic Centre

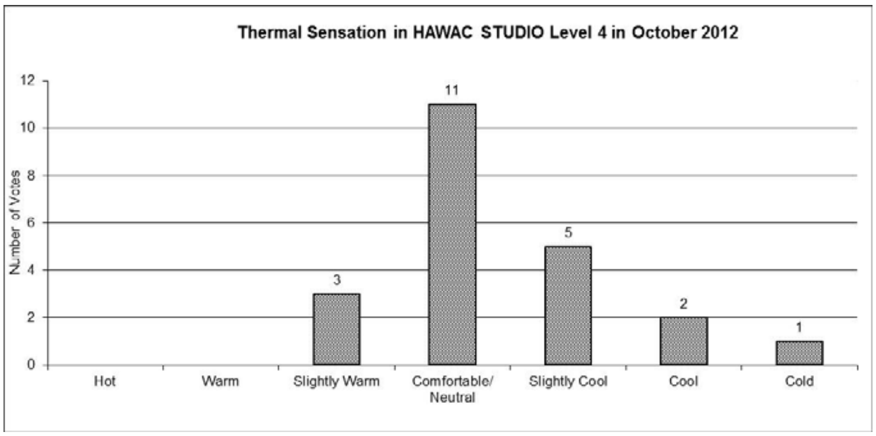


Figure 6: Indoor air quality in naturally ventilated HAWAC Library

CONCLUSIONS

The Harm A. Weber Academic Centre and the Frederick Lancaster Library are deep plan and they use generally less annual energy than similar buildings in their climates. Some important contributory factors include the use of high thermal mass that provides thermal inertia, building orientation that is within 30° due south, use of natural ventilation, use of natural daylight and use of deep-recessed windows. The most innovative and unique feature of these buildings are the mixed-mode, natural ventilation system. In the Harm A. Weber Academic Centre, HVAC systems are needed only 48% of the occupied hours of the year. The Lancaster Library uses more than 50% of the occupied hours because of the significantly milder climate. The use of natural ventilation, natural daylight and thermal mass altered the period for which active mechanical cooling energy is needed. Hybrid natural ventilation is an applicable strategy in an academic building in the climate of Chicago, IL and Coventry, UK. The performance of natural ventilation and daylight in deep-plan buildings is improved through the use of operable windows, doors, and stack-effect ventilation strategies that serve also as a large natural light-well.

ACKNOWLEDGEMENTS

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Visualizing a Living Building

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ABSTRACT: This paper will chronicle the design process of the Odum School of Ecology at the University of Georgia and its objective to accomplish Living Building™ certification. In order to accomplish this, the architect (BNIM) and project partners applied Triple Bottom Line thinking, an Integrated Design Process and Life Cycle Analysis. The author, a member of the design team, will focus on the variety of representation techniques used and their roles within this design process pursuing Living Building™ status.

KEYWORDS: Restorative Design, Triple Bottom Line, Living Building™, Integrated Design Process, Life Cycle Analysis

INTRODUCTION

Currently used terms such as ‘sustainability’ and ‘green’ are evocative but ambiguous. Depending on the use these terms can have multiple meanings. As an example, for some ‘sustainable design’ is synonymous with energy efficiency. For others it also encompasses many other factors such as water use, landscape and social dimensions. The development of third party standards such as LEED, Green Globes, Energy Star and the IgCC help to provide specific metrics and objectives that can be shared by individuals and across disciplines. Arguably the most ambitious set of standards is represented by the Living Building Challenge™. The LBC intends to go beyond sustainable design and achieve what the LBC literature refers to as Restorative Design. The Odum School of Ecology (Fig. 1) design process illustrates how the requirements of the LBC standards affect this process in the pre-design, schematic and (elements of) the design development stages and define ‘sustainable design’ in a distinct way. Another project with similar sustainability objectives will be used to illustrate the steps that would be taken to complete the project. The Omega Center for Sustainable Living – also designed by BNIM with its partners – became certified under the Living Building Challenge™ shortly after work on the Odum project was put on hold. As a member of the design team for the Odum project, the author of this paper offers an insider’s view of this process as it applied the principles of restorative design as defined by the Living Building Challenge™.

Figure 1: Odum School of Ecology Illustration, View from Southwest: (BNIM, 2009)

1.0 PRINCIPLES OF RESTORATIVE DESIGN

1.1. Living Building Challenge™

The Living Building Challenge 2.1™ (ILFI, 2012) was developed by the International Living Building Institute™ (ILBI) as a set of "imperatives" - all of which are mandatory. In addition, unlike other such programs such as LEED, LBC certification is based on actual, rather than modeled performance. The LBC categories are: Site, Water (net-zero water use), Energy (net-zero energy use), Health, Materials, Equity and Beauty. Under each of these categories are organized the specific imperatives. These categories and imperatives have strong parallels to the LEED rating system. This should not be surprising as the local USGBC affiliate (the Cascadia Green Building Council) shares a common umbrella organization (the International Living Future Institute) with the LBC. But the LBC contains some obvious exceptions to LEED such as the inclusion of 'Beauty' as a category. It is through the meeting of the LBC imperatives that 'Restorative Design' is intended to be accomplished. As a way of defining 'Restorative Design', the ILBI uses the metaphor of a flower. A Living Building™, just as with a flower, must: be rooted in place, harvest all energy and water, be adapted to climate and site, operate pollution free, be comprised of integrated systems and be beautiful.

1.2. Triple Bottom Line

The USGBC identifies Triple Bottom Line thinking as an important component of sustainable design. Restorative design must satisfy the Triple Bottom Line (TBL). Originally published in his book Cannibals With Forks, John Elkington (Elkington, 1998) defined the TBL as a way to measure corporate performance. TBL thinking has since been applied to design and become commonly described as 'the three P's': People, Planet and Prosperity (or Profit). It is alternatively known as 'the three E's': Equity, Ecology and Economy. When synergistic solutions equally incorporate all three 'bottom lines' into a design, sustainability is achieved. Applying TBL strategies can also contribute to meeting the LBC and the making of a Restorative Design. As the three categories become more synergistically integrated, there is an increase in sustainability.

1.3. Integrated Design Process

According to the AIA's, "Integrated Project Delivery: a Guide" (AIA, 2007), an Integrated Design Process is guided by the following principles: Mutual Respect and Trust, Mutual Benefit and Reward, Collaborative Innovation and Decision Making, Early Involvement of Key Participants, Early Goal Definition, Intensified Planning, Open Communication, Appropriate Technology and Organization and Leadership. In brief, as many stakeholders and participants in the design process are brought together at the beginning of the process in order to collaborate from concept to construction. This early collaborative process can control construction and life-cycle costs while improving performance. One illustration of how this process can work is in the case of an architect considering a high performing envelope with sun control and daylighting features. The more expensive glass and louvers would mean greater initial construction cost in a conventional design process. But if the engineers are involved in this decision, they could make recommendations about the envelope design and coordinate their systems with the enhanced performance characteristics of the envelope in mind. So compared to the design for a building with a standard envelope, the hvac system could be a smaller and less expensive one. And the lighting system could integrate lighting controls designed to take advantage of the daylighting, thus posing less operating costs. In addition, an environment with high degree of daylighting has been shown to have beneficial effects on user satisfaction, productivity, absenteeism, etc. (quantifiable human HSW benefits) Having the owner and a consultant with expertise in environmental effects on users involved in the design decisions early in the process would make the benefits, as well as the costs, apparent to everyone throughout the design process. In short, not only would everyone know know why decisions were made as they were, they would have contributed to those decisions at the initial stages. This process also facilitates decision assessment on the basis of a Life Cycle Analysis.

1.4. Life Cycle Analysis

As its name suggests, Life Cycle Analysis is a method of determining the value of a design's projected performance and costs over its life. At the opposite extreme is the practice of evaluating a design based solely or primarily on initial construction cost. Employing the principles of restorative or sustainable design above leads the design team to evaluate the value of a design over time – suggested in the very word 'sustainable'. So in order to evaluate the cost/value of a given design such factors as Energy, Pollution, External Cost to Society, Construction Cost, Furniture Fixtures and Equipment Costs, Management Fees and the total Cost (capital and operating) over the project's life span need to be considered. BNIM completed such a study for one of their projects - the David and Lucille Packard Foundation Los Altos Project (BNIM, 2002). The study was documented in the form of a matrix that compares different solutions for the same program and site.

2.0 THE CONCEPT TEAM

The University of Georgia – including representatives from: central administration, facilities management, and other academic units that collaborate with the School.
The Odum School of Ecology – faculty, students and administrators from the first stand-alone college of ecology in the world with research and educational programs that include: infectious diseases, ecosystem ecology, watershed ecology, evolutionary ecology, sustainability, global climate change, conservation and invasive species.
BNIM – members from all parts of this interdisciplinary design firm consisting of architects, urban planners, landscape architects, interior designers, graphic designers and members of 'Elements', the in-house group devoted to sustainability research and analysis.
BIOHABITATS – a consultancy group devoted to ecological restoration, restorative design and water management.
SUPERSYMMETRY – an engineering consultant with expertise in energy efficiency and sustainable design.
VIVIAN LOFTNESS, FAIA - an internationally renowned researcher, author and educator in environmental design and sustainability, the integration of advanced building systems, climate and regionalism in architecture, as well as design for health and productivity.
COSTING SERVICES GROUP – a consultant with expertise in construction cost analysis through all phases of a project's development.

3.0 THE PROJECT: THE BUILDING AS A SPECIES IN A HABITAT

One of the ways of maintaining the Concept Team's focus on Living Building objectives through the design process was to conceive of the project as a Species in a Habitat. This emphasized the interrelated systems of the building, the human activities served by the building, and the building's context as an organic whole. This conceptual framework facilitated finding ways by which the metaphor of the flower could be applied to design decisions. As with the flower, the project must: be rooted in place, harvest all energy and water, be adapted to climate and site, operate pollution free, be comprised of integrated systems and be beautiful.

3.1 The Building as a Species

The building is comprised of three general categories of activity/space: Laboratory (approx. 8,800 m^2), Collaboration (approx. 1,350 m^2) and Office/Education (approx. 4,850 m^2). These general categories are further broken down into sub-categories of: Community, Faculty/Administration, Classroom, Research, Exhibit, and Student. This comprises approx.15,000 m^2 (165,000 sf^2) of enclosed activity/space. (Fig. 2

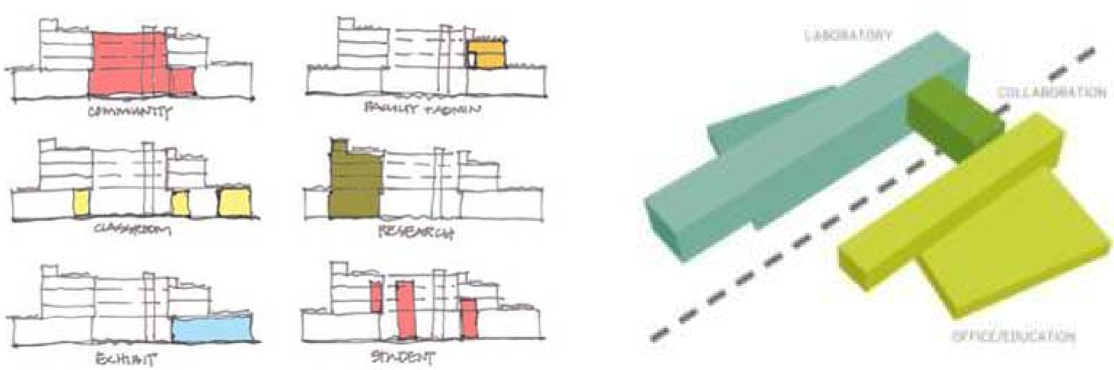

Figure 2: Odum space categories. Source: (Courtesy of BNIM, 2009)

For purposes of meeting the LBC, this set of activity/space categories poses several challenges and opportunities. For instance, laboratories require a large capacity of exhaust ventilation that has an impact on the entire hvac design for these spaces. In addition the lighting requirement in lab spaces is high. Both of these requirements typically result in a high energy requirement for lab space.

The purpose of the building – to facilitate the educational and research mission of the School – suggests a special relationship to the surrounding landscape. Consequently, visual and functional connections of interior and exterior functions and the project developed as a 'living laboratory' became important design strategies. In further support of the educational mission of the School, the project uses devices that mediate the natural elements (light, air and water). In order to demonstrate these mediating devices, they were to be visually expressed.

3.2 The Habitat

Prior to any design conceptualization, site and climate data was collected and documented. This documentation included: solar, temperature, moisture, wind, psychometric and regional ecosystem data for the Athens, GA region (Fig. 3).

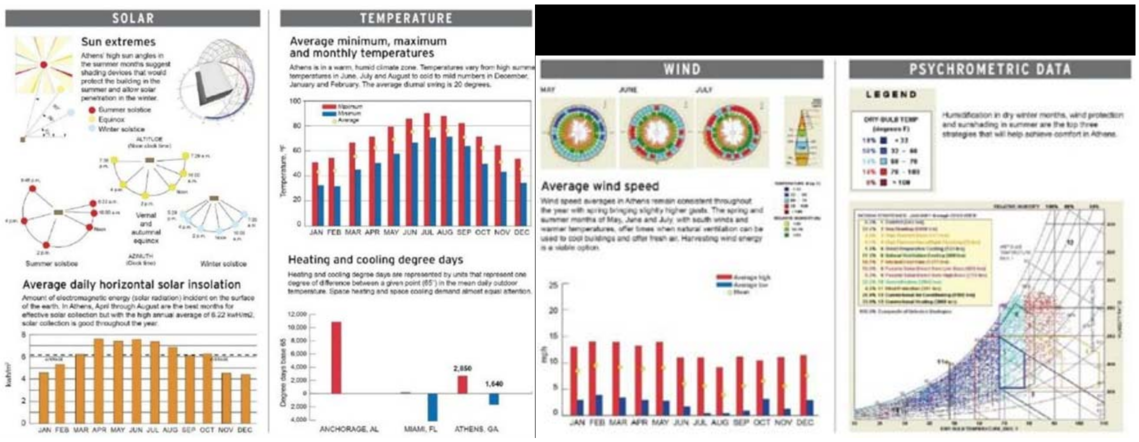

Figure 3: Odum Site and Climate Analysis. Source: (Courtesy of BNIM, 2009)

The site is on the main campus of the University of Georgia on a hill overlooking the North Oconee river valley. As an important strategy of restoration design, the restoration of the watershed in this area of the campus was integrated into the project. In order to accomplish this, the landscape immediately around the project collected rainwater and directed it to a new riparian corridor, diverting this rainwater from the storm water system. This riparian corridor slowed the rainwater and cleaned it on the way to the river beyond (Fig. 4). The restored watershed and riparian corridor also is to serve as a research and pedagogical purposes as it provides subject matter for data collection as well as a case study to illustrate water management techniques for the School's courses.

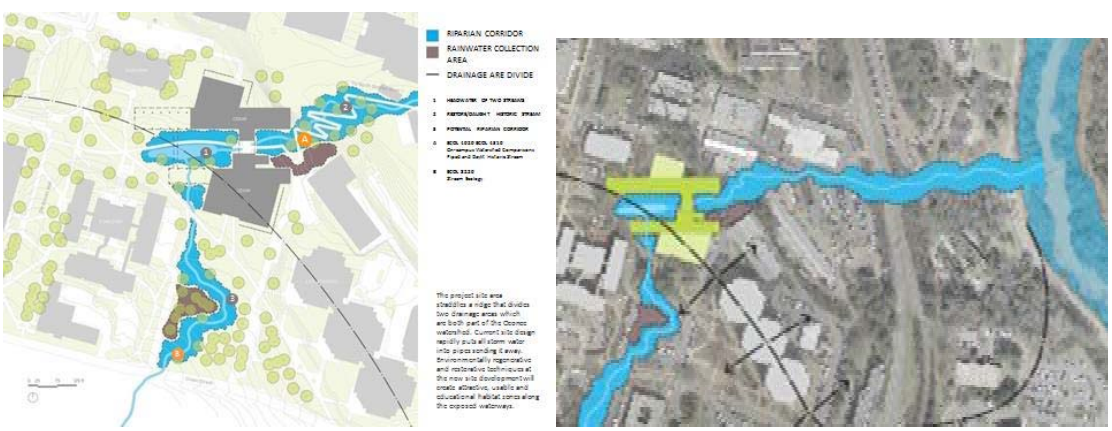

Figure 4: Odum Riparian Corridor. Source: (Courtesy of BNIM, 2009)

Another way in which the surrounding landscape served research and pedagogical purposes was in the development of five separate biodiversity zones. This is seen in an overview of the biodiversity zones going west to DW Brooks and south to Green St. The sensitivity and diversity of developing the site this way offers a more appropriate headwaters condition, increases habitat potential, offers curriculum opportunities and provides readily accessible public demonstration areas.

In addition to the riparian corridor, four other biodiversity zones were proposed to be established. They are to include: piedmont forest, native meadow, permaculture and an arboretum. Once the plantings appropriate to the zones are established, it is anticipated that the fauna associated with these zones will be attracted. The resultant landscape can then be enjoyed by everyone passing through the landscape, observed by the students of the School's courses and studied by the School's researchers.

(Fig. 5) shows the biodiversity zones and the courses associated with each.

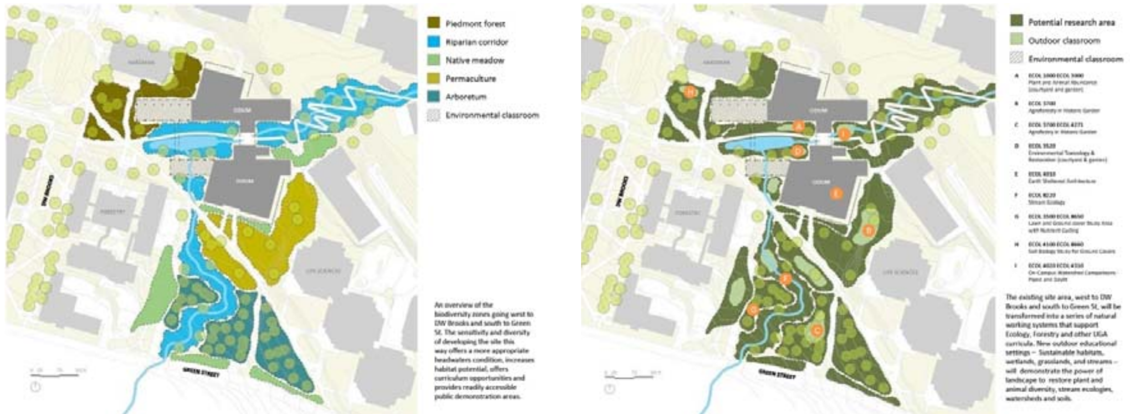

Figure 5: Odum Biodiversity Zones and Pedagogical Areas: Source: (Courtesy of BNIM, 2009)

The connection between the biodiversity zones and the curriculum is an important aspect of the design. Just as important is the connection of the landscape and the building. As is the case with a species in its habitat, there is a co-dependent relationship. (Fig. 9) above helps to illustrate this point. Illustrated with the biodiversity zones are 'environmental classrooms' tucked under west ends of the elevated north and south laboratory and office wings. This indoor/outdoor space takes advantage of its ground level position and overhead protection to provide a place for presentations to be made within the environmental conditions being studied. In addition, the inclusion of green roofs and green walls in the built fabric will also provide for biodiversity. And finally, the building's (species) water management function is intended to be integrated with the environment's hydrological functions. Specifically, rain water is collected from the roof and used or stored for later use as grey water. In addition, all of the waste water from the building is to be processed through the 'eco-machine' and recycled though the building's grey water uses. What is not needed for these grey water uses is sent on to the stream running through the middle of the project and from there down the hill through the riparian corridor and on to the river beyond.

Many of the built features of the project that establish a co-dependent relationship between the building and its environment as conceived as a 'species within a habitat' can be seen in the Building Section (Fig. 6).

Figure 6: Odum – Building Section looking East: Source: (Courtesy of BNIM, 2009)

The features numbered in (Fig. 6) are: 1) Mechanical, Storage, Overflow, 2) Laboratories, 3) Courtyard (stream, trees, living laboratory), 4) Offices, Administration, Café, 5) Auditorium, Exhibit Space, Entry, Eco-Machine, 6) Green Roof, 7) Mechanical Room, 8) Green Wall/Green Roof, 9) Green House, 10) Living Wall, 11) Balconies, 12) Photopholtaics, 13) Access Between Upper Levels and Green Roof, 14) Double Skin Façade.

The building was laid out on an east/west axis. This facilitates day lighting, sun control and natural ventilation strategies. The depth of the major multi-story wings also facilitate these strategies. At approx.. 20m in depth, day light can be reflected into the full depth of the space and air flow from the north to the south is relatively unimpeded. In addition, when in full natural ventilation mode, replacement air is brought in from the central courtyard where the stream and plantings condition the air by reducing particulates, oxygenizing and cooling.

4.0 LBC PERFORMANCE

4.1 Sun

Figure 7: Odum Sunlight and Day Lighting Studies: Source: (Courtesy of BNIM, 2009)

(Fig. 7) Illustrates the initial sun studies done for the proposed massing and the Building Section showing the elements of the design intended to control the sun and maximize day lighting.

The numbered design elements in (Fig. 7) include: 1) All south exposure glazing is protected from the summer sun by overhangs and/or louvers. 2) Deciduous trees in the courtyard provide shade in the summer. 3) The building massing allows for sunlight to reach the courtyard and lower level of the north wing. 4) East and west walls have limited glazing and green walls for light modulation. 5) Rooftop photopholtaic array help off-set electrical use. 6) Light shelves maximize day lighting. 7) Clerestory and skylights illuminate public gathering spaces and the Eco-machine. The pedagogy of the School is also served by related elements. ECOL 3100 is served by a roof top green house and ECOL 4700 by a soil lab wall.

4.2 Air

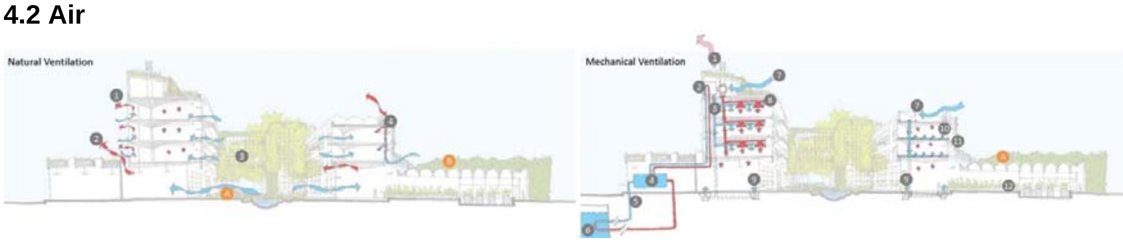

Figure 8: Odum Natural Ventilation and HVAC Systems: Source: (Courtesy of BNIM, 2009)

(Fig. 8) illustrates the natural ventilation and hvac design features.

The numbered design features in the building section labelled ‘Natural Ventilation’ include: 1) North corridors ventilated by natural convection. 2) Exhaust through operable skylights. 3) Vegetated courtyard with running stream cleans and tempers the air. 4) Double skin façade acts as a convection chimney providing a stack effect. The pedagogy of the School is served by related elements. ECOL 3520 is served by the courtyard. And ECOL 4100 and 8660 is served by the varieties of soils and ground covers on the south green roof.

The numbered design features in the building section labelled ‘Mechanical Ventilation’ include: 1) Exhaust from labs through heat exchanger. 2) Variable frequency air handler served by chiller or boiler. 3) Overhead air distribution to labs. 4) Chiller. 5) Pre-chilled water from re-purposed fuel oil tank. 6) Gound coupling system. 7) Fresh air in-take draws air over green roof and through green wall before going through heat exchanger. 8) Low flow fume hood exhaust system in labs. 9) Under-floor air supply. 10) Return air used for lab make-up air. 11) Under-floor air supply in offices. 12) Interior plants and moving water provide natural cooling. The pedagogy of the School is served by related elements. ECOL 4010 (Earth Sheltered Architecture) is served by the south green roof.

4.3 Water

Figure 9: Odum Water Systems and Projected Use: Source: (Courtesy of BNIM, 2009)

(Fig. 9) illustrates the water systems and projected water cycle and water savings of the new design.

The numbered design features in the building section labelled 'Water Systems' include: 1) Green roofs drain rain water to water tank. 2) De-ionization water to labs. 3) Green roof. 4) De-ionizer. 5) City water. 6) Overflow from chiller to stream. 7) Water tank (re-purposed fuel tank) filled from roof drainage and condensation from chiller . 8) Wastewater from lavatories, sinks and toilets to Eco-machine. 9) Treated water from eco-machine to toilets. 10) Clarifying tanks/stream. 11) Eco-machine aerobic tanks. 12) Eco-machine anaerobic tanks. The pedagogy of the School is served by related elements. ECOL 8220 (Stream Ecology) and ECOL 8150 (Wetland Ecology) are both served by the Eco-machine.

The water cycle diagram shows both the existing water cycle and the proposed new water cycle. The new water cycle features a (preliminary and conservatively projected) 75% reduction in the use of city-treated water (and the associated energy/carbon footprint due to the conveyance and treatment of both supply and waste water). This is to be accomplished by the harvesting and storage of rainwater and process water, the use of low flow fixtures and systems, the in-house treatment of waste water by the eco-machine and the use of this treated and harvested water for grey water applications. With further development of the design and more exact performance analysis, it is expected that there will be a net 0% use of city supplied potable water.

4.4 Energy Use and Material Cycle

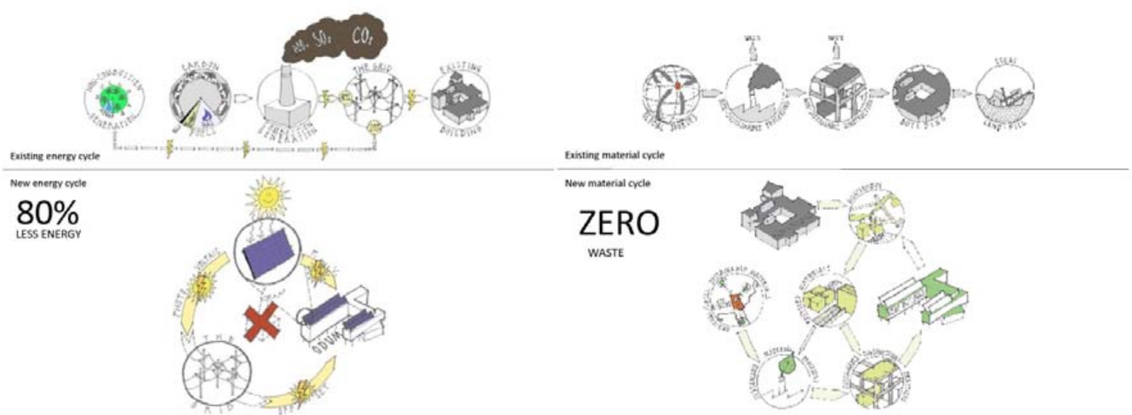

Figure 10: Odum Projected Energy Use and Material Cycle: Source: (Courtesy of BNIM, 2009)

(Fig. 10) illustrates the existing and projected cycles of energy use and material use

The new energy cycle diagram features a (preliminary and conservatively projected) 80% reduction in energy use over the existing energy cycle (with its associated pollution and carbon footprint). This is proposed to be accomplished through the use of more energy efficient systems throughout the project, the harvesting of daylight and the use of photovoltaic arrays (approx. 6,000 m^2) to off-set the remaining energy used. With further development of the design and more exact performance analysis, it is expected that there will be a net-zero energy use.
The material cycle diagram in (Fig. 10) illustrates the differences in the existing material cycle (materials from global sources, non-sustainable and hazardous manufacturing processes, non-sustainable construction practices with a high degree of waste and full demolition of the structure – with the material to the land fill at the end of its life) with the projected new material cycle (regionally sourced materials processed in ways that

produce minimal contaminants and a small carbon footprint, assembly practices that enhance the opportunity to disassemble and reuse/re-purpose the building materials at the end of the building's life.

CONCLUSION

As was the case with so many projects in 2009, the Odum project was put on hold pending further funding. As discussed above, the level of preliminary analysis did not allow the team to claim that the requirements of the LBC had been met. In order to complete the Odum project a good deal more finite analysis and more refined design decisions would be needed to be made – particularly with regard to the use of BIM and digital analysis applications for energy modeling, air flow and daylighting/lighting for instance. But this was not due to a lack of confidence that they could be in the future with additional design refinements and analysis. This is at least in part due to the fact that BNIM had already met the Living Building Challenge^{TM} with the 'Omega Institute for Sustainable Living' project, one of the first two projects to earn Living Building^{TM} certification. In the Omega project, BNIM led the project team in a similar way, employing Triple Bottom Line thinking, an Integrated Design Process and Life Cycle Analysis. Similar design strategies were also employed. (Fig. 11) shows the results of the Omega project in the form of a photograph, and a presentation of data collected for the LBC process. If the Odum design process resumes, similar results are expected.

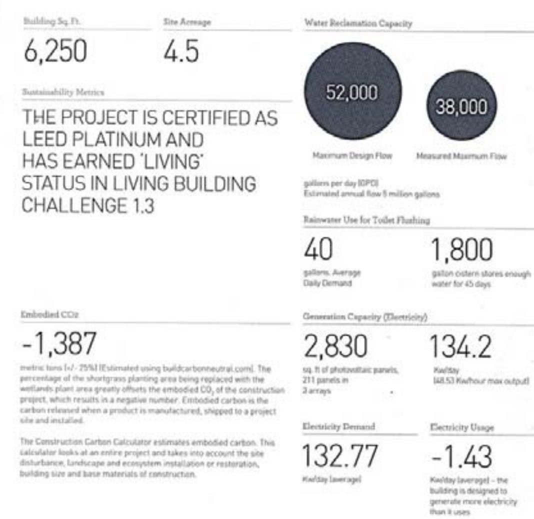

Figure 11: Omega Institute for Sustainable Living: Source: Photo (c) Assassi, Date Page: Source (Courtesy of BNIM, 2009)

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US Map Visualization of Optimal Properties of Phase Change Materials for Building Efficiency

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ABSTRACT: Incorporating phase change materials (PCM) in construction materials can reduce the heating and cooling loads of buildings significantly. During the past ten years, many studies have estimated potential reductions of energy consumption of buildings between 10 and 30 percent. This wide range is due to the large number of parameters that affect energy consumption and make the process of selecting the type and amount of PCM challenging. In fact, extensive engineering studies are generally necessary to determine the practicality of PCM in any specific case. As a result, architects and engineers are reluctant to use PCM because of the lack of design guidelines. The International Energy Conservation Code (IECC) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) identified eight climate zones in the United States, each determined on the basis of annual degree heating and degree cooling days. Climate zones are further divided into moist, dry and coastal regions leading to 15 specific climates. Phase change materials are defined by their melting temperature, energy storage capacity, i.e., enthalpy, and cost, among other parameters. For a given building in a given climate, there exist an optimal melting temperature and enthalpy that minimize the energy consumption and the payback period. In this research, the optimal properties of PCM are determined for all 15 climates and results are visualized in the form of maps of the United States. Additional topics discussed in this paper are the sensitivity of the optimal properties of PCM and the effect of the average cost of energy on the selection of PCM. Fifteen different maps of the United States were created, from which the most relevant are presented in this paper. The energy consumption is determined numerically using the Department of Energy software EnergyPlus, which calculates the energy consumption for heating and cooling a building under any climate and operation schedule. The software is run on a computer cluster for a wide range of properties from which the optimal values are extracted.

KEYWORDS: Phase change materials, energy, visualization maps, design guidelines, payback period.

INTRODUCTION

Energy efficiency is a dominant theme in today's global lexicon. It is becoming increasingly clear that our finite energy resources cannot meet our needs of the future. Currently the global energy consumption rests at a staggering 513.2 Quadrillion British Thermal Units (Quads) and is projected to increase to 769.8 Quads by the year 2035 (Conti et al 2011). Among the industrialized nations the United States is one of the leading energy consumers with approximately 1/5th of the global annual energy consumption, of which the built environment accounts for approximately 40% (Buildings Energy Databook 2010). It is therefore incumbent on engineers, scientists and designers to explore sustainable ways to curb the energy consumption within the building sector.

Thermal energy storage (TES) technologies for buildings have been gaining considerable attention over the last few decades. Thermal energy storage mechanisms are known to decrease indoor temperature swings, improve indoor thermal comfort for occupants and shift electrical consumption from peak to off-peak hours by storing heat or cold for use at a later time when indoor thermal conditions fall outside of the comfort zone (Dincer & Rosen 2011; Mehling & Cabeza 2008). There are three physical processes of storing thermal energy i.e. sensible heat storage, latent heat storage (LHS) and chemical storage. Among these approaches, the latent heat thermal energy storage using phase change materials (PCMs) has attracted attention for its use in building applications due to its inherent ability to store and deliver lager amounts of energy at a narrow phase transition temperature (Pasupathy et al 2008; Zhang et al 2007).

Phase change materials are capable of storing and releasing large amounts of heat by melting and solidifying at a given temperature. Phase change materials are classified into three categories (i.e. Organic, Inorganic and Eutectic) based on their chemical makeup. However each of these PCMs can also be appended to construction materials forming a homogenous mixture which exhibits the heat storage properties of the PCM itself. The investigation of PCMs as thermal energy storage systems in buildings has a long history. However, the studies have been sporadic and scattered throughout the globe. This makes it hard to draw any conclusive guidelines for its viable use in buildings under different climatic conditions. Therefore there exists a widespread consensus among researchers and practitioners on the need for a more systematic and comprehensive study of the dynamic characteristics and energy performance of buildings using PCMs (Chen et al 2008; Zhu et al 2009; Roth et al 2007; Zhang et al 2006; Kuznik et al 2011). While PCM gypsum boards are becoming commercially available in the construction industry in the US, designers and engineers are still unsure as to the guidelines for selecting the proper PCM (i.e. Melting temperature, heat storage capacity) specific to particular climatic conditions.

The high capital cost and subsequently long payback period of new technologies is seen as one of the most significant barriers in implementing it in buildings (Cooke et al 2007). Three cash-flow analysis tools – payback period, return on investment and present worth analysis – are commonly used to evaluate investments that improve energy performance. While the latter two analyses are predicated on the notion of setting a time frame of useful life, the payback period analysis is the most basic financial gauge to obtain the time (usually in number of years) for an investment cumulative cash flow to reach zero. Assuming that energy prices rise to keep up with inflation the change in time value of money is ignored in this analysis. In addition, the availability of tax benefits and subsidies for energy efficient homes provided by the federal government adds significant complexity to the payback period analysis. The effect on the payback period by the inclusion of the time value of money, the savings accrued from the downsizing of HVAC equipment, reduction in construction costs, the lower interest rates provided by the energy efficient mortgage (EEM) will be analyzed in a further study. By relegating the 'systems' thinking approach for a later study, this paper therefore considers 'pseudo' payback periods (PPP) based solely on the initial capital investment for the PCM boards and the money saved due to the savings in energy.

In the existing literature, research on payback periods for the use of PCMs is predominantly assessed on the basis of its environmental impacts. In a rudimentary sense such payback period analysis seeks to answer questions such as, how long does it take for the use of PCMs in buildings to surpass its embodied energy to mitigate greenhouse gases. Chan (2011) has studied the environmental and economic impact of PCM impregnated walls in subtropical Hong Kong. Based on the embodied energy of the particular PCM in question, the study concludes an energy payback period of 23.4 years. On the other hand the economic payback period, disregarding the time value of money, is concluded to be 91 years. Gracia et al (2010) and Castell et al (2012) performed LCA analysis on five different test huts with and without PCM in Puigverd de Lleida, Spain. They concluded that the energy payback period can be reduced by lowering the embodied energy of PCM since it was too large to counteract the benefits during its operation. Stovall and Tomlinson (1995), through better management of the thermostat set point temperature schedules during the winter months and also by taking into account the differential tariff systems, found an economic payback of using PCM boards in a small house in Boston to be 5 years. Moheisen et al (2011) performed test on a typical office space in an environment chamber and have concluded that the economic payback period of PCM was 5 years as well. As such the economic payback period of using PCM in buildings depends on a number of factors (i.e. the cost of PCM and the cost of energy etc). For this paper the cost of PCM is set to an arbitrary yet reasonable number and the cost of energy is based on the cost per kilo-watt-hour of electricity according to the average state electricity rates.

1.0 METHODOLOGY

The aim and scope of this research is to identify the optimum melting temperature and enthalpy of PCM for each given climate type and also quantify the 'pseudo' payback period (PPP) associated with the use each optimum PCM board. The energy analysis was performed using EnergyPlus, a whole building energy simulation software developed by the US Department of Energy. The objective is also to perform a sensitivity analysis as to understand the magnitude of difference in savings if a less than optimum melting temperature or enthalpy is chosen. To that end different theoretical gypsum boards-PCM mixture (PCM boards) were defined using the Enthalpy-Temperature function in EnergyPlus. The PCM property was thus appended to the Gypsum board which lined the interior surface for all walls and the roof. A total of 60 different PCMs were defined to test the optimum PCM for each specific climate. The PCM's melting temperature ranged from 16^{o}C to 30^{o}C in increments of 1 degree. Each PCM was defined to have a sharp melting range of 0.1 degree. Similarly, for each PCM board the enthalpy ranged from 20kJ/kg to 80 kJ/kg in increments of 20 kJ/kg.

The International Energy Conservation Code (IECC) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) have identified eight climate zones in the United States, each determined on the basis of annual degree heating and degree cooling days. Climate zones are further divided into moist, dry and coastal regions leading to 15 specific climates each represented by cities within the United States (PNNL 2011).

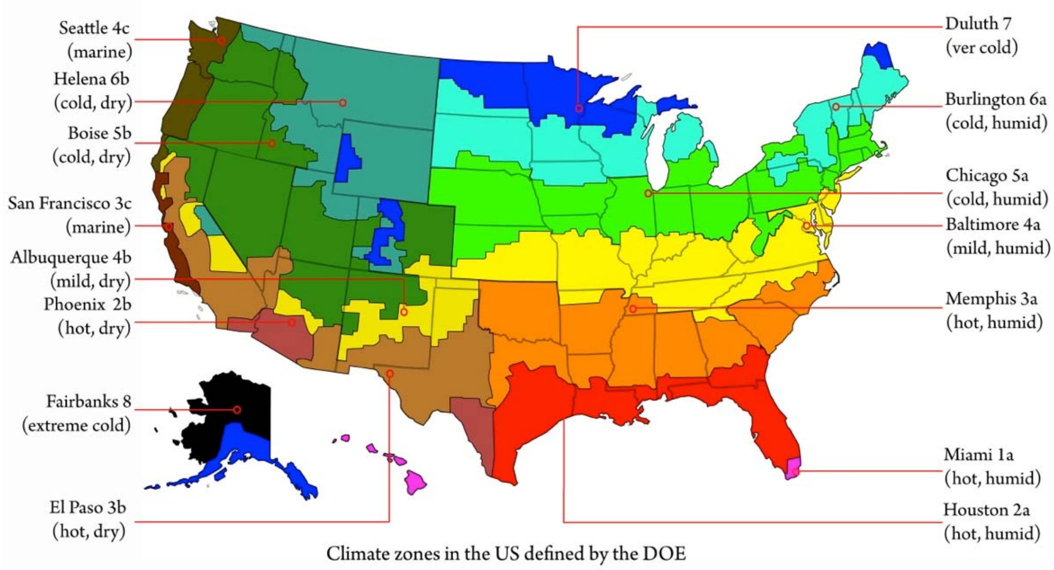

Figure 1: DOE developed climate zones and representative cities. Source: (PNNL 2011)

A baseline building was developed for each representative city following the guidelines recommended in the ASHRAE 90.1 - 2010 standard. The 15 different climate specific buildings were created to match the specific recommendations on the insulation R-value, window SHGC and U-value in the standard. The construction specifics recommended in the standard were adopted for the building surface as well as the fenestration components. Figure 2 depicts the surface construction and the dimensions of the building simulated for this study.

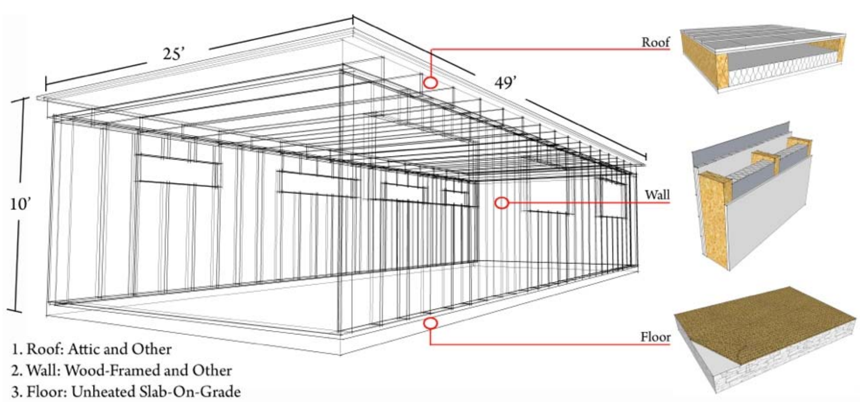

Figure 2: Baseline building construction as per ASHRAE 90.1 – 2010.

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In terms of the internal loads, the building was set to be occupied by five people throughout the 24 hours of the day and every day through the year. Each person was set to dissipate 120 watts of energy into the interior environment. The heating and cooling thermostat setpoint temperatures were set at 21^{o} and 25^{o} Celsius respectively throughout the year and the building was set to be conditioned by the Ideal Air Loads System. The energy performance of each specific building was simulated for the 15 different cities using the typical meteorological data (TMY3) weather data available from the EnergyPlus weather repository. The output variables, annual cooling and heating energy were requested as the dependent variables. Due to the high number of simulations required for each climate the software JEplus (Zhang 2009) was used to setup and perform parametric runs for each PCM board. The data was then compared to the control or baseline building without PCM properties appended to the gypsum board in order to quantify the magnitude of savings offered by the inclusion of PCM.

2.0. RESULTS AND DISCUSSION

2.1. Optimum melting temperature and enthalpy

The results for each climate was obtained and analyzed separately. It is clear from Figure 3 that the climate zone 8 (Fairbanks, AK) has the highest magnitude in annual load predominantly due to its high number of heating degree days (HDD) that requires a significant heating load throughout the winter. On the other end of the spectrum climate zone 3c (San Francisco, CA) has the lowest annual loads predominantly owing to its all year round mild temperature that requires neither too much heating nor cooling.

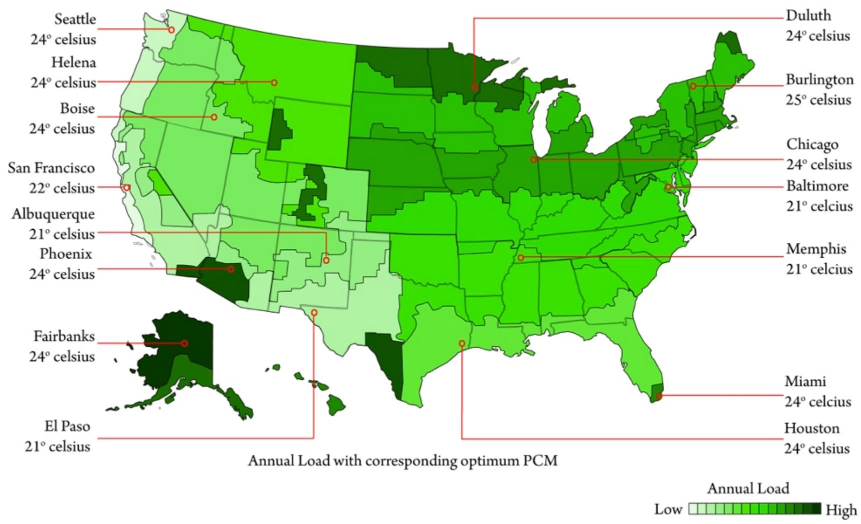

Figure 3: Analytical map for the annual load (magnitude) with the optimum PCM melting temperature for each climate.

The optimum melting temperature and enthalpy were determined for each climate by selecting the corresponding lowest annual load. The results show that the annual load for every climate was the lowest when the PCM board had the highest heat storage capacity. The PCM boards in this particular study were set to take four different heat storage capacity values (i.e. 20, 40, 60, 80 kJ/kg) and the optimum energy savings was obtained by the PCM board with 80 kJ/kg enthalpy for all the climates.

In terms of the optimum melting temperature, it can be seen in Figure 3 that the melting temperatures vary by climate. Due to this variability in optimum melting temperature a causal relationship between the heating degree days (HDD) and cooling degree days (CDD) and the optimum PCM melting temperature cannot be conclusively drawn. The heating and cooling setpoint temperatures along with the HVAC schedule can be an important determining factor for the selection of the optimum melting temperature of the PCM. The HVAC system in this particular research was set to be available 24 hours a day and all year round. The heating and cooling setpoint temperatures were set to 21ºC and 25ºC respectively. The principle of free-cooling of PCM that can provide cold storage and also naturally 'charge' PCM through night ventilation was not applied for this study and set for a later study. The application of the PCM free-cooling principle can further help alleviate the stress on the HVAC systems by providing cold storage through night ventilation as well as help 'charge' the PCM for use the next day. Similarly different HVAC schedules can also provide for energy efficient management of indoor thermal conditions. The effect of these parameters on the optimum melting temperature will be presented and discussed in a later study.

2.2. Percent savings in energy

The magnitude in savings in energy was determined once the optimum melting temperature and enthalpy for each climate zone was obtained. It can be seen in Figure 4 that the maximum percent in savings was obtained for climate zone 4c (San Francisco, California). It should also be noted that the percent savings in energy (51.91%) for San Francisco is very high due to the fact that the annual load without PCM is very low compared to other climate zones to begin with. Since PCM was applied, the percent decrease in annual load came to be 51.91% compared to an already relatively low annual load compared to the other climates.

It is also clear that the highest percent savings occurs in the dry and marine climates. Within the subset of dry and marine climates, the PCM technology performs better in the warmer climates. The diurnal temperature fluctuates to a greater extent in the dry climates than in similar humid climates. It is not uncommon for the ambient air to cool significantly during the night in the dry climates and thereby cooling (discharging) the PCM boards for use the next day. Since the PCM is cooled by this drop in ambient temperature there is no need for the HVAC to expend extra energy in these dry climates to 'discharge' the PCM. It is possible that the effect of free-cooling and cold storage will improve the percent energy savings in the colder climates.

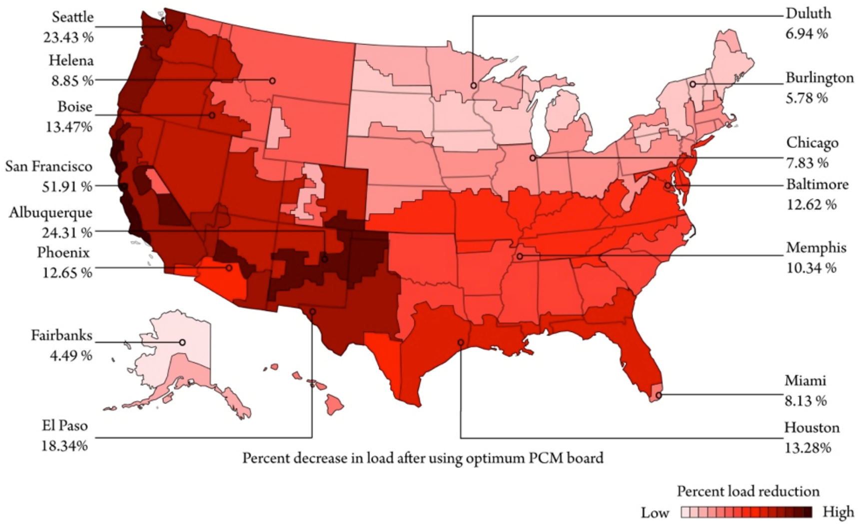

Figure 4: Analytical map of the energy savings in magnitude by using the optimum PCM in each climate zone

A sensitivity analysis on the optimum temperature was also performed in order to provide an understanding of the magnitude of loss in percent savings if optimum temperatures of 1 degree higher or 1 degree lower is to be chosen.

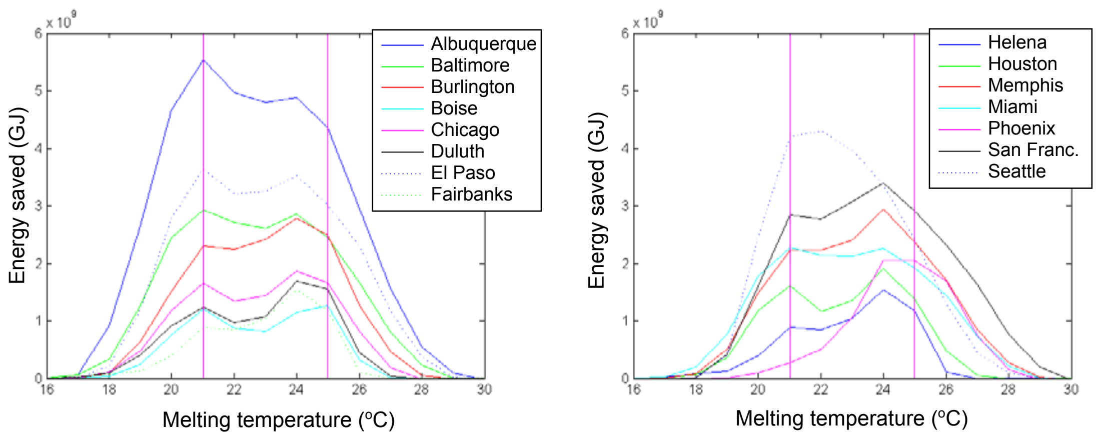

Figure 5: Energy saved as function of PCM's melting temperature for the 15 climates (setpoint temperatures: 21°C and 25°C)

In Figure 5, PCM boards melting at 21°C offers the most in energy savings for Albuquerque. If however the designer chooses to select a PCM melting temperature of 20°C then there is a loss of 20% in energy savings. A similar trend can be seen for the other climates as well. It is crucial to choose the optimum melting temperature to obtain the maximum benefits of using PCM boards.

Additionally it can also be seen that the optimum melting temperature hovers in and around the heating and cooling setpoint temperatures. There is no distinct pattern in the results to suggest a direct correlation between the setpoint temperatures and the optimum melting temperature. Clear guidelines for the selection of optimum melting temperature based solely on the setpoint temperatures are not feasible.

2.3. Payback period

A 'pseudo' payback period (PPP) is determined for the use of the PCM boards for each climate. The cost of commercially available PCM boards varies on the basis of melting temperature, heat storage capacity from each manufacturer. In order to evaluate the PPP of the optimum PCM boards for every climate type, a wider range of costs were incorporated into the calculation. The cost of PCM board was therefore set to vary from \$1/kg to \$3/kg. Similarly every state has a different electricity tariff. In order to encompass a wider range of tariffs the cost of electricity was also set to vary from \$0.07/kWh to \$0.18/kWh. In the PPP calculations the time value of money, the savings accrued due to the downsizing of HVAC equipment, reduction in construction costs, and the lower interest rates provided by the energy efficient mortgage (EEM) and other federal subsidies for the investment in energy efficient homes are ignored.

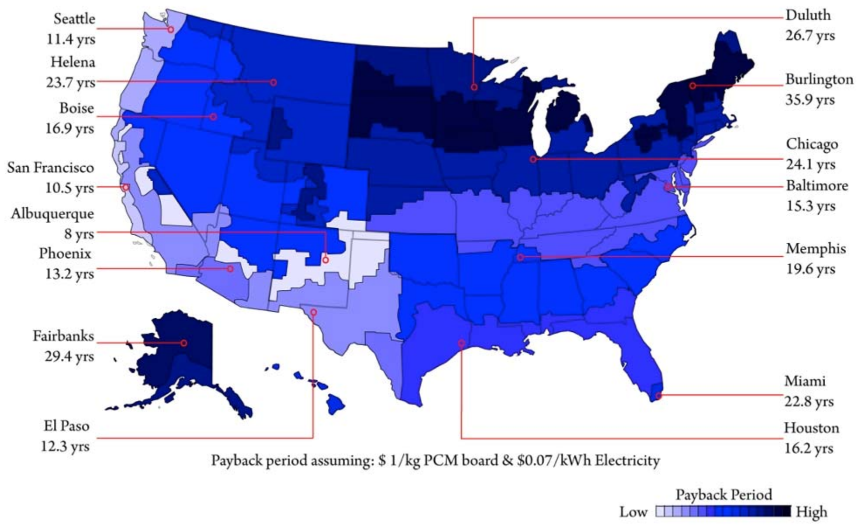

Figure 6: Analytical map of the pseudo payback period assuming a \$1/kg cost of PCM board & \$0.07/kWh cost of electricity

It is evident from Figure 6 that the lowest PPP is for the climate zone 3b represented by Albuquerque, which is a mild and dry climate. Even though the highest percentage savings in energy was seen for climate zone 4c represented by San Francisco, climate zone 3b fares better in terms of the economic payback period. Similarly while climate zone 2a represented by Houston, exhibited a slightly higher percentage savings in energy than climate zone 2b represented by Phoenix, zone 2b is better in terms of the number of years to payback the initial investment in PCM boards. Again it can be seen that PCM boards perform best in the warm, dry and marine climates as opposed to cold and humid climates.

The PPPs were plotted against the cost of PCM and electricity (Figure 7(a)). In addition, the required costs of PCM and electricity to achieve a PPP period of 10, 20 and 30 years were obtained for each climate (Figure 7(b) shows the case of Albuquerque).

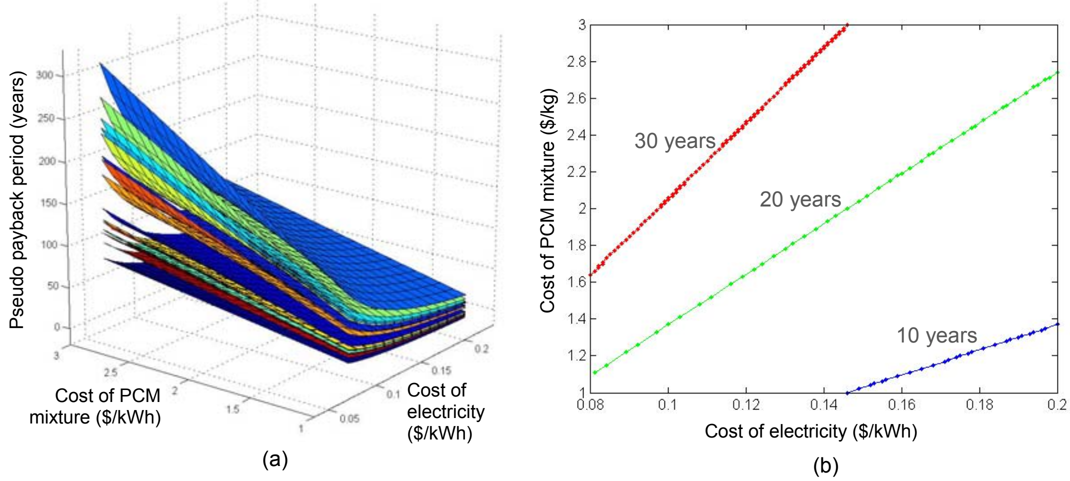

Figure 7: (a) Pseudo payback period as function of cost of PCM mixture and cost of electricity for all 15 climates and (b) Cost of PCM and electricity needed to achieve a PPP of 10, 20 and 30 years in Albuquerque.

The PPP of all the 15 climates can be visualized in Figure 7(a). The PPP is influenced by a greater degree by the cost of PCM due to the greater slope. The cold and humid climates exhibited a PPP far greater than the warm and dry climates. The plot in Figure 7(b) shows the optimum cost of PCM and electricity for Albuquerque. If a PPP of 10 years is desired for Albuquerque then any combination of cost of PCM and cost of electricity on the blue line will achieve that.

CONCLUSION

In this study, building energy performance simulations were performed for a simple building fitted with PCM boards on all interior surfaces except the floor. The simulations were carried out for the 15 different climate types as defined by the U.S. Department of Energy. The application of PCM wallboards in those buildings shows significant benefits in terms of annual energy savings.

- The PCM boards perform best in hot, dry and marine climates. The diurnal fluctuation of ambient temperature in the hot and dry climates as well as the mild marine climates can be attributed to the better performance of PCMs.
- The PCM boards did not perform well in the cold and humid climates. This can probably be improved by allowing free-cooling during the night. In addition, different set point schedules for the HVAC, different occupancy schedules as well as different night ventilation schemes need to be further studied in order to optimize the performance of PCM boards in such climates.
- The 'pseudo' payback period of the use of PCM boards were comparatively very high. For the PCM boards to be economically viable, the cost needs to be close to \$1/kg and have a higher heat storage capacity. The effect of the time value of money, the savings accrued due to the downsizing of HVAC equipment, reduction in construction costs, and the lower interest rates provided by the energy efficient mortgage (EEM) and other federal subsidies for the investment in energy efficient homes need to be applied as well in order to conclusively determine the economic viability of PCM wall boards in the US climates.
- The sensitivity study shows that the optimum temperature is an important factor in determining the energy saving potential of the PCM board. A slight divergence from the optimum temperatures for each climate can reduce the energy saving potential by 5-10 percent.

The present study is an attempt to assess theoretically the energy performance of PCM boards on all climates in the United States. Starting with a simple building model the later studies will gradually add more variables to the simulations and register the changes assessed.

ACKNOWLEDGEMENTS

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Commercializing Energy-efficient Affordable Housing: The EcoMOD South Project

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ABSTRACT: This paper addresses some of the recent activities of the ecoMOD project, a research and design / build / evaluate initiative at the University of Virginia School of Architecture and School of Engineering and Applied Science. In 2011, the ecoMOD received a substantial portion of a $2.45 million grant from a regional economic development funder to work with commercial companies and non-profit organizations in the two most economically deprived areas of Virginia, Southside and Southwestern Virginia. The funding is being used to develop a commercially available version of an ecoMOD home design. Since 2004, ecoMOD has designed, built and evaluated prefabricated affordable homes for affordable housing organizations such as Piedmont Housing Alliance and Habitat for Humanity. This recent grant is intended to commercialize a modular Passive House Standard version of one of the previous designs and help develop the capacity for fabricating sophisticated, high-performance homes in the region. The effort is dubbed 'ecoMOD South' because the affordable housing organizations and fabricators are based in Southside and Southwestern Virginia.

KEYWORDS: Passive House, Modular, Affordable Housing

INTRODUCTION

The ecoMOD Project is a research and design / build / evaluate initiative at the University of Virginia that since 2004 has created a series of highly energy-efficient affordable housing units. In 2009, a sister project, ecoREMOD, was formed, focusing on renovations and deep-energy retrofits. The projects are embedded in UVA's curriculum and structured to maximize the educational opportunities. To date, almost 400 students (and a handful of faculty members) have helped to create a total of nine housing units on six sites. Once occupied, student evaluation teams monitor and evaluate the homes carefully, with the results guiding subsequent designs. The ecoMOD / ecoREMOD project (Quale, 2012 and www.ecomod.virginia.edu) is a partnership of the UVA School of Architecture and School of Engineering and Applied Science. The goal of the project is to provide a valuable educational experience, while demonstrating the environmental and economic potential of prefabrication and renovation. ecoMOD / ecoREMOD teams work directly with affordable housing organizations to ensure sustainable housing is no longer a luxury reserved for the wealthy.

The project teams strive to address the two most important challenges facing the next generation of designers: the significant environmental impact of the building environment, and the growing economic divide between high-income and low-income individuals. In the context of this multi-year project, participants have included architecture, engineering, landscape architecture, historic preservation, planning, business, environmental science, economics and high school vocational education students and faculty. The curriculum and the projects have been recognized nationally and internationally as a model for sustainable architectural and engineering education, and have won over a dozen major awards.

The evaluation phase is structured to monitor and analyze completed housing units. It is essential to the project because it can contribute to building both confidence and humility in students. The evaluation teams typically assess the environmental impact, efficiency, affordability, and occupant satisfaction of each housing unit. The monitoring systems deployed by the engineering teams measure indoor and outdoor air temperature; relative humidity; CO_2 levels; and electricity, gas and water usage.

The University of Virginia Innovation office has registered the copyrights for the designs of the completed homes. Since the beginning, the intent was to allow affordable housing organizations to benefit from the convenience of getting a high-performance home delivered for a reasonable construction cost. By taking the ecoMOD designs into production, our intent is to give affordable housing organizations quick, low-cost and sustainable infill housing options that cost less to operate.

1.0 ecoMOD SOUTH DESIGN PHASE

1.1. Redesigning the Prototype

In the summer of 2011, the Tobacco Indemnification and Community Revitalization Commission of the Commonwealth of Virginia approved a $2.45 million research and development grant for the University of Virginia's ecoMOD Project and another project (reCOVER – focused on post disaster transitional housing). The grant is to work with modular and structural insulated panel (SIP) manufacturers and non-profit organizations in creating commercially viable manufactured housing. The ecoMOD South research project is currently commercializing one of the project's modular homes with Cardinal Homes, a modular homebuilder in Southside Virginia. The original prototype of the home -- ecoMOD4: the THRU house [Figures 1 and 2] -- was designed and built by students in 2009 for Habitat for Humanity of Greater Charlottesville. The two-story, two bedroom home has just over 1,000 square feet, and is home to a refuge couple from Afghanistan. It has a donated photovoltaic array, which when combined with a well-insulated and carefully air-sealed building envelope, allowed the designers to target zero-net energy. As of the summer of 2012, the home has achieved a few months of net zero living, although not consistently. It is believed that the energy habits of the homeowners, and the fact that the construction budget did not allow for high-performance windows, contributes to the higher than anticipated energy use, which remains substantially lower than a comparably sized conventional home.

Figures 1 and 2: Exterior and interior views of ecoMOD4: the THRU house. Source: Scott Smith Photography

The research team has collaborated with Cardinal, as well as Southside Outreach from South Boston in Southside and People Incorporated from Abingdon in Southwestern Virginia to create a four-bedroom version of the design. The housing organizations, the modular homebuilder and the SIPs manufacturer receive the majority of the funding for materials, new technology and training.

As of this writing, the units are being fabricated, and the design and build phases will be complete in the spring of 2013. Two identical versions of the home will be built to Passive House standard (PH) and placed in two different cities (South Boston and Abingdon) – with slightly different climates. The South Boston PH home will be rented by low-income individuals in a city with a moderate / humid climate. The Abingdon home will be purchased by low-income homeowners in a city located in the foothills of the Appalachian mountains, which has a slightly more extreme climate. A third house will be constructed to look exactly the same from the outside, but the insulation, air barrier and mechanical systems have been redesigned to go no further than meet the energy requirements of the standard building code. This “code unit” will be located next door to the PH home in South Boston. The research team will monitor the performance of all the units, and also assess the return on investment of the added cost to achieve Passive House standard.

The current grant-funded effort in not as directly integrated into curriculum as the previous design / build / evaluate efforts, although current students have contributed to some aspects of the work, including the development of the monitoring system and eventually the analysis of the data. The majority of the work has been completed by a team of former students acting as paid research assistants, three of whom have previous experience with the project.

Over a year and a half, the ecoMOD South research team adapted the ecoMOD4 design to become a four-bedroom, 1,800 square foot home [Figure 3]. In addition to the redesign process, the team critiqued the materials used in the prototype, and spent many months researching material choices, construction details, landscape design strategies, Passive House modeling, and created simulations of energy use, daylighting and thermal bridging. The effort is led by the ecoMOD Project Director, who works with three other faculty members with expertise in engineering, landscape architecture and building simulation. A PH certified consultant manages the PH modeling process, and a PH certified engineer designed the mechanical system.

Figures 3: Exterior view of ecoMOD South homes shown on the South Boston, VA site. Source: ecoMOD South Team

The design process took longer than originally anticipated. With the schematic design already in place, the team assumed a relatively straightforward process to add a third bedroom (a fourth was later added), adjust the design of the building envelope to respond to the Passive House standards, and work closely with Cardinal Homes to understand their process. All the partners agreed on the goals of achieving high performance housing on a limited budget, but not surprisingly, the difficulty was in finding a shared understanding of the meaning of ‘high performance’ and ‘limited budget.’ In the end, the team was pleased it had the opportunity to extend the grant period to ensure we could come up with the best possible project within the budget available.

The collaboration with Southside Outreach and People Incorporated was productive. The most significant challenge the research team faced working with these two well-experienced affordable housing non-profits is the fact that they are quite different from each other. Southside Outreach consists of two full time staff and a community board. Given their limited size and resources, they have been able to have a significant impact on the communities they serve. In addition to developing new affordable housing, they also repair and renovate housing, and offer educational programs to help clients learn how to prepare themselves for homeownership. They work in six counties in Southside, and have been in existence for 17 years.

By contrast, People Inc. is one of the largest community action agencies in the nation. Almost 50 years old, it currently counts 12 counties in Southwestern and Northern Virginia as primary service areas, with an additional 11 counties in Southwestern Virginia as secondary areas. Affordable housing is just one of their interests. The organization has over 200 staff members, and runs a wide variety of programs. Examples include efforts to support elder care, child daycare, preschool and head start programs, after school programs, tutoring, community development, business development and financing, consumer loans, weatherization and repairs of homes, transitional housing, Section 8 housing, health care, dental care, court appointed special advocates, domestic violence support programs, drop out prevention programs, and workforce development programs of various types.

For Southside Outreach, the ecoMOD South initiative is an important project and consumes a significant percentage of staff time. For People Inc, ecoMOD South is just one of many housing initiatives that they are working on. The Southside Outreach staff, and the housing team at People Inc. know each other well, and have even partnered on a project in the past. Yet, the research team worked with the two organizations in very different ways. The team made sure to understand not only the differences in administrative processes, but also the unique interests and preferences of each organization. The two PH homes will be exactly the same for the two organizations, but the methods of financing the community partner's portion of funding, and individual size and configuration preferences led to a unique working process for both.

From the beginning, the team sought certification under the Passive House standard, while remaining limited to an affordable housing budget. Early PH simulations led the team to add a fourth bedroom because it meant a better ratio of exterior surface to interior volume, without necessitating a major design change. Over time, the ecoMOD South research team, working with the PH consultant, researched a wide variety of insulation and air sealing ideas, glazing specifications, technologies and materials. A particularly difficult challenge was testing the PH design variations on both sites. Fairly often, a small change to a detail or material selection meant the design would fail to achieve PH certification in one site but not the other. This issue was complicated by the fact that while the designs were identical, the sites are not, and orientation of the buildings on the two sites are also quite different.

The portion of the grant funding available for construction allowed the housing organizations to exceed their typical budget compared to a similarly sized home. The total cost of modular production of the PH units is about $105/SF, with the code unit coming in about $65/SF. This does not include site and landscape costs, which vary considerably due to radically different topographic and site conditions. The Abingdon PH home is infill housing in a somewhat dense urban context on a very steep lot, with a much more expensive foundation and little opportunity for landscape development. The PH and code home in South Boston are being placed on a mostly flat empty lot, with 13 more adjacent lots that may someday be filled by other ecoMOD designs. Across the street from these homes, there are six two-story apartment buildings (approximately eight units per building) that are owned by the same non-profit partner, Southside Outreach. (An ecoREMOD team recently completed a schematic design for energy upgrades and aesthetic improvements to these buildings. The ideas are being handed over to a professional architecture / engineering firm from the South Boston area.)

These per square foot costs, while higher than similarly sized affordable housing in Southside and Southwestern Virginia, are in line with the affordable housing market in Central Virginia and the Richmond area. They are also below the cost of similar affordable housing in most of Northern Virginia near Washington DC. Therefore the homes are unlikely to be duplicated by these partners as PH homes, but there is clearly a market to sell them as PH units to housing organizations in other parts of the state, as well as to market-rate homebuyers throughout the state and region. The ecoMOD Project, recognizing its inability to achieve a PH design that can be replicated for these two partners in their primary services areas, offered a design studio and engineering seminar in the fall of 2012 to design lower cost, one-story, Energy Star rated homes that will meet the necessary budget for future affordable housing development in South Boston and Abingdon. Cardinal Homes will be able to sell both the ecoMOD South PH and non-PH design, as well as these one-story home designs, called ecoMOD RANCH because they are a reinterpretation of the standard American ranch house.

For the UVA research team and the staff of Cardinal Homes [Figure 4], the experience has been an important educational opportunity for both sides. The ecoMOD South team had to learn about the normal process of designing, engineering and building a home with Cardinal Homes (each modular homebuilder is somewhat different), and the Cardinal staff was exposed to innovative building materials they had not previously procured, and learned how to build a modular home to meet PH standards. Early in the collaborative process, it became clear the expectations on both sides did not align with each other. Cardinal was used to operating as a for-profit company that provides a service to a client with specific interests. The ecoMOD team was expecting a collaborative research lab experience, while Cardinal was looking for clear cut direction from the UVA team. Once this misalignment of expectations was identified, both sides were able to adjust and find process that worked for both sides.

Figure 4: Cardinal Homes staff members discussing the ecoMOD South project. Source: John Quale

The first serious attempt at cost estimating the project was an important moment. The team discovered that the construction budget was not sufficient. Initially the team was planning on creating four homes – two units built as an attached duplex for each of the non-profit partners. The budget for the grant, created several months before, was not based upon actual construction costs for these homes, but on what seemed to be a reasonable request given the scope of work. Since the estimate was roughly 30% over budget, the team suggested simply eliminating one of the homes. The site that People Inc. had selected in Abingdon was proving to be too narrow for the two-unit duplex, and changing to a single family detached home also made more since in that urban context. Southside Outreach was willing to change to two single family homes, and actually would have preferred that from the beginning. An upside of this significant change is that is helped to clarify the research questions. Rather than dealing with the ambiguity of townhomes, which at that stage were assumed to have SIPs construction in one home and a double wood stud wall in the other, the research team was pleased to have clarity of two PH houses homes of exactly the same construction on two separate sites, as well as a home that looks the same, but is only built to standard building cost right next door to one of them. The variables have been reduced and clarified, and the evaluation of the performance of the homes will more clearly document the advantages and disadvantages of the Passive House standard for affordable housing in the mid-Atlantic region.

1.2. ecoMOD Decision Analysis Tool (DAT)

One of the most difficult challenges of working collaboratively is making decisions. Among the individuals involved in this complex project, there are a wide variety of backgrounds, priorities and responsibilities. This topic has been a difficult challenge since the founding of the ecoMOD project in 2004. The very first ecoMOD team struggled with this issue, and developed a decision making process that involved a research database, and the use of spider diagrams to allow the team to visualize their priorities. This process helped the team to ensure that all relevant research on any individual decision was being discussed, and also helped them to set priorities when it came to selecting design strategies, building materials and technologies. These diagrams became known as “Decision Webs” among the ecoMOD teams over the years. The points of the webs were organized into six major categories: Energy, Environmental, Social, Financial, Aesthetic, and Technical. As a system of graphic representation, Decision Webs allowed for the quick appraisal of several components at once, and provided a concise statement of values to be handed to the community partner, or to the next design team if the project was stretching across semesters.

One of the unexpected benefits of using paid research assistants to help run the ecoMOD South project (rather than students in design studios and engineering seminars) is the further development of decisions webs into a much more sophisticated database and ultimately a web-based tool that can be shared with others. The ecoMOD South research team has developed an online database system to collect information on construction materials, partner surveys, design strategies and equipment, as well as a web interface that can generate diagrams to use in discussions. The tool, known as the Decision Analysis Tool and nicknamed DAT, is a graphical system which represents information, major categories, sub-categories, and scoring data in a terse radar graph format [Figure 5].

The driving goal for the development of the Decision Analysis Tool is to accumulate research on sustainable building components, and display this information in a freely accessed way. Comparable tools include the Pharos project, organized by the Healthy Building Network, which aims to increase product transparency by providing a score according to several “impact categories” to explain information to consumers, and ARUP’s SPeAR diagram, a propriety application used by ARUP consultants clarify sustainability priorities with a variety of clients. Besides the unique graphic interface that the team has developed, the DAT differs from these precedents in two major ways. First, it is a system that can be applied to any decision or situation. Already it has been used to assess the values of the different partners in the ecoMOD South project, and to evaluate complex components such as wall systems.

Figure 5: DAT diagram showing a possible wall system for ecoMOD South. Source: ecoMOD South Team

The first live use of DAT outside of ecoMOD South was for a summit of political leaders, real estate developers, engineers, state regulators, environmentalists and academics to discuss stormwater guidelines in the state of Virginia. The UVA School of Architecture’s Institute for Environmental Negotiation facilitated the summit, and used DAT in several open sessions to help the audience articulate priorities on this topic, and project the ‘votes’ for these various priorities live on a screen. The DAT diagrams helped these leaders get an immediate understanding of where they might find common ground, while also testing the versatility of the system to convey real-time survey data in a large group setting. This flexibility accounts for the second distinguishing factor: DAT is conceived to be freely-accessible without a fee. We intend to continue to build an expanding database so it could be used more broadly, but also to develop the tool so that anyone can develop their own categories and relevant sub-categories, and then define priorities.

The ecoMOD team anticipates that the tool will benefit the partners already involved in the project by providing a way to understand and record complex design decisions, while continuing to grow as a resource for sustainable construction product information and designed building components. For example, modular builder Cardinal Homes will have access to this sustainable research database, and will also have an interface for visualizing their own private research and development decisions. Southside Outreach and People Inc. will have a way to convey their goals for sustainability to interested parties and get access to design information to help develop other projects. As the database and interface grow, the targeted market could widen to include affordable housing organizations across the region, and the sustainable building community as a whole.

2.0 ecoMOD SOUTH BUILD PHASE

After months of research, design, collaborative decision-making, cost estimating and material procurement, the ecoMOD South project finally went into production in late December 2012. As of this writing, construction is not complete, but work is progressing quickly [Figure 6] – both on the modules under construction in Cardinal’s manufacturing facility, but also on the two sites, where foundations and site work are underway. Minor problems have arisen – mostly related to a couple building materials that had been selected but were mistakenly replaced with choices that are typically used by Cardinal. The communication of the desired choices has now been more thoroughly distributed to the appropriate Cardinal staff, and the ecoMOD South team has remained flexible.

Figure 6: The ecoMOD South code unit under construction at Cardinal Homes in January 2013. Source: John Quale

There has been one major problem in the construction phase so far, related to the delivery of the structural insulated panels (SIPs). One of the partners in the grant is a SIPs manufactured based in Southside. This company is the recipient of a very substantial portion of the grant funding to acquire sophisticated digital fabrication equipment to allow them to use CAD / CAM technology for routing SIPs panels. After a long delay in the final assembly of this is large system in their facility, the company was forced to meet the ecoMOD South deadline and assemble the SIPs for the project using conventional tools. The SIPs were delivered to Cardinal, but were deemed to be below the quality standard required for an efficient building envelope for a PH standard home. Rather than wait for the company to get their new equipment working, or switching to a double stud wall construction method, Cardinal recommended asking another SIPs manufacturer to build replacement SIPs. Unfortunately, the company is based in Georgia rather than Virginia, but they were able to produce excellent quality panels in a very short time. The three homes will be on their foundations by the end of March, and ready for occupation soon after.

CONCLUSION

Besides the exciting opportunity to deliver high quality homes for three affordable housing clients, the most important aspect of this project will be the results from the monitoring and post occupancy evaluations. The ecoMOD engineering team has assembled an affordable, wireless monitoring system that will gather data about local weather; indoor air temperature, humidity and quality; energy use; and building envelope heat flow with sensors in all three homes, including sensors inside the wall and roof sections of the homes. The team will also monitor a recently completed home designed and built by Southside Outreach for comparison.

One of the most interesting questions is whether is makes financial sense to build PH standard housing for affordable housing organizations in the kind of mixed climate found in the Mid-Atlantic region. PH as a formal standard has emerged from Germany and other parts of northern Europe where heat and humidity are less of an issue. Passive House Institute of the U.S. (PHIUS) is in the midst of a process of recalibrating the standard to the wide range of climates in the U.S. – a process that is likely to take several years to perfect. This project has the opportunity to contribute data for analysis to assist PHIUS with this process, but could also be an important precedent to allow affordable housing organizations, modular homebuilders and individual market-rate homeowners to understand the possible return on investment for PH standard homes in this region. We have already proven that the additional costs associated with high performance windows, doors and other components of the building envelope that achieve PH standard put the price for these homes beyond the amount considered to be accessible for affordable housing organizations in the southern part of Virginia. Yet, the ecoMOD South project has the potential to create economic development with the sale of homes to market rate homebuyers and affordable housing organizations in other parts of the state and the region. The larger question of return on investment is the next important question to answer. In addition, the ecoMOD team intends to assess the overall life cycle impact of the PH homes, comparing them to the code unit, and to a conventional home. While the grant funding will officially end with the occupation of the homes, the longer term relationships with the partners will continue to evolve, and the research questions will likely take at least two or three years to deliver preliminary answers.

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Performing Sustainability: Life Support Inside Biosphere 2's Glass Box Theater, 1991-1993

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ABSTRACT: Recently, the term Performative Architecture has been increasingly used as a pseudonym for sustainable design. In the case of Biosphere 2 (B2), performative architecture became not only a service oriented container for long-duration life support, it became the stage on which multiple sustainability narratives were played out. Perhaps unconsciously achieved by the project's architects, Phil Haws and Margaret Augustine, the functional form of B2 provided the front-of-house and back-of-house venues that propelled the operation, and the perception of sustainable life-support during Mission 1. This paper defines the troupe of performers: ecology, ecotechnics, Biospherians, scientists, tourists, and popular media, and utilizes their performances upon the B2 stage to unpack the ensuing drama of Mission 1 through the lens of this glass box theater architecture, while speculating on the value of the lessons learned for today's performative architectures.

Here, conventionally understood quantitative aspects of performative architecture link the eco-technological design and operation of B2 to qualitative humanities based frameworks of Performativity such as theater, service oriented design, and object studies. Through the case study of B2, it becomes apparent how and why these coupled quantitative/qualitative understandings are critical to the future success of performative architecture in the Anthropocene, at a time when adaptive architectural strategies for sustaining and enhancing global life support, which supplements diminishing ecosystem services during rapid climate change, are becoming more ubiquitous. Ultimately, we can utilize the performative architectural apparatus of B2 to develop a more sophisticated understanding of trans-disciplinary architectural design and its operational implications, which will ultimately facilitate the design and performance of more productive constructed eco-techno-socio environments.

KEYWORDS: performative, sustainability, Biosphere 2, ecological systems diagram, environmental ethic

1.0. MUD WRESTLING IN A GLASS HOUSE

On July 20th, 1992, in celebration of Biosphere 2's (B2) crew member Taber MacCallum's birthday, a Mud-wrestling Olympics was performed. *Terrible Taber* faced off against *Sly Wiley Coyote,* Roy Walford, from a drained rice patty, adjacent to B2's glass envelope, which had just been harvested (Walford and Rowland 2005). From inside B2, the crew participated with delight, and outside, members of Mission Control and the design team watched the performance from the south viewing plinth/walkway, faces pressed up against the glass.

> Gaie announced the start of the fight over her two-way radio and Roy leaped from the spaceframe, knocking Taber down in the gray mud. They rolled, they threw each other, they headlocked with great showmanship, until finally Taber flung Roy over his shoulder and slashed him facedown in the mud to claim his victory. It was completely staged, but the crowd went wild as the victor, dripping with watery grey mud, waved and beamed (Pointer 2009, 219-220).

Many performances of various kinds permeated Mission 1. The crew was comprised of individuals, hand selected from an independent group of *total systems ecological managers* who designed and inhabited B2. Theatrical performance was embedded within their alternative lifestyle. Prior to the advent of B2, when they were not practicing ecological restoration, they were traveling as members of a theater troupe called *The Theater of All Possibilities* performing original works (Reider 2010). Mark Nelson, one of the crew members and head of the Institute of Ecotechnics, described the dynamics of this alternative group:

> We do whatever we need to do, and play what roles we need to play, to get done what we need to get done (Pointer 2009, 237).

Performance had become a way of life for the crew, blurring lines between dreams, realities and fictions. This state of perpetual performance not only brought B2 into being, but also assisted the Biospherians in managing not only socio-cultural stresses that arose from life within the fully enclosed architecture of B2, but the ecology itself.

2.0. BIOSPHERE 2 AS BUCHNER FLASK

B2 sits outside of Oracle, Arizona, about one hour drive north of Tucson. It was designed by a trans-disciplinary group of environmental managers, architects, ecologists, engineers and visionaries eager to test the plausibility of biodiverse closed-loop polyculture life support for space exploration. Their inspiration, and ultimately the diagram of the building, came from Exobiologist Clair Folsome's ecological samples containing "… complete functional suite[s] of microbes together with [water and air]…inside a closed laboratory flask…" (Allen 1990). Resulting in a 3.15 acre spaceframe megastructure that operated as an ecotechnical instrument "…for materializing anthropocentric/anthropogenic change on an ecosystemic scale" (Luke 1997, 113), it operated as the tightest envelope ever built, exchanging only ten percent of its atmosphere with earth's annually (Dempster 1999). The surrounding complex of engineered architectures included B2, two redundant *Lung* structures that mitigated air-pressure, a power generation station, quarantine and lab facilities, and an external Mission Control.

B2 operated as a materially closed but energetically open system, analogous to the earth and sun. The above ground *biosphere* consisted of rainforest, wetland, ocean, savannah, and desert wildernesses, agricultural, and human habitat/mini-city *biomes*, enclosed in glass to ensure maximum solar exposure, and a basement *technosphere* (Pointer 2009). Sandwiched between them was a carefully controlled photosynthetic datum of soil, water, nutrients and life, penetrated by mechanical and digital systems sensing and servicing it from below. This datum cycled atoms through augmented ecosystem service provisioning landscapes.

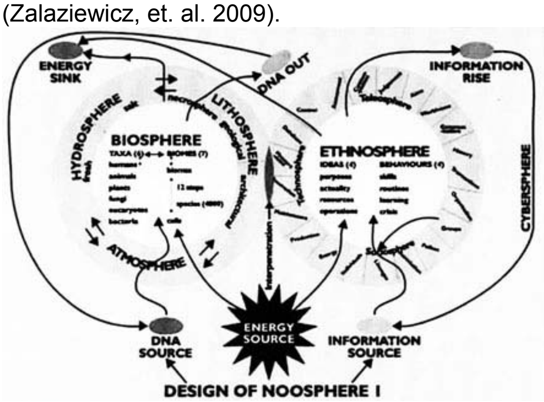
B2 was the ultimate embodiment of ecology, the perfect expression of the word's etymology: the study of the house. In this case, the house was designed as a performative model of planet earth, scaled down by a factor of 23.3 million. A systems infrastructure, in productive tension between scales of planet, mega-structure, humans, and microorganisms that required the creation of unprecedented technologies for its operation: energy powered hybrid electronic/mechanical/biological feedback infrastructures, serviced by humans, which manufactured and regulated carbon, oxygen, water, and nutrient cycles necessary for human survival. B2 demanded the development of some of the most sophisticated hybrid digital/environmental control systems and synthetic ecologies of the time in order to intensify earth systems processes that typically perform invisibly in space and time. Through the design, construction and operation of these, invisible processes, such as carbon dioxide residence times, which accelerated to a maximum of ten days inside B2 (Cronise, Noever and Brittain 1996), were revealed and aggressively manipulated. These invisible processes took the forms of eco-technological constructions, sensing and surveillance equipment, and management protocols and regimes.

2.1. A Culture of Ecological Performance: Noösphere

Long before B2, the Biospherians utilized a holistic, service oriented approach to restore diverse degraded landscapes they amassed across the globe. They took inspiration from geochemist Vladimir I. Vernadsky's biogeochemical theories of the *biosphere*. Vernadsky defined *biosphere* and *noösphere* as the two *spheres,* or systems of influence, that affect the qualities and performance of life on the earth's surface. He describes the *biosphere* "…as the domain of life on Earth [that] is a *biogeochemical* evolving system…" (Grinevald 1998, 26), and the *noösphere* as

> …a new geological phenomenon… [where] Man becomes a great geological force for the first time. He can and must reconstruct the realm of his life with his work and mind." (Vernadsky 2007, 415).

In 1944 Vernadsky outlined *noösphere*, an ecological ethic that the Biospherians modeled themselves after (Fig. 1), which resembles the recent definition of the emerging geologic age of the Anthropocene (Zalaziewicz, et. al. 2009).



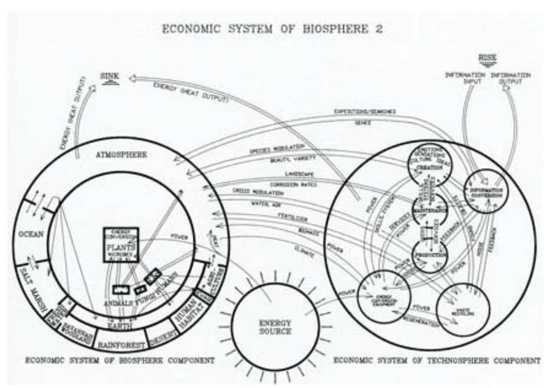


Figure 1: Noösphere of B2. Source: (Me and the Biospheres, 2009)

Figure 2: Economic System of Biosphere 2: Biosphere and Technosphere. Source: (U of A B2 Archives, 1987)

The Biospherians utilized Vernadsky's writings on the *biosphere* and *noösphere* to structure their understanding of the relationships between earth patterns and processes, and the evolution of human ethics. They added a third *sphere*, the *technosphere,* in order to specify the mechanism of human action and agency that can create the *noösphere* from the *biosphere* (Allen 2003). This duality of *biosphere* and *technosphere* was utilized to generate their own ecological systems diagrams which they employed in the design of the eco-technical architectural systems of B2 (Fig. 2). Thus, the ultimate goal of B2 was the creation of a *noösphere* prototype, an enlightened ecologically driven society that would

> …produce understandings to assist in the creation of a transformative culture where Homo sapiens become creative collaborators with ecological earth systems…[to]…create living art forms that champion life and space exploration (Allen and Nelson 1989, 55);

a synergistic blend of the quantitative sciences with the qualitative humanities that resulted in an ecotopia experienced through the coordinated performance of technology, ecology and ethics.

2.2. Scripting the Invisible

The creation of ecological system diagrams that communicated flows, behaviors and quantities comprised the pre-schematic programming phase of B2's design. Systems diagrams identified the performative relationships and constituents (the script and cast of characters) necessary to construct B2's operation. But these diagrams are not easily deployable design tools because they lack of spatial explicitness. Their

> …boundary and network structures are topological and functional duals of each other. The boundaries define a space of containers and places (the traditional domain of architecture), while the networks establish a space of links and flows" (Mitchell 2003, 7).

The Biospherians, with their interdisciplinary team of expert scientists and engineers, manifest the design of B2 by translating and mapping their systems diagrams into adjacencies and scales of space, built form, building control systems, and biotic habitats. These diagrams manifested a top-down operational space of known quantities which theoretically would operate as a seamless choreography of *biosphere*, *technosphere,* and *noösphere* idealized by the Biospherians. However, throughout the design process, tension between *top-down* and *bottom-up* control heightened as designers brought multiple disciplinary understandings of ecological performance into the mix.

The highly quantifiable *systems* approach facilitated schematic design, despite the fact that it favored a "technological and scientific view of *nature* and *humans* at the expense of wider social and cultural values" (Anker 2010, 127-8). This scientific view ignored the Biospherians humanist bent. This bias was continually reasserted via calculated relationships between human beings' survival requirements and the earth's biophysical carrying capacities (Luke 1997). Ultimately, it was facilitated by B2's *Nerve* monitoring and communications system. Within the *Nerve's* operation humans were

> …reduced to differentiable but integral engineering functions. Caught in the grids of scientific surveillance, the ecological interface of human organisms and biological environments [were] transformed into technological design criteria…" (Luke 1997, 103).

The Biospherians were able to reconcile their place within the larger system, in part, because they understood the ecological performance of B2 as a dramatic play, within which they each would perform their scripted role, as they had done in their Theater of All Possibilities productions.

They simultaneously anticipated that the performance of their script would be subject to massive change as the ecological systems of B2 struggled to mature and ultimately find equilibrium. In this way, they would be living in a highly uncertain post-normal science constructed environment (Kay 2008), in dynamic tension between recitation and improv. They looked to Zoologist G. Evelyn Hutchinson writings, particularly his book *The Ecological Theater and the Evolutionary Play* for insights into how to manage the ecosystem recalibration that would begin upon enclosure. They anticipated massive extinctions, and ultimately endured significant hardships to prevent their own, in order to prevent a premature termination of their mission.

2.3. Performing the Invisible

The first experiment, Mission 1, began at 8:00 am on September 26, 1991. Eight people were sealed inside this 5.15 acre biotectural mega-structure, commencing the two year and twenty minute (Pointer 2009) ecological theater performance. Once inside, the Biopsherians began to experience the ecological systems script, how it drove ecosystem service performance, and facilitated management decision making. It troubleshot feedbacks, ensured redundancies, and facilitated trans-disciplinary communication. Most importantly, it checked and balanced energy-matter exchanges. The photosynthetic *biosphere* surface required significant energy inputs, unnecessary on earth-scale, to maintain functionality. Because the biomes were enclosed in glass, heat gain was a significant problem. Massive inputs of energy were required to cool the structure to prevent flora mortality and ensure photosynthesis functionality. Energy was also necessary to power basic building usage, environmental control systems (including rain and ocean wave-making), hybrid eco-technical systems that provisioned life-support services, and the *Nerve* communications system that monitored and facilitated the entire system. The systems diagram feedback loops kept the

Biospherians inside alive. Because of this, much time was spent within B2, and Mission Control, crunching numbers and balancing budgets.

Simultaneously, reports from inside B2 glorified the qualitative, haptic experience of the ecological systems diagram. Biospherian Jane Poynter described it as:

> "… technically beautiful, with the mechanical and life systems working in concert to maintain a functioning biosphere…it seemed that technology and humans had found their rightful place, working hand in hand to maintain and enhance life…" (Pointer 2009, 139).

Indeed the idealized stable systems diagrams that facilitated the design, construction, and operation of B2 functioned, at times, as an overarching synergetic "…logic of Bios (bio-logic, biology)…uniting the organic and the mechanical" (Kelly 1994, 165), the quantitative and qualitative. Ultimately, this resulted in a Biospherian experience of embodied cognition of their *biosphere*, creating an operational consciousness of their "Molecule Economy" (Kelly 1994, 159) and actualizing a version of *Noösphere* in the process:

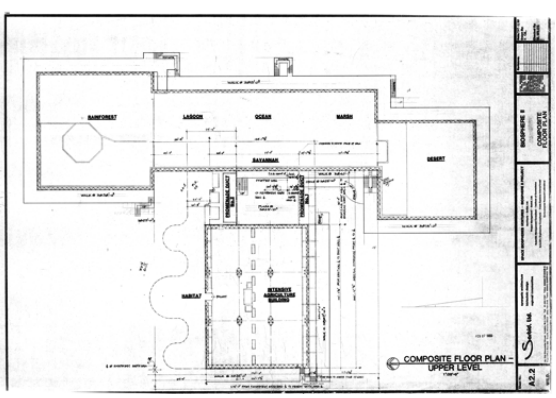
> "… [We] reveled in the experience of being consciously a part of the day-to-day biospheric cycle. As [we] stood in the grass, [we] knew [we were] breathing the oxygen the plants produced and they were absorbing [our] carbon dioxide…Our relationship with the other living organisms in our Biosphere was equally symbiotic. While it seemed we held dominion over them by our ability to turn the rain on and off and rip out unwanted plants, our lives depended on them…We were in fact on equal footing…experience[ing]…a direct connection to [our] life support system…" (Pointer 2009, 291-2).

It was through this embodied experience that invisible earth systems processes became visible and tangible, and moments of *noösphere* were actualized. This message was regularly relayed through teleconference calls to school children, interactions with tourists, media relations, and scientific symposia during Mission 1.

3.0. BIOSPHERE 2 AS GLASS BOX THEATRE

B2 was essentially designed from the inside out. Much preliminary design work was focused on structuring the internal ecotechnical systems, and ensuring that there would be enough daylight penetration to support photosynthesis. The project architects, Phil Hawes and Margaret Augustine, looked to multiple global architectures to inform B2's form, but ultimately performance inside the envelope dictated the project's parameters. B2 quickly evolved into a spaceframe structure that could support the uninterrupted longspans and glass envelope necessary for the biota inside. Ultimately, the image of the form of the building itself evolved into not only a brand, and symbol for the operations within, but also a physical stage set for tourists to view the Biospherians inside. Because of its form, B2 operated as a glass house, the ultimate glass theater for the *Theater of All Possibilities*. Only the Human Habitat biome was clad in opaque material. Programmatic elements inside this *back-of-house* biome included a Magic/Wardrobe room stocked with fabric and sewing machines, an Art studio stocked with materials, and a Media suite, further reinforcing the projects theatrical undercurrents.

As the programmatic needs of the site developed, the design focus flipped to the spaces surrounding B2's envelope: accommodations for visiting scientists, educational facilities, and tourist attractions. Viewing platforms and pathways almost completely wrapped B2's transparent skin (Fig. 3), and visitor centers with outdoor amphitheater spaces were designed (Fig. 4). In 1990 the surrounding land was master planned to include an 18 hole golf course and convention resort, all of which were designed to educate and entertain.



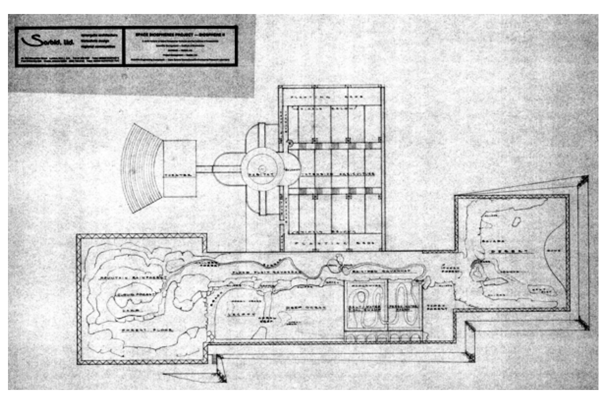


Figure 3: Plan of B2, see exterior viewing plinth/walkway surrounding much of the structure. Source: (U of A B2 Archives, 1990)

Figure 4: Schematic B2 plan, see outdoor amphitheatre on upper left, on axis and across from entrance/Human Habitat. Source: (U of A B2 Archives, 1988)

3.1. Locating Front and Back of House

The project designers had some awareness of the implications for the residents of the emerging glass house they were creating. In response, there were private zones designed into B2 wilderness biomes, such as the rainforest Cloud Mountain, which included a small waterfall and watering hole called Tiger Pond that was used extensively for skinny dipping. And as the rainforest and mangrove tree canopies matured, it became easier to *disappear* into the forest. But for a group of environmental managers who were accustomed to having free reign over large tracks of land, the surveillance through the glass, and the cameras and sensor systems inside, proved tiresome. Their duties did require spending significant amounts of time working in back of house spaces such as the basement *technosphere*, communication bridge, labs, and their living quarters. Nonetheless, they quickly found they were living their roles as Biospherians full time, and that these roles were becoming increasingly complex as the audiences grew more diverse and sophisticated.

3.2. Playing to Multiple Audiences Simultaneously

These audiences radiated out from the B2 building in concentric circles. The innermost was the eight Biopsherians playing to each other. They cooked for one another, played music together, created performance art, and celebrated birthdays and other events with elaborate themed costume feasts. Roy Walford and Lazer Thillo made documentary films, and Roy shot a performance art music video titled *Ecological Thing* (Walford and Rowland 2005).

They also played to the Biosphere itself and to Mission Control through the performance of scripted protocols, in order to keep B2 operating. Eventually, this scripting functionally reprogrammed the eight Biospherians of Mission 1 as "…spatially extended cyborg[s]" (Mitchell 2003, 39) which were seamlessly dissolved into the operational body of B2, despite their rebellious attempts to resist. Similar phenomenon have been observed on early space missions. Historian Walter McDougall described NASA's space age treatment of astronauts as an "individualism…subsumed into the rationality of systems" (McDougall 1997, 449). Astronauts' bodies, similar to those of the Biospherians, were eminently at risk, yet they surrendered much of their control, autonomy, and ultimately privacy to Mission Control, who was tasked with managing the system. In the case of B2, the Biospherians bodies were physically extended and simultaneously emotionally reduced to extensions of the *Nerve*.

Once sealed inside, the Biospherians gentle rebellion began: during their first non-regulation mission they dismantled several surveillance video cameras (Arrington 2011). Soon after, they agreed to take days of rest from response to relentless system alarms and mission control video-conferencing. They quickly realized, barring sudden major mechanical failure, the *biosphere* would survive without their management for 24 hours per week. Nonetheless, the Nerve Center was not only their savior and master, it was also increasingly becoming an appendage. They were physiologically merging with it as they were physically merging with the "natural" system of molecule exchange which fed them oxygen, calories and nutrients. Their bodies mirrored the sensors, transducers and actuators of their augmented reality, each picking up on the phenomena, and labor, the other wasn't designed for. They were literally becoming one with the *technosphere*, rendering themselves spatially dispersed cyborgs. B2 became

> …not only the domain of [their] networked cognitive system, but also—and crucially—the spatial and material embodiment of that system (Mitchell 2003, 19)

rendering the less idyllic realities of life inside ecotopia visible.

Given their diminishing oxygen and food resources the Biospherians' physical bodies were taxed to the limit. Increasingly they needed rest and psychological recuperation time. As Mission Control increasingly assumed responsibility for function inside B2, the Biospherians perceived they were losing control of their life support system, as "the Mission Control support team perform[ed] maintenance and control[led] changes from outside Biosphere 2" (Allen and Nelson 1999, 24). One of the more dramatic examples was the removal of the analytical lab from the facility a little over a year after closure. Less visibly and more invasively, Mission Control monitored the Biospherians e-mail and tapped all phone lines inside B2 (Pointer 2009).

The next concentric ring of audience was comprised of visitors to the site. Scientists, tourists, and the media came to glimpse and interact with the Biopsherians through the architectural glass. One product of the reality of transparent enclosure was the Biospherian handshake, the lining-up of palms on either side of the glass pane (Fig. 5). Another was a growing confusion between the relationship of actor and audience. At times, the Biopsherians appeared more as a captive audience through the glass than as the actors they were trained as (Fig. 6). There were times when Mission Control brought performances to them, such as the first anniversary of enclosure when a country band serenaded them and there was a simultaneous cake cutting on both sides of the glass (Walford and Rowland 2005).

Figure 5: Biospherian Handshake: Mark Nelson, John Allen, Visitor. Source: (Life Under Glass, 1993)
Figure 6: Biospherians of Mission 1 looking through the viewing window at Closure. Source: (U of A B2 Archives, 1991)

Beyond that was the audience of the Space Biosphere Ventrues (SBV) Scientific Advisory Committee (SAC). This audience was grappling with the scientific legitimacy of the B2 experiment; attempting to lend it credibility among the intellectual scientific community. The SAC was an interactive audience attempting to restructure experiments within B2 while simultaneously restructuring perception outside of B2 (Pointer 2009).

Next was the media, who initially responded overwhelmingly favorably to the Biospherians' project. But as word got out about their alternative society, and questions arose about the scientific validity of the project, the tables turned and the media utilized B2 as an almost endless source of dramatic entertainment. The more the Biospherians attempted to play to the media, seemingly the worse the situation became (Reider 2010). The final concentric ring of audience consisted of the general public who watched the project predominantly through the eyes of the media. The Biospherians ultimately were unsuccessful in maintaining control of the content of this performance.

3.3. Which Performance?

Because of the nested complexity of the performer/audience relationships that the Biospherians maintained, it proved difficult at times to keep the roles separate and hierarchized. Among these, the performance of work, particularly hard manual labor necessary for maintaining life support, was eminently present. Maintenance of the digital and mechanical components within B2 was endless at the points where its sensors caressed the *biosphere*. This work could only be accomplished from inside. It consumed approximately ten percent of the Biospherians time (Allen and Nelson 1999), time increasingly needed for agricultural production. The Biospherians were steadily being reduced to manual laborers in service of the *Nerve* and its shifting hierarchy of control. Even as the technology facilitated the shifting power dynamic, "nature" was challenging the technology, creating a positive feedback loop resulting in even more manual labor:

> The sensors for temperature, humidity, light, energy, gas concentrations, water quality, and soil conditions were industrial grade. Although they were seal-tight terminal boxes and conduits covered with silicone, the most difficult problem was corrosion of electronic equipment because of humidity or the use of dissimilar metals. Most of the maintenance hours were spent on the data acquisition system, calibrating and replacing corroded sensors or terminals (Pointer 2009, 24-5).

As agents in the mechanical mastery of B2's Gaia body, and by implication their own bodies, the Biospherians obeyed orders from their Nerve like slaves: when carbon dioxide levels skyrocketed, they harvested biomass by hand, and dried it to halt decomposition (Pointer 2009). They played simultaneous conflicting roles in their experiment: ecologists, naturalists, gardeners, explorers, prisoners, guinea pigs, gods, laborers, survivors. They acted as gods when determining the change of seasons, and with the push of a *rain button* they accomplished their will (Pointer 2009). They were simultaneously objects and subjects of experimentation and study. As an embodied script within the systems diagram they became embodied systems of control: they *managed* the system that was managing them, playing to an audience that was playing right back at them through feedback loops.

3.4. Performing Survival as Cyborg

Because the ecologies were synthetic and immature, and their behavior triggers poorly understood, the overarching bio-logic feedbacks facilitated by the communication *Nerve,* and augmented by redundancy, were critical for life support within B2. As these synthetic ecologies were increasingly understood as experiments, not guarantees of life support,

> "surrendering control became one of the 'Principles of Synthetic Ecology...We ha[d] to accept the fact that the amount of information contained in an ecosystem far exceeds the amount contained in our heads. We

> …[would] fail if we only tr[ied] things we [could] control and understand.’ The exact details of an emerging Bio2 ecology…were beyond predicting” (Kelly 1994, 165)

Sniffer sensors detected patterns of molecule concentrations not apparent to human bodies, cameras detected movements, environmental control equipment reported its own usage, all of which were communicated as messages (Wiener 1956) to the Biospherians, and to Mission Control through *The Nerve*.

The Nerve facilitated ecological production under challenging conditions, but the technical and ecological systems proved mediocre partners without human mediation. Growing plants and salinity would regularly damage sensors (Alling and Nelson 1993), computer programs were too slow and didn’t correspond to social rhythms or sick days. On average, Biospherians spent up to twenty-one percent of their time tending their technological control system, (performing sample and data collection, sensor repair/calibration, infrastructure maintenance, and technical tasks), in comparison to eleven percent on wilderness biome management (Allen and Nelson 1999).

> Every valve, every pipe, and every motor of the infrastructure was simulated in a software network. Very little activity in the ark, either natural or man-made, happened without the distributed computer knowing about it. Bio2 responded as if it was one beast (Kelly 1994, 162).

One beast that carried within it the power to transform itself through surveillance feedback loops. *The Nerve’s* sensors, transducers, and actuators became real-time decision making devices as they managed the range of tolerances acceptable to human and biome environmental conditions. Because the Biospherians had been scripted into this set of protocols, their performances were predetermined, offering little room for creativity or inspiration, until the system threw them a curve ball, at which time they were forced into an emergency improvisational mode. This proved to generate a stressful version of *noösphere* for the Biospherians.

4.0. THE PERFORMANCE OF SUSTAINABILITY

4.1. Post-Normal Science at Play

Today’s Sustainability Revolution, often defined by the 3E’s (ecology, economy, equity) might be more productively redefined for designers as the performance between *biosphere*, *technosphere* and *noösphere.* Like the Biospherians, we currently struggle with the post-normal scientific conditions of elevated atmospheric carbon levels, increased toxicity, loss of biodiversity, and declining health of basic regulating and provisioning ecosystem services (MEA 2005). These require increasing deployment of complex management and adaptation strategies to maintain human homeostasis conditions globally, a task with which architecture is already deeply implicated. We are already seeing comprehensively service oriented and managed projects like Masdar City come online. Like B2, Masdar was designed from a series of systems diagrams, and forces its occupants to leave the outside world at the gates (read as *system boundary*) by leaving their normative consumptive behaviors, including their carbon spewing vehicles, parked outside. We are also keenly aware that curbing downstream energy consumption within buildings requires first and foremost, reductions in consumption patterns, only then followed by increases in the efficiency of equipment, and finally utilization of alternative energy sources (Addington 2007). Reduction in consumption is primarily reliant on *occupant/user performance, not technological performance*. The implications of B2’s scripting of human performance, and the lessons learned from the Biospherians experience of object-subject control, are now becoming urgent.

Given this context, it is logical to assume that a performative ethic that encourages more consciously considered actions and deeper relationships between *biosphere*, *technosphere* and *noösphere* would prove beneficial. However, these relationships and actions must be carefully designed into the constructed environment in order to be effective. As we have seen in the case of Mission 1, despite this considered design, the unintended consequences of synthetic ecological architectural top-down systems of control can be devastating. B2 demonstrates how these unanticipated products of entwined relationships between atoms, bits and humans reveal contradictory dynamics of power and control, which have dramatic implications for people, and therefore, the future success of the complex integrated biotectural sustainable life support systems increasingly needed to mitigate and adapt to global climate change.

As architects it behooves us to take valuable lessons from B2: understandings of how to better address weak points of contact between seamless bio-technological infrastructures, methodologies of discerning the deployment of top-down (authoring) vs. bottom-up (adaptation) design approaches, and ways to link scales and durations (human brain-body to Gaia-body) within resilient architectures. Through an examination of the eco-architectural forms that embody these lessons, and their deployment within the B2-body, we extract critical lessons for the creation of future *noöspheres*, take them back to the drawing board, and iterate again. Today, we are increasingly tasked with the mission of creating eco-technical net-zero theatres within which we can all perform. Twenty years after the conclusion of Mission 1, it is imperative that our discipline recognize how essential it is to engage deep practices of research, exploratory design, and post-occupancy analysis in order to mitigate the risk of perpetuating post-industrial paradigms to the point of collapse. A leap into the blurred quantitative/qualitative space of performance, where fictions, realities and dreams propel vision into actualization, may be just the space that facilitates the creation of future resilient and performative architectures of *global sustainable possibility*: ecotopic or distopic *noöspheres*.

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"A New Norris House”: Making Criteria for Sustainable Landscapes Visible

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ABSTRACT: *A New Norris House* is an award-winning, university-led design|build|evaluate project located in Norris, Tennessee. Norris is a model community constructed in 1933 by the Tennessee Valley Authority as part of the Norris Dam construction project. A key component of this New Deal village was the Norris House, a series of homes built for modern, efficient living.

A New Norris House commemorates the 75th anniversary of the Norris Project and seizes the opportunity to reconsider the shape of landscapes, communities and homes today. A LEED for Homes Platinum project, the *New Norris House* pursues complimentary performance and design intentions where water systems provide greater independence from the central grid. This paper focuses on the project as a case study for sustainable water systems and the designed landscapes of which they are a part. Design goals include: collecting, treating and re-using rainwater; infiltrating greywater on site; and managing 100% of run-off and stormwater on the project site.

An evaluation and residency program is ongoing. One year of collected water quality and quantity data prove we are able to collect, treat, and provide water that 01) is safe for human contact by EPA human health criteria, 02) meets drinking water standards, and 03) is sufficient in quantity to meet 30% of a two-person household’s needs. Preliminary data indicates safe and effective greywater infiltration. This paper describes these and other results of the water monitoring program.

Underlying the town of Norris’ picturesque vernacular landscape is a history of progressive planning and design. *A New Norris House* provides a unique case study for once again making visible the powerful union of environmental, technological and social forces.

KEYWORDS: Sustainable Landscape, Greywater, Rainwater, Stormwater Management, Water

Figure 1: NNH as seen from street (left); View of greywater and rainwater infiltration bed. Bags are planted with native grasses that will eventually grow to conceal the terrace structure (right). Source: Valerie Friedmann 2012

1.0 A NEW NORRIS HOUSE – A CASE STUDY

1.1 Project Team

A New Norris House (NNH) is an educational, research and outreach project by the University of Tennessee Knoxville (UTK). Initiated by the School of Architecture and Planning department, the project engages faculty and students from the College of Engineering and the Environmental Studies and Biosystems Engineering and Soil Science departments. The team designed and constructed the home and landscape, partnering with Clayton Homes, Inc. on the prefabricated shell. The LEED for Homes Platinum project received awards for design, pedagogy, and environmental performance, including the EPA P3 Award, the NCARB Prize for the Creative Integration of Research and Practice, the ACSA Design|Build Award, a RADA Merit Award, and an AIA Gulf States Award of Merit. An evaluation and residency phase is ongoing.

1.2 Project history

A NNH was inspired by the town of Norris and the 75th anniversary of the Tennessee Valley Authority (TVA).The TVA is a federal corporation formed to manage the region's development and resources during the Great Depression. The TVA was a technological and social experiment. President Roosevelt declared:

> *The work proceeds along two lines, both of which are intimately connected - the physical land and water and soil end of it, and the human side of it…* (Van West 2001, 212)

In 1930, few rural households in the valley had running water or electricity. Norris Dam, the first in a series of TVA hydroelectric dams, was built to generate electricity and prevent flooding and erosion. As part of the Norris Project, the TVA designed and built a model town, Norris, one of the nation's first planned communities. Municipal electricity, water and sanitary systems served the town, including all residences. A key feature of this New Deal village is the original "Norris House," a series of experimental cottages. The TVA program produced vernacular and traditional home designs that incorporated innovative building materials and equipment, as well as construction means and methods. Design, cost and performance were studied and recorded by the TVA with the goal of appropriate and broad adoption of in future housing.

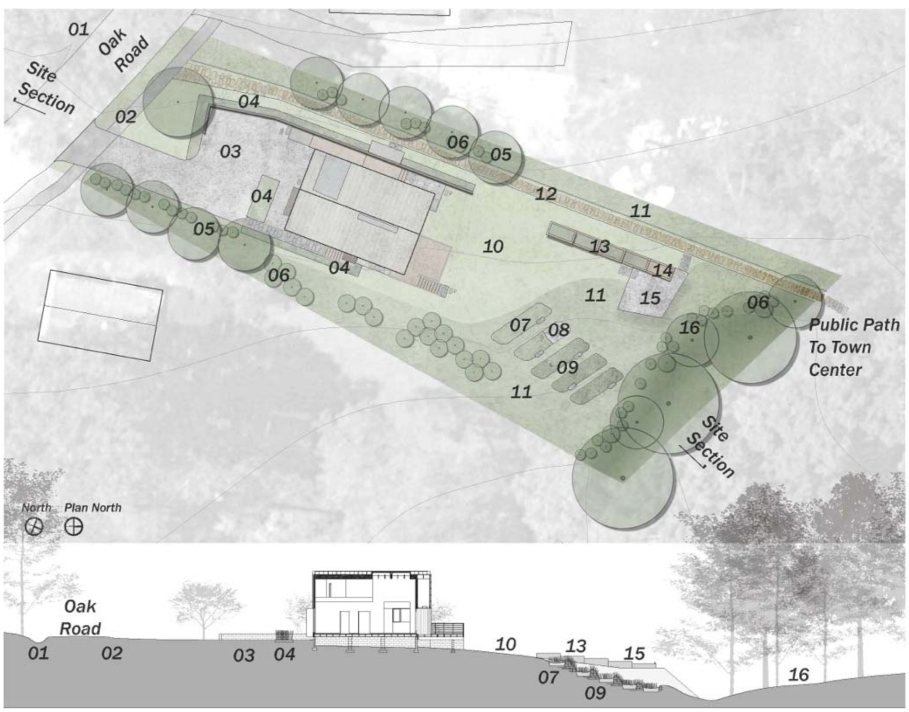

Figure 2: Site Plan and Section. 01 Existing Swale; 02 Sidewalk; 03 Parking Court/Site of Original Demolished Home; 04 Perennial Bed; 05 Small Native Trees; 06 Native Shrubs; 07 Greywater Treatment Bed; 08 Forebay/Rainwater Inlet; 09 Rainwater Infiltration Beds; 10 Drought Tolerant Turf; 11 Native Grass Meadow; 12 Crab Orchard Stone Community Path; 13 Raised Vegetable Beds; 14 Irrigation Cistern Enclosure/Hand Pump; 15 Gravel Patio and Fire Pit; 16 Existing Swale/Forest.

1.3 A New Norris House

A NNH is a single-family home (1,006ft^2) sited on a previously developed infill lot (.25 acre). As with the original Norris designs, the NNH is compact, carefully sited, and incorporates new building materials, techniques and technologies. The project goes beyond creation of a model home; realization required reforming perceptions and constraints that limit green development, such as home size and water regulations. The project emphasizes resource conservation and energy conscious design strategies. A gravel court marks the previous home's footprint and a public path leading to the town center was reconstituted on the site. Vegetable beds, a gravel plinth and fire pit, native grass meadow, and terraced infiltration beds are sited to fit the compact lot, prevent erosion, and provide outdoor living space.

1.4 Evaluation and residency phase

Projections of water and energy use are currently being evaluated against actual data collected during a two-year residency and post-occupancy evaluation. Residents support continuing education through blogs and tours, and their occupancy patterns are monitored using digital sensors. Collected data includes overall and specific energy use, temperatures and humidity, rainfall and water use, solar radiance, and water quality. This paper evaluates data collected during the first year of rainwater harvesting and treatment, greywater infiltration, and stormwater management.

2.0 RAINWATER HARVESTING AND TREATMENT

2.1 Objectives and outcomes: treated water quality

Water goals at the NNH begin with questions surrounding the appropriate balance between public and private services as they relate to safe, convenient, efficient and environmentally responsible water use. Rainwater from the roof is collected and treated for use in the house and landscape. Laboratory results show that rainwater stored and treated at NNH is safe for human contact under EPA Human Health Criteria.

Water quality of collected samples is tested at two laboratories - a state certified drinking water laboratory and a UTK laboratory. Samples are collected monthly for analysis in the UTK laboratory and quarterly for analysis in the certified laboratory. Two event-based sets of samples are tested by the certified laboratory to study summer/winter extremes. Samples are tested for 24 potential contaminants determined by the NNH team with guidance from the Tennessee Department of Environment and Conservation (TDEC) and results are compared with EPA Maximum Contaminant Levels (MCL) for drinking water (US EPA 2012).[1] To date, samples of treated rainwater collected from the NNH meet EPA regulated, secondary regulated, and non-regulated drinking water standards (Figure 3); however, TDEC restricts use of treated rainwater to non-human consumption uses. NNH permitted uses include clothes washing, toilet flushing, and landscape uses.

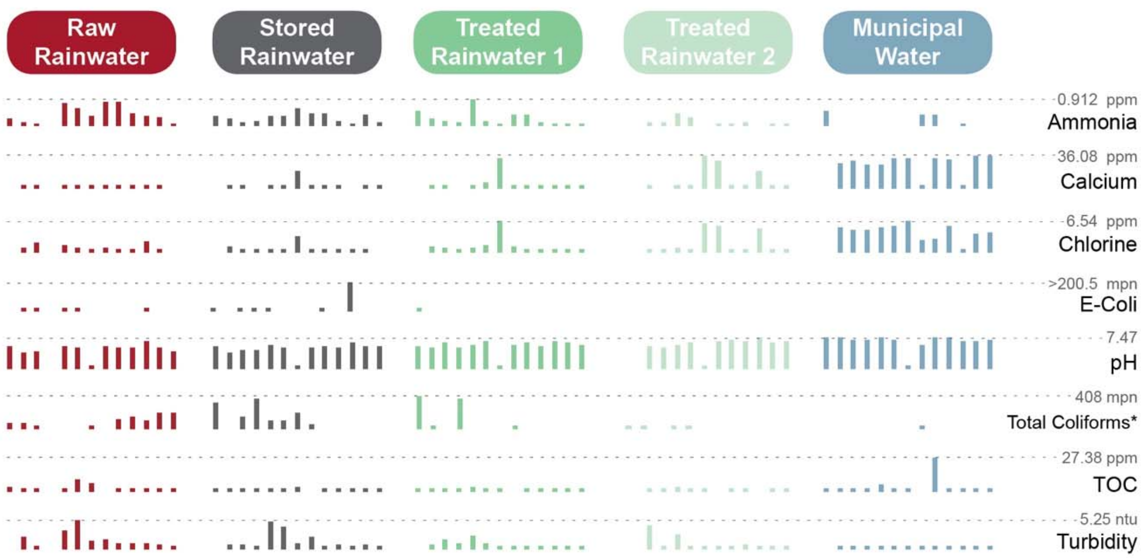

Figure 3: Results of 12 monthly UTK lab tests performed December 2011 – November 2012. Treated Rainwater 1 is sampled from a port in the cistern room installed February 2012. Treated Rainwater 2 is sampled from an exterior hose bibb. December 2011 positive result for e-coli in Treated Rainwater 1 is due to decomposing matter in exterior hose bibb. Four quarterly and one event-based state-certified water laboratory tests produced similar results. A full list of contaminants tested and associated EPA MCL is available at the conclusion of this paper.[1] *Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present.

2.2 Methodologies: treated rainwater quality

One "set" of water quality test samples is comprised of one sample taken from five locations: 1) raw rainwater collected from the gutter at the southwest corner of the house; 2) untreated rainwater collected from a port in the cistern 14" above the bottom; 3) treated rainwater collected from a port in the cistern room, just before the supply enters the house; 4) treated rainwater collected from the east hose bibb; and 5) city water sampled from the bathroom lavatory for comparison. A research assistant collects samples in vials (sterile vials for bacteriological tests) provided by each lab for testing. Care is taken to avoid contaminating water samples during collection, including the wearing of sterile gloves, removing faucet aerators, and allowing water to flow approximately five minutes before sampling. Water is allowed to flow into the vial at an angle to reduce aeration, per EPA-817-R-08-003 *Sampling Guidance for Unknown Contaminants in Drinking Water* (US EPA 2008). Collected samples are stored in a refrigerator or on ice in a cooler and delivered to the lab within 30 hours from the time of collection. Both the UTK lab and state certified water lab use the Enzyme Substrate Coliform Test (SM 9223, B.) to determine the presence of coliforms and/or E-coli. This test is approved by the U.S. EPA and is included in the EPA *Standard Methods for Examination of Water and Wastewater* (US EPA 2008).

Water quality tests are augmented by interviews with residents. The residents noted that treated rainwater did not look different than municipal water supply but did smell slightly different; the "earthy" smell did not bother them, however. Clothing washed in treated rainwater did not differ from their experience with clothing washed in city-supplied water. During one period, residents observed a further change in the smell of treated rainwater. The smell occurred when a filter in the treatment system was overdue for replacement. The residents received an operations manual but the team addressed most maintenance.

2.3 Objectives and outcomes: water quantity

The rainwater treatment system provides an average of approximately 800 gallons of treated rainwater every month for use in the home and hose bibbs. On average, 2,000 gallons of rainfall falls on the NNH roof ***each*** month; or, just over 25,000 gallons of total rainfall in year one. In year one, nearly 10,000 gallons of treated rainwater was used in the home.

A 0.5" rain event will fill the cistern, thus rainfall events regularly exceed cistern storage capacity. When the 400 gallons cistern reaches capacity, it overflows and diverts untreated rainwater to a 200 gallon cistern for vegetable garden irrigation. If capacity in the second cistern is exceeded, rainwater from this tank overflows to four terraced rain gardens for infiltration. (See section 4.0 Stormwater management.)

2.4 Methodologies: treated water quantity

Water-use volumes are digitally recorded at 15 minute intervals using a Campbell Scientific Datalogger system and digital flow-meters. Recorded water uses include: a) total volume of city water used; b) volume of city makeup water supplied to the cistern when emptied; c) total water volume pulled from the cistern; and d) total volume of hot water use. Other relevant measurements include calculated volumes based on measured values, total rainfall, and electricity used by the cistern pump and the clothes washer. (Figure 4)

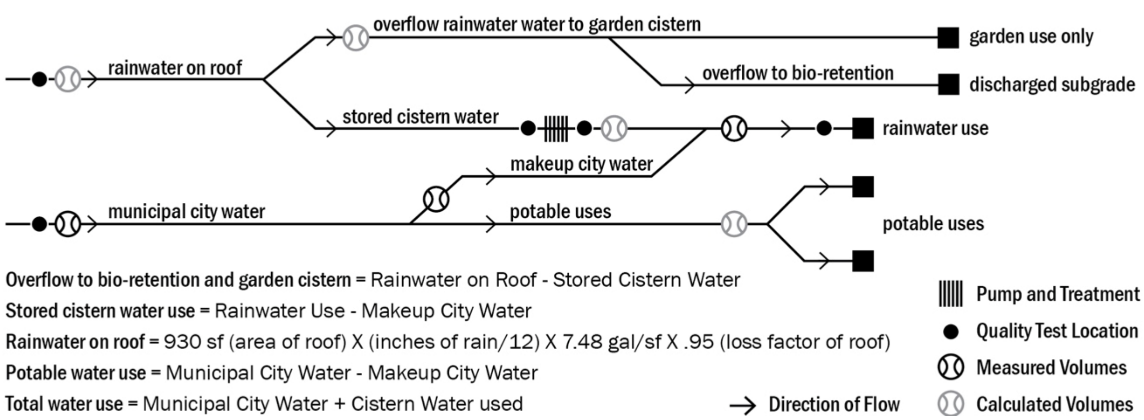

Figure 4: Schematic view of water supply system and categories for monitoring quantities.

Residents' shared their consciousness of water use in blog posts on the project website, for example:

> *After being in the house for a few months, I found myself looking forward to rain, knowing it would keep the cistern full and provide water inside. Before living in the house, I hadn't given any thought to repurposing rainwater; the firsthand experience of being able to reuse [rain]water has made me more mindful about how much fresh water I use daily.* (Leverance, 2012)

2.5 Design description and criteria: rainwater harvesting and treatment system

The team specified low-flow fixtures to reduce water consumption, then developed a water budget and researched codes. State and local codes currently prohibit treated rainwater use in the home; and the equipment supplier does not guarantee its system will produce potable water. The team thus obtained variances for use of treated rainwater solely for toilet flushing, clothes washing and exterior hose bibbs.

An insulated, at-grade equipment room accessed from the exterior houses the primary 400 gallon, plastic cistern. PVC piping concealed in a soffit connects gutters to the cistern. The first flush of rainwater containing loose contaminants from the roof is diverted before entering the cistern. A simple ball float allows subsequent rainwater to pass through a strainer box and enter the cistern. On demand, stored rainwater is pumped through the treatment assembly. In series, this includes: a 100 micron Y strainer; a 10 micron filter; 0.5 micron carbon block filter; and an ultraviolet lamp. Pressurized, treated rainwater (12 gallons) is stored in a hydro-pneumatic tank to minimize pump use. If the primary rainwater cistern is empty, make-up water from the city is automatically supplied. Make-up water supply avoids cross-connections with an air gap. The rainwater system can be turned off and residents can rely on solely city supply water to meet their needs.

2.6 Lessons learned

The team worked with the city manager and city water board on revising code ordinances to allow treated rainwater use. The process took 1 year and 6 months and resulted in a permit that expires at the end of the study (though results could extend the permit). The process, and length of time required - along with the the prestige of the university, the organization of the study program, and the study's limited scope (no human consumption) - developed trust and assurance that human health and liability concerns are addressed. The equipment supplier, BRAE / Watts Water Technologies, contributed pro-bono on-site commissioning (not a standard service) along with technical, regulatory, and maintenance experience. Even though it is meant to be 'plug and play,' local inexperience and unfamiliarity with rainwater treatment systems makes these important educational opportunities for contractors, government agencies, the design community and the academic team. The team's and residents' experience with maintenance and trouble-shooting, and their impacts on the user experience and data provide a valuable account that is documented for use by others.

3.0 GREYWATER ON SITE INFILTRATION BED

3.1 Objectives and outcomes

Similar to supply water goals, finding a balance between public and private services drove greywater goals. Greywater produced in the home is infiltrated on site, and existing sewer connections remove blackwater.[2] Primary benefits of on site greywater management include reductions of municipal energy used to transport and treat wastewater at a central facility, and re-charge of the local groundwater through infiltration.

Consultation with technical advisors revealed the importance of bed saturation - specifically, the assurance that greywater discharged below ground would not percolate to the surface. A broad study of gathered NNH greywater data was conducted to identify possible saturation events and causations (rainfall, high levels of discharge, etc). Focused studies were then conducted to evaluate individual greywater events as they were processed through the bed. Findings suggest average infiltration times based on discharge volume, discharge duration, and resulting bed saturation. Measurements show that the bed has yet to be fully saturated, with ample capacity to infiltrate all of the home's greywater discharge below grade.

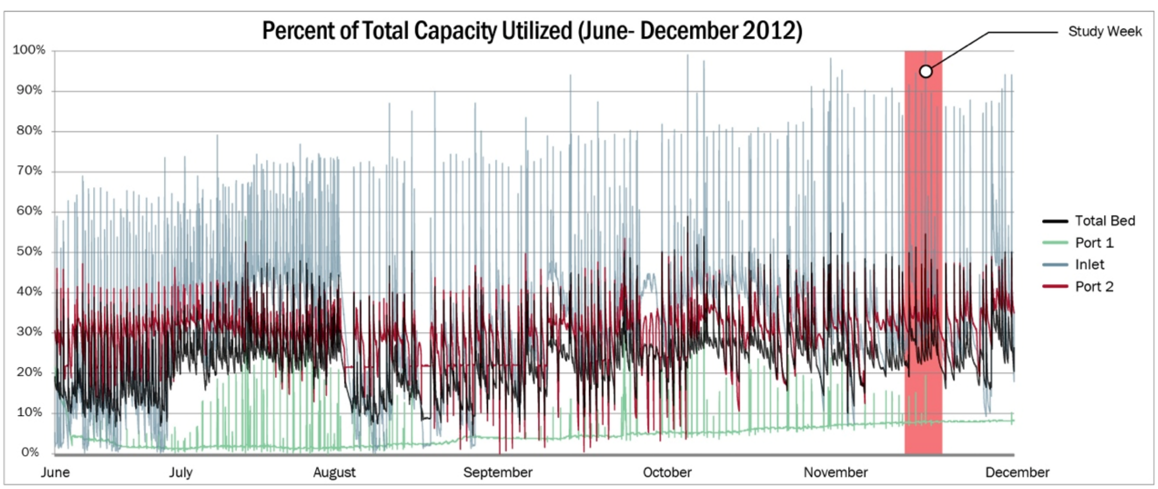

Figure 5: Saturation values within greywater bed during first six months of study. The area highlighted in red indicates the study week shown in Figure 6.

The spikes on the graph (Figure 5) show an increase in utilized capacity as recorded at each of three monitoring locations within the greywater infiltration bed. Though the total holding capacity of the bed (shown in black) rarely exceeds 50%, the greywater inlet (shown in blue) is routinely subjected to higher values. As the inlet for greywater collected from the entire house, this result is expected. Analysis of data recorded during the first 6 months of the study period indicates that capacity levels were observed above 90% only 0.035% of the time (the longest period lasting only 12 minutes). The inlet only reached full capacity once during the study period - a 3 minute inundation (Figure 6). Infrequent and short durations of high utilized capacity within the monitoring station suggest that complete saturation of the bed was unlikely and that discharge water stayed below the surface level. Initial results suggest it takes approximately 4 hours for a load of clothes washing water to infiltrate in the bed, and about 2 hours for a 15 minute shower to infiltrate.

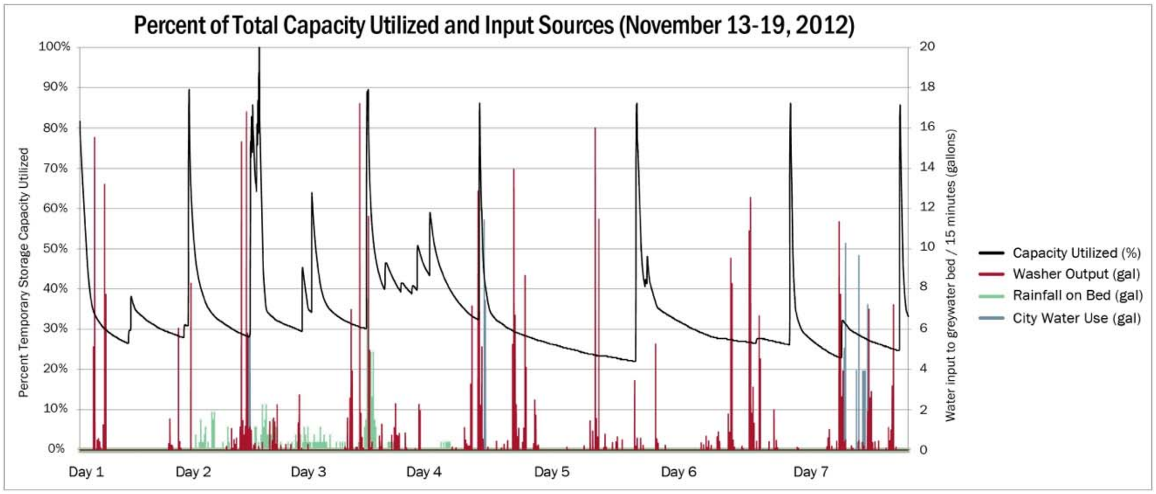

Figure 6: A seven day period of high saturation rates (including the highest level reach over the course of the initial six month study period). Heavy, red line indicates saturation percentage, which includes rainfall and greywater exiting the house and entering the bed.

3.2 Methodology

The team installed a simple monitoring system, three piezometers (monitoring wells) instrumented with atmospherically corrected pressure transducers, to collect data on water levels within the greywater bed. Data is used to determine the rate of water movement – either through infiltration and/or evapotranspiration. Values are recorded at 60 second intervals to a Campbell Scientific Datalogger, which is manually downloaded once per week. Observed measurements are returned in millivolts and converted to inches. Minimum millivolt values are first normalized using a static adjustment to establish a common bottom elevation to account for elevation differences between stations. A dimensional water level is determined by designating the minimum and maximum values of the inlet port station as 0" and 14", respectfully, (derived from the dimensional height of a large-diameter, perforated piezometer, used as an inlet surge). A linear interpolation between the minimum (0") and maximum value (14") yields the height of sub-surface water within each piezometer.

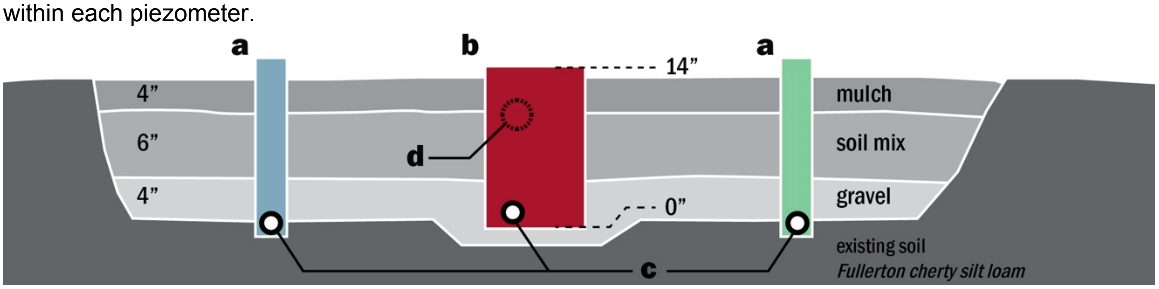

Figure 7: Diagrammatic section of greywater bed with monitoring piezometers (a) 4" piezometers; b) large diameter piezometer; c) pressure transducer; d) greywater inlet)

Holding capacity utilization is calculated [1] and allows analysis of the duration of potential saturations. These values are further informed by collected data measuring the volume of rainfall and estimated greywater discharge [4]. Observations and weekly logs note conditions such as the presence of standing water at the surface of the greywater bed, greywater seeping from the bed into adjacent landscape areas (neither condition has been observed to date), and the amount of organic matter in the large-diameter piezometer. Conditions are logged for submission to TDEC, per permit requirements.

Holding Capacity Utilization = Actual Greywater Held [2] / Potential Capacity [3] [1]
Actual Greywater Held (Volme) = Observerd water level in bed x bed area x porosity of each stratum [2]
Potential capacity (volume) = as-built dimensional volume of greywater bed x porosities of its strata [3]
Greywater (volume) = measured total water use - measured toilet use - estimated kitchen sink use[3] [4]

3.3 Design description and criteria

The design process began by testing the infiltration rate of the soil. The soil type on the project site is Fullerton cherty silt loam. The USDA classifies this soil type as “well drained” with a depth to a restrictive layer or the water table of more than 80.” An on-site infiltration test was performed by excavating a hole where the bio-retention bed was to be located. The hole was filled with water and an average infiltration rate of 0.2” per hour was observed. Though this rate is not considered “well drained” (in contrast to the site’s USDA soil survey), differing soil types are not uncommon. The bed is located away from existing surface water features, and in full sun.

Based on two residents and specification of low-flow fixtures, the team projected 40 gallons of the one-year return storm for this region ("Precipitation Frequency Data Server"). The greywater bed area was conservatively constructed at 7.5 (2.5 times larger accounting for an additional 83 gallons of rainfall from a 2.5” storm) times the required volume. Greywater is discharged to the bed via a 4” diameter PVC pipe that terminates into a perforated standard 5 gallon bucket that serves as a large diameter piezometer (see Figure 7). The 14’ long, 4.5’ wide, and 16” deep bed contains a 4” #57 gravel layer topped by an 8” layer of 20% sand 80% compost. The bed is top-dressed with an additional 4” layer of pine bark mulch. Greywater bed plants were chosen for their native status, ability to withstand frequent inundation, and support of microbes that aid in the decomposition of common greywater contaminants such as phosphates from soaps.[4] Resulting greywater bed holding capacity is projected at 300 gallons.

3.4 Lessons learned

Though greywater evaluation is ongoing, findings to date are promising. The system has operated without interruption, maintenance, or service for 1.5 years. Added difficulties arose by building into the steep slope of the site, but these concerns were mitigated using a permanent, vegetated retaining system and no adverse effects on performance have been shown (though cost did rise). The greywater system was easy to design and install, and operates largely independent of other water systems.

As with rainwater permits, the team worked with the Municipal Technical Advisory Service, the Norris Water Commission and city officials to revise city ordinances (written to be exclusive to the NNH research site). However, the main authority for greywater rested with the state (TDEC) Division of Water Pollution Control (WPC);a delegation visited the site and issued a State Operating Permit good for two years. The permit requires informational signage in the bed, an annual report summarizing the team’s inspection logs, suggested design revisions, and a maintenance manual. Future studies may include: exploration of shared systems that can process greywater from multiple homes; alternative methods for greywater delivery to and dispersal within the bed and the effects on saturation; and, refinement of regional plant recommendations.

4.0 STORMWATER MANAGEMENT

4.1 Objectives and achieved outcomes

Stormwater management objectives include utilizing treated rainwater for in-home use and hose bibb irrigation (see section 2.0), and on-site infiltration of untreated cistern-overflow rainwater. Combined, these practices manage 100 percent of stormwater generated from on-site impervious surfaces. Site stormwater management features are designed to integrate performance and aesthetic experience.
During the study period approximately 15,600 gallons of untreated cistern-overflow rainwater was infiltrated in four terraced infiltration beds—providing groundwater recharge and decreasing reliance on treated rainwater or city water for irrigation. A portion of the overflow rainwater was used to irrigate 105 ft^2 of raised vegetable beds, providing 100 percent of vegetable watering needs. Approximately 4,700 gallons of treated rainwater (66% of total irrigation water via hose bibbs) was used to establish 325ft^2 of drought tolerant native perennials and 2,070 ft^2 of native grass meadow (Figure 8).[5] Drought-tolerant plants and rainwater irrigation led to a 97 percent reduction from the average US home’s use of potable water for irrigation.[6]

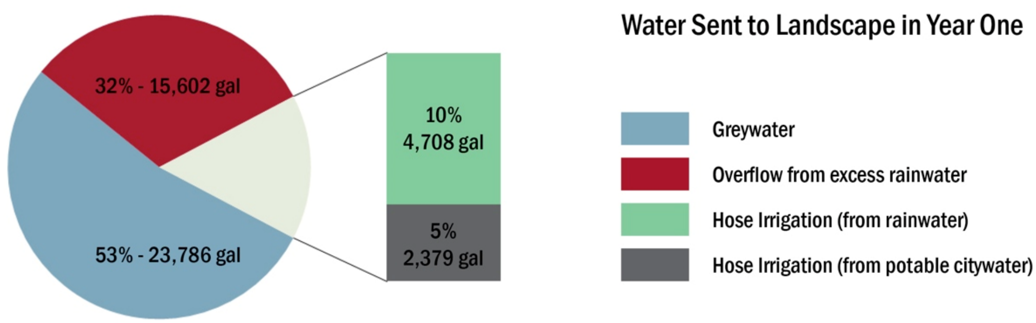

Figure 8: Water sent to landscape in year one. In the study period, a total of 39,388 gallons of greywater and cistern-overflow rainwater was infiltrated via the greywater treatment bed and 4 terraced infiltration beds. 7,087 gallons of water was drawn from hose bibbs for irrigation. 66 percent of water drawn for irrigation was provided from treated rainwater.

4.2 Methodology

Rainfall is measured with a Texas Electronics TR-5251 rain gauge and digitally recorded at 15-minute intervals with a Campbell Scientific Datalogger system. During the 12 month study period, 45.47" of rainwater fell on the site, resulting in approximately 25,000 gallons of rainwater harvested from the roof.[7] Of this, roughly 15,000 gallons overflowed as excess to terraced infiltration beds.

The resident records conditions during periods of both high intensity and high volume rain events. Observations included no overflow, seeping, or standing water in terraced infiltration beds during or after rain events, minimal on site sheet flow, and minimal sheet flow to adjacent properties. The terraced beds remain lush during drought periods and provide habitat for numerous birds and insect species.

4.3 Design description and criteria

The design of integrated on-site stormwater management features began with a pre-construction plan for the staging of construction equipment and materials. The previous/demolished home's footprint was used as a staging area, and later as the finished gravel parking court, reducing on-site soil compaction and maintaining undisturbed soil infiltration rates on the majority of the site. Excluding the roof area, the site is 99 percent pervious, which promotes quick on-site infiltration of stormwater.

Rain events generate excess water as 1) overflow rainwater from the cistern, and 2) as stormwater sheet flow from up-slope impervious surfaces. Overflow rainwater from the cistern is piped via an underground 4" diameter PVC pipe to a second 200 gallon sub-grade cistern located at the north end of the raised vegetable beds. Rainwater stored in this cistern is accessed with a hand pump for vegetable irrigation. Overflow from the second cistern is piped via an underground 4" diameter PVC pipe to a gravel forebay in the uppermost of four terraced infiltration beds. The forebay slows the velocity of the overflow rainwater before it enters the soil media; where it is evapotranspired by native plants or allowed to infiltrate. Infiltration bed plants were chosen for their drought tolerance, as well as their ability to thrive under frequent inundation.

The four lower beds (uppermost bed dedicated to greywater infiltration) provide level areas for infiltrating overflow rainwater on an existing 1:4 sloped site. Terraces are built from structural Geotextile bags filled with a sand/compost mixture and backfilled with an 80% mushroom compost and 20% sand soil mix. Each bed is approximately 14' long, 4.5' wide, and 16" deep. Water moves through the beds in a serpentine pattern following overflow channels and filling all beds for a combined holding capacity of approximately 930 gallons.[8] Stormwater sheet flow is intercepted by the perimeter native grass meadow—a "sponge" that slows the velocity of stormwater and provides deep root zones for infiltration. The meadow blend includes low-growing native grasses and perennials acting as the site's own greenbelt, a microcosm of the greenbelt that protects and recharges Norris's municipal water supply.[9]

4.4 Lessons learned

Due to the steeply sloped existing site, additional cost was incurred when terracing to create level infiltration beds. However, the beds are low maintenance, requiring little attention after establishment and no mowing. The beds are an ecological improvement over the pre-existing 1:4 sloped turf area and require less time and cost for general maintenance.

Rainwater irrigation and infiltration are permitted in TN, and the NNH practices could be implemented on other sites without additional regulatory oversight. Future studies may apply rainwater irrigation and infiltration at multiple single-family homes or multi-family units. Although Norris does not have a municipal stormwater sewer, rainwater infiltration practices such as those at NNH are particularly useful in areas with increasing demands on sewer and water treatment plants.

CONCLUSION

If one assumes the future of infrastructure (including water, energy, and food) will include decentralization and lower energy solutions pushed down to the level of the site, then society, at least in the US, has a long way to go toward implementation. Projects that combine education, research and community outreach, like the NNH, are effective vehicles for beginning those conversations. Such projects bring together crucial participation by all parties affected so that problems can be encountered, worked through, and resolved – and then disseminated. A NNH did not originate with the team its water goals required; rather, the process led the team to identify *who* needs to take part, *how* such a team can be assembled and organized, and *what* issues should be tackled first. While the NNH goals may be modest for parts of the US or world (the low hanging fruit") the reality in Tennessee demands demonstration projects that provide reliable data and that can lead to the regulatory changes that will make it not only permissible, but hopefully commonplace.

ACKNOWLEDGEMENTS

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ENDNOTES

[1] NNH Test List for EPA Primary, Secondary, and Non-Regulated Drinking Water Contaminants MCL*
Primary Contaminants: Ammonia (-),Cadmium (0.005 mg/L), Chlorine (4.0 mg/L), Copper (1.3 mg/L), E-Coli (0.05%**), Lead (0.015 mg/L), Glyphosate (0.7 mg/L), Nitrate (10.0 mg/L), Nitrite (.0 mg/L), Sodium (20.0 mg/L***), Total Coliform (0.05%**), Turbidity (5ntu)
Secondary Contaminants: Aluminum (0.05 - 0.2 mg/L), Iron (0.3 mg/L), pH (6.5 – 8.5), Sulfate (250 mg/L), Zinc (5 mg/L)
Non-Regulated Contaminants: Alkalinity, Calcium (Ca), Conductivity, Magnesium, (Mg), Potassium (K), Total Organic Carbon (TOC), Total Suspended Solids (TSS).
* The highest level of a contaminant that is allowed in drinking water.
** No more than 5.0% of samples positive in a month.
*** For individuals on a 500 mg/day restricted sodium diet

[2] For this study, greywater includes lightly used wastewater from the bathroom sink, shower, and washing machine, but excludes water from the kitchen sink and toilet (black water).

[3] An estimated value of 5.4 gal./capita/day was used as 50% of cited "Faucet" use per day. (Vickers 2001)

[4] Greywater bed plant list: *Iris virginica, Juncus effuses, Lobelia siphilitica, Saururus cernuus*
Infiltration bed plant list: *Baptisia australis, Conoclinium coelestinum, Helianthus angustifolia, Iris virginica, Liatris spicata, Monarda x media, Vernonia lettermanii* 'Iron Butterfly'.

[5] Native drought-tolerant perennial plants: *Amsonia hubrichtii, Baptisia australis, Coreopsis verticillata* 'Moonbeam', *Echinacea pallida, Echinacea purpurea, Echinacea tennesseensis, Liatris microcephala, Liatris spicata, Porteranthus stipulates.*

Warm season grass and perennial meadow plants: *Andropogon ternarius, Andropogon virginicus, Aster laevis, Coreopsis verticillata* 'Moonbeam', *Echinacea pallida, Echinacea tennesseensis, Elymus hystrix, Liatris spicata, Muhlenbergia capillaris, Panicum virgatum* 'Shenandoah', *Rudbeckia fulgida* 'Goldsturm', *Schizachyrium scoparium, Solidago rugosa* 'Fireworks', *Sporobolus heterolepis.*

[6] The average US home's outdoor water use is defined as 100.8 gallons/capita/day. (Mayer 1999)

[7] Average yearly rainfall in the Tennessee Valley is 51" per year indicating that our study occurred in a relatively "dry" year. ("TVA: Rainfall in the Tennessee Valley")

[8] 930 gal. holding capacity is 64 percent of gal. generated by a 2.5" design storm including cistern overflow rainwater (1,375 gal.) and rainwater falling directly into beds (83 gal). A more common 1.5" rain event is held in the beds with 54 gallons to spare.

Equation used to generate gallons from rainfall inches: Area * (rain"/12) * 7.48 * .95 = gallons

[9] The Norris Town Plan incorporates elements of the Garden City Movement, including a greenbelt. (Ezzell 2010)

Performative Parametric Design of Radiation Responsive Screens

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[2]Florida Atlantic University, Fort Lauderdale, Florida

ABSTRACT: In subtropical or tropical region, shading is one of the most important design strategies due to exposure to intense solar radiation. The study addresses the need for flexible design method identified in today's architectural practice. Different workflows for coupling the parametric design with simulations of heat flow and radiation are examined. A workflow consists of tools running on modeling or simulation platform. The paper establishes three workflows, static, cross-platform and dynamic. Each workflow has similar capabilities in terms of access to simulation engines but different flow of information. Therefore, they can be employed in different design circumstances. The current investigation indicates the need for multi-objective optimization in the future.

KEYWORDS: Parametric design, façade, performance simulation

INTRODUCTION

With current industry trends in software, there is a vast selection of tools for designers to utilize. Traditionally, digital design tools in architecture follow a linear process and consequently limit possibilities for iterative modelling and exploration. In this study, a part of a collaborative project between Florida Atlantic University and BRPH (an architectural firm based in Melbourne, Florida), software packages are evaluated for their individual capabilities as well as interoperability. The project becomes an experimental model for applying and transferring knowhow and knowledge between academia, practitioners and manufacturer. The study began as a class project in Directed Independent Study (DIS). Later on, a continued effort received internal funding as a part of the Quality Enhancement Program. Future effort will be included in an elective course titled Performative Parametric Design.

The study examines designs and design methods of building skin. Like human skin, building skin can function as active thermal regulator. Heat gain and loss through building skin is governed by different modes of heat transfer. Heat gain is a major concern for cooling dominant region like South Florida. Radiation contributes roughly 20% of total thermal load through glass façade in this region.

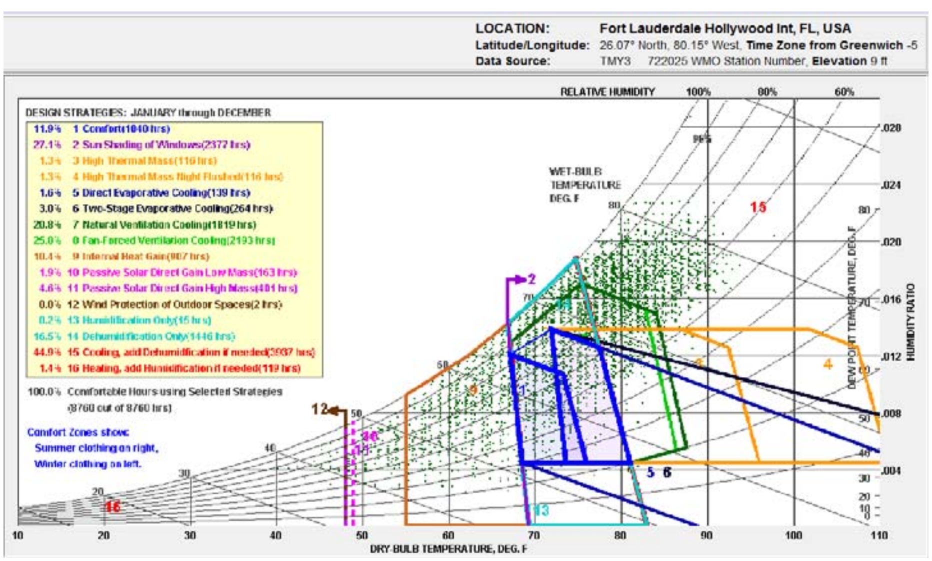


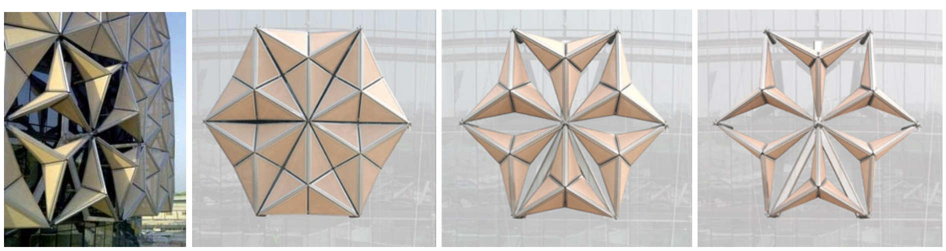
Figure 1: Psychrometric plot of Fort Lauderdale weather data

Fig. 1 shows that shading of windows is a strategy that is should be applied 27.1% of the time in Fort Lauderdale, Florida according to 2005 ASHRAE Handbook of Fundamentals Comfort Model. Climate Consultant 5.4 is used to plot Fig. 1. The software recommends window overhangs and operable sunshades (extend in summer, retract in winter) as design strategies for reducing heat gain.

In order to explore different variations of shading designs, and their effects on both radiation protection and daylight utilization, this study employs parametric design that allows parameterized manipulation of geometry to generate and populate exterior sun screen designs. They are developed on Rhinoceros (Rhino) with Grasshopper®, a visual programming tool where different plug-ins can be used to manipulate the designs and transfer data. Different plug-ins are explored to connect the parametric modeling tool with simulation software. A combination of Revit® Architecture® or Autodesk Vasari® constitute a platform with similar capabilities. Different combinations create workflows for coupling the parametric design with simulations. Platform interoperability issue of the workflows must be scrutinized in terms of compatibility and the flow of information from one plug-in or software to another.

There are multiple performance criteria in shading design. Ecotect®, Daysim® and Vasari® are simulation tools identified as candidates for performance assessment of design variations in terms of radiation exposure, daylight utilization and energy consumption respectively. All of them can be connected to Rhino through different Grasshopper® plug-ins. The paper will discuss about an approach to combine criteria into a single objective function that can be used to inform sun screen design. Response of the designs to the environmental inputs can be animated to show screen operation. The animation can also be used to visualize design optimization.

In our consideration of façade systems, we looked at precedents to identify possible actuation mechanisms (Drozdowski and Gupta 2009). The shading system developed by Aedas[1] for the "Al Bahar" tower **(Fig 2)** project consists of a secondary skin of 1,000 "umbrellas" that "mediate light and reduce glare" on the east and west facades, according to the architects. Such devices are necessary for thermal regulation of buildings in extreme environments.



Figures 2: Al Bahar towers responsive façade mechanism, Abu Dhabi
(Design by Aedas, 2012; image source: http://www.designboom.com/architecture/aedas-al-bahar-towers/)

1.0 DISCUSSION

1.1. Objectives

Informed Design

The first and possibly most important objective of the project is to make informed design decisions which are based on contextual factors. The design solution(s) is a result of performance criteria that relate to the environmental conditions and is, therefore, unique to the given context. Consequently, we are interested in establishing a methodology that is parameter-driven, and not a discrete design solution. Such a methodology may then, be applied universally, adapting the criteria to match the idiosyncrasies of the given project but following the same schema that is proven to work a priori. The advantage of a process that reaches design optimization based on criteria that are case-specific is tailor-made solutions to particular problems. In addition, one could say that such a design that is a result of comfort-related simulation and analysis is an "honest" expression of architecture's response to the needs of the occupant.

Use of Parametric Design

The use of analysis to inform design decisions has been implemented in the past; our intention is to optimize the process of integrating the quantitative data derived from analysis within the design modeling process, thus establishing a seamless workflow that is both easy to apply and more efficient. Using parametric tools like Grasshopper enabled us to achieve this integrated workflow. Having established original models in

Rhino and /or Revit®, we transferred them to parametric modeling tool and subsequently linked them performance assessment engines.

Versioning
During the beginning of the last decade, architectural practitioners began to shift their interest from a visual-driven to process-driven architecture, placing emphasis on “technique”. This promoted a design methodology that relies on interdisciplinary exchange between architects and other experts, as well as a design workflow that utilizes a broad set of tools to arrive to an optimal solution. According to SHoP, “Versioning is important to architects because it attempts to remove architecture from a stylistically driven cycle of consumption”[2] (SHoP 2004). This notion of versioning expedites the design process and allows for a multiplicity of results that allow comparison; instead of one singular solution, the process yields “generations” of results.

The parametric workflow, as opposed to manual modeling provides a flexibility that permits the investigation of multiple solutions. The designer is able to generate “versions” of a design proposal which are slightly different to one another and subsequently test these with each other to determine the one with the optimal performance.

Developing efficient workflows that respond to technological innovations
The use of parametric design to integrate analytical results with 3d modeling reflects the current status of "digital design" and its inclination to be more integrative, linking processes through software and hardware, not only within Architecture but also between Architecture and Engineering. Being able to establish and maintain a clear mode of exchange between architects and engineers has always been important but not easily attainable. A workflow that combines modeling and analysis tools is more comprehensive and can relate to both disciplines.

Analysis of workflow
There are two possibilities to design a component that adapts to changing conditions based on real-time data capture, or design a component that is static, but whose configuration has been determined by investigating various responses to environmental conditions and selecting versions that we believe to be the most efficient under different conditions **(Fig 3)**. During this project we have mostly followed the first method, where components along a surface respond dynamically to changing conditions of the pre-set parameters within a parametric workflow (see “Parametric Design” section below).

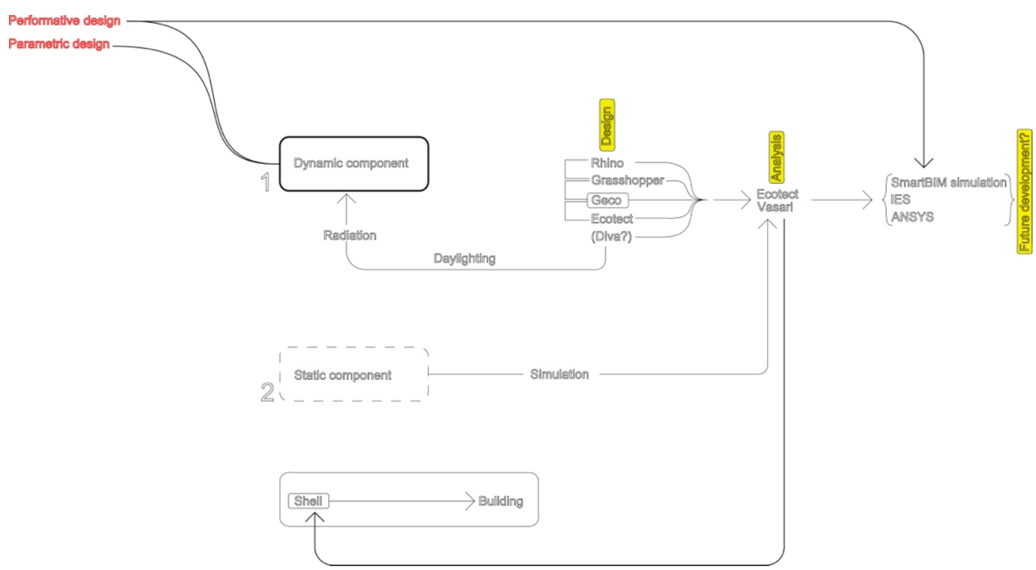


Figure 3: Workflow schema showing relationships between critical components of the project

1.2. Methodology
This investigation uses two distinct methods of software integration to achieve real time analysis, parametric surface generation, and validation of the effectiveness of these solar devices in building performance. The benefit from linking multiple platforms is the possibility to generate tested solutions in real time. These models are reacting to linked simulation, thus automating the design process to provide detailed results.

Three different workflows were developed relying on capabilities of modelling platforms. Different workflows require different sets of additional tools. They share a common objective: the generation of a reactive facade, comprised of panel systems, optimized against solar exposures for a particular location. The two processes begin to diverge when the study looks into both a static application, optimized for annual averages, and a dynamic system capable of responding on an hourly basis.

The static system provides a more direct method of optimization. Additionally the final geometry can be more directly integrated with Autodesk Revit® Architecture and other BIM components. While BIM software packages are robust in their practical applications, this study demonstrated their limitations for linking facade geometry to be updated and re-evaluated, when large changes are made to the design model. Consequently, instead of importing a dynamic file that links to the facade shape, it is rather an object on its own, listed as a shading device that cannot respond to changes in geometry without running the process again. Furthermore, spaces are not recognized as thermal spaces outside BIM software limiting the cross-platform data exchange to analyses other than thermal simulation.

However, the benefit of using static components is the use of Autodesk's built-in energy modelling. Any imported shading device from Rhinoceros®/Grasshopper® can be used directly in the environmental model of Revit®/Vasari® as a shading device. Autodesk's model can show the resulting influence of these surfaces on the building’s estimated heating/cooling performance, operation cost, comfort and lighting. While not being able to achieve a variable, fully dynamic surface, the final objective of this method was validating building performance. Without validation of even a simplified system, the scope of practical application for these shading surfaces within the industry remains very narrow. Cost and feasibility are equally relevant to the success of practical application, however the system must provide an effective result in its primary purpose before other validation takes place. This method is ideal for a single, non-operable system optimized for average/cumulative annual solar shading.

To achieve a dynamic system that is updated on an hourly basis, the Rhinoceros®/Grasshopper® model is linked to Autodesk Ecotect® via a plugin called GECO[3]®. GECO® facilitates real-time data exchange between both software packages. The solar path can be traced/imported into the Rhinoceros® model through Grasshopper’s parametric engine; changes in solar position/angle directly affect the models response. This allows for more complex panel systems or other large quantities of variable shading components to be automated and animated. However, this dynamic adaptive model is only capable of running in the Rhinoceros®/Grasshopper® environment and can only be exported to BIM models as a “baked” or finalized model. The individual panels and their variable apertures cannot support reciprocal communication between parametric and simulation tools. Therefore, the design process cannot be interactively visualized.

A way to circumvent this constraint is by using interoperable tools within the same platform. While this dynamic model has its export limits into BIM platforms, it can still execute energy and performance calculations within Rhinoceros®/Grasshopper® for similar validation. GECO® allows Ecotect® to import geometry from Rhinoceros® and calculate building performance, thermal values, solar radiation and day-lighting separately. This allows users to perform complete conceptual design and mass modelling in Rhinoceros® with the benefit of seeing design changes in real time and make faster more informed decisions. With the exception of dynamic solar values, the Rhinoceros® model can be exported to Revit® to proceed with BIM modelling and documentation. Both processes have their limitations when used separately, but when used simultaneously in the same project they can yield similar results for design and energy modelling. Using both methods allows for cross referencing their results in order to balance the design further.

1.3. Parametric design and simulation

Static platform

An experiment on static workflow is based on Revit®/Vasari® platform. Simple models are employed. With a static system the process can begin with traditional mass modelling methods such as the provided capabilities in Revit® or Vasari®. This study uses a standard Torus geometry component in the Vasari® library (Fig 1). The torus was chosen for its continuous surface subject to variable solar exposure. The scale is chosen to model at minimum five stories, Vasari® then automates the massing of the floor slabs in the ‘modify mass’ tab and approximates spaces and circulation when a benchmark analysis is enabled. The analysis is executed using the provided default setting for typical construction types, materials, glazing and location.

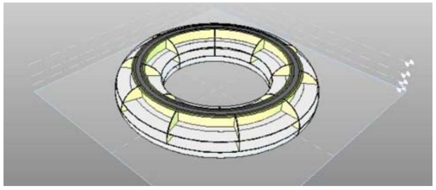


Figure 4: Torus geometry used for analysis

This baseline simulation calculates energy use intensity, life-cycle cost, emissions, heating and cooling loads, based on data from a weather station in the location selected. Additional variables considered in the calculation include floor area, exterior wall area, average lighting power, occupancy load, and exterior glazing ratio. After this benchmark is complete, another simulation model is created by increasing the exterior glazing ratio to a fully glazed façade. These two analyses show the extremes in building performance and give insights towards the direction of optimization. For example, comparing a 40% typical glazing construction to a 90% glazing construction shows a significant increase in the monthly electrical consumption. The optimization of performance can take place within this preliminary mass model by selecting the construction types and variables desired and then further investigate those in the Rhino®/Grasshopper® environment. The benchmark model selected for this study is the high glazing extreme.

Cross-platform

For this study, a triangulation pattern is selected in Revit®/Vasari® and set to full glass panels which are exported as (.dwg with ACIS solids format) for use in Rhino®/Grasshopper® as mesh geometry. Mesh geometry is imported by system default as exploded single surfaces based on the UV divisions chosen in Revit®/Vasari®. The grasshopper definition's first task is collecting all surfaces and relating these to the rest of the process as one single entity comprised of points for generating new panels. Grasshopper® has built-in capabilities to organize all point geometry of a mesh and apply an individual panel to each surface based on a standard model. The standard geometry used here is a diamond surface similar to the division created in Revit®/Vasari®; it is then divided into two smaller triangulated components. Along this division line, the aperture is created at the centre by generating two edges that symmetrically increase the space between them **(Fig 5)**.

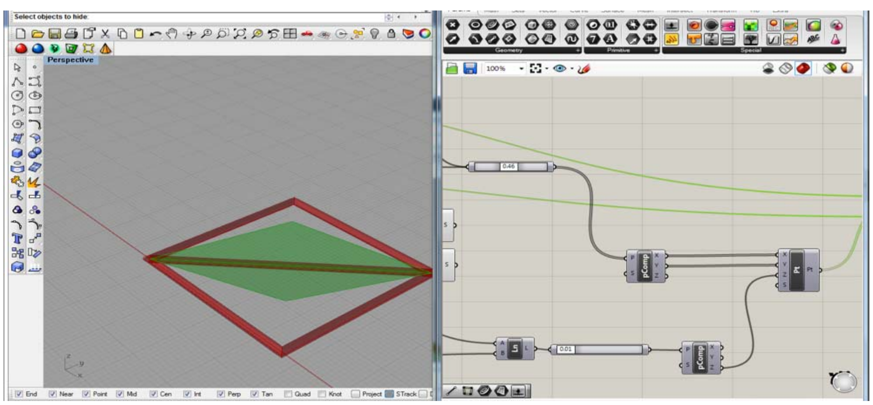


Figure 5: Aperture division in two panels (Rhinoceros®) and controlling definition (Grasshopper®).

The primary plugin that is required to initiate this process of mesh management is called Weaverbird®[4]. This Grasshopper® plugin enables the model to sort and organize the divisions of mesh geometry but more importantly contains management tools such as 'Mesh Edit' that refines the imported geometry into an organized set that comprise one refined group to be exported into Ecotect® to obtain solar radiation calculations. The object is exported as a whole via GECO® from Rhinoceros®/Grasshopper® but individual panel geometry, originally exported from Revit®/Vasari®, receives its own calculation. GECO® sets up simultaneously within Grasshopper® and Ecotect® the environmental parameters based on weather files similar to the Revit®/Vasari® data. Since both software packages use the same weather files and Ecotect® calculation, the consistency of results is maintained in both project files.

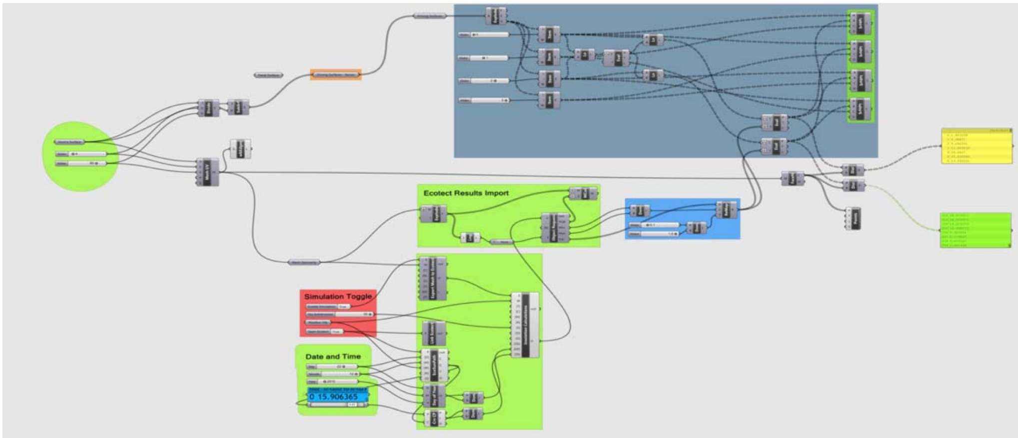


Figure 6: Overall parametric definition controlling the apertures

The Grasshopper® definition is set up to import solar values based on a domain range and then converts this set of values to correlate with panel aperture **(Fig 6.)**.

Dynamic platform

This dynamic method can begin entirely in the Rhinoceros® environment. It has much wider capabilities for conceptual modelling because it is a NURBS-based system (Non-uniform rational B-spline). Users can maintain complexity in the initial design phase by including Grasshopper® definitions when creating changes in the model for iterative solutions. Once a form is selected -in this scenario, a variation of the Möbius strip[5]- the Weaverbird® plugin is essential for dividing the surface into a UV panel system similar to the automated process that Revit®/Vasari® provides. The benefit of this method is that all the modeling, surface division and analysis can be completed without any intermediate exporting across platforms. The overall process from form generation to analysis and validation can be completed in the Rhinoceros®/Grasshopper® environment via GECO® and Weaverbird® plugins. The final export of this method will serve solely for BIM models to import as a component for the documentation, as well as a Revit®/Vasari® building energy model.

After the building façade has been divided to desired parameters, the same definition components used in the static process for creating adaptable panels is used again in this method. Again the system Rhinoceros®/Grasshopper® system contains by default these components to organize the divided geometry into a point list that can reference the individual panel design as multiple surfaces, complete with access to the panel number, location in relation to the surface and its aperture values that will be accessed from Ecotect® via GECO® **(Fig 7).**

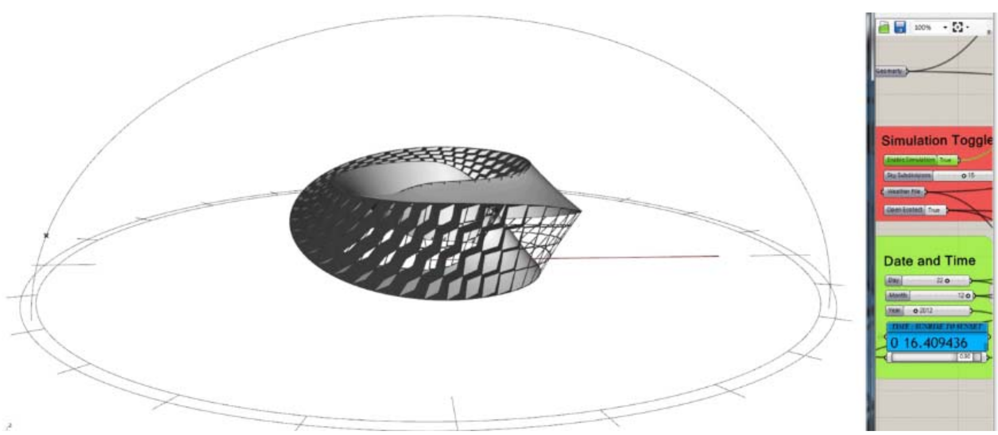


Figure 7: Möbius surface geometry used in the later stage of analysis

The similarities in both methods here is from the processing of the geometry to GECO® for Ecotect® and then finally taking the values of Ecotect® results and remapping their domain ranges to match a logical domain for controlling shading aperture, distance, rotation and any additional Euclidean transformations of individual panels. **(Fig 8).**

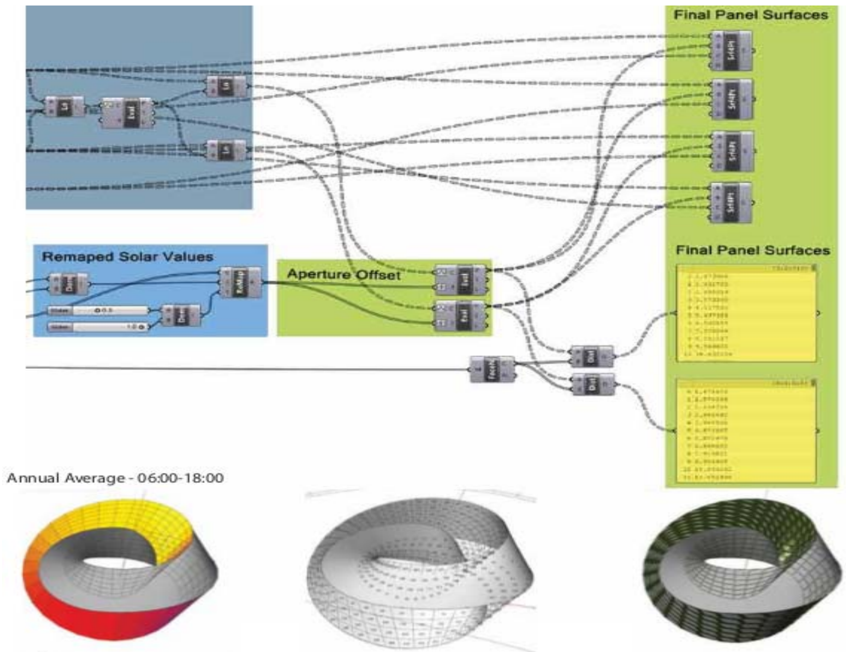


Figure 8: Definition used for the panelization of Möbius surface geometry

1.4. Results

Static platform

This method allows for Revit®/Vasari® to automate a curtain wall system by selecting the mass model and applying a curtain pattern division. In addition, the study minimizes other variables by using all glass surfaces to compare the effectiveness of the façade system. This method prevents a portion of the optimized shading device from acting on a solid surface such as an exterior wall.

Cross-platform

The model is simplified and conceptual in order to reduce simulation time. The desired final output for these panels, once applied to the imported surface, is a list of data pertaining to aperture by individual panel, individual panel dimensions, and location in relation to other panels and their position respective to surface. This data is extracted through default grasshopper components and does not require additional plugins. Detailed assembly documents can show a final product's mechanical assembly and controls with future collaboration with manufacturers.

As the simulation calculates an average annual study for this static cross-platform model, the parametric model simply calculates one aperture per panel on the overall instance of the calculation. No further action is required in modelling. Ecotect® does however provide multiple options for type of radiation study, environmental factors such as cloud cover or window cleanliness and the default parameters are used in all options to provide consistency with the Revit®/Vasari® environmental modelling. The final averaged Grasshopper® geometry is 'baked' into the Rhino file as a group and again exported as an ACIS(.sat) file type for single object import into Revit®/Vasari®, this file format prevents unnecessary mesh geometry on already simplified surfaces. This should be loaded into the existing mass model from the previous simulation and included as such in a new building performance calculation **(Fig 9).**

Dynamic platform

To take this method further, and match the process automated by Revit®/Vasari® in the static model, we use the GECO® component to export the model to Ecotect® as a mass without reactive panels and then run building performance simulation. Simulation options include energy use intensity, life cycle cost, emissions, heating and cooling loads. These available simulations are exactly the same as those available in Revit®/Vasari®. Essentially, Autodesk Ecotect® is available in both methods. It is built into the Revit®/Vasari® platform and linked to Rhinoceros®/Grasshopper®. With the dynamic method, the model remains available for output of panel information and environmental calculations as long as Rhinoceros®, Grasshopper® and Ecotect® are running. For practical applications these platforms are running the simulation at regular intervals to create dynamic data lists to inform the final constructed mechanisms of a façade. Additionally the simulation can be run at intervals and saved to create a spreadsheet, ideally organized with variables such as time of day, panel aperture, location of panel, and panel number. **(Fig 10)**

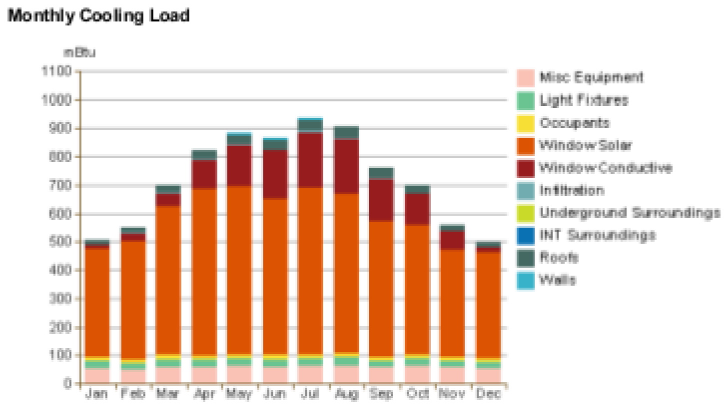


Figure 9: Graph showing monthly cooling load from toroid geometry

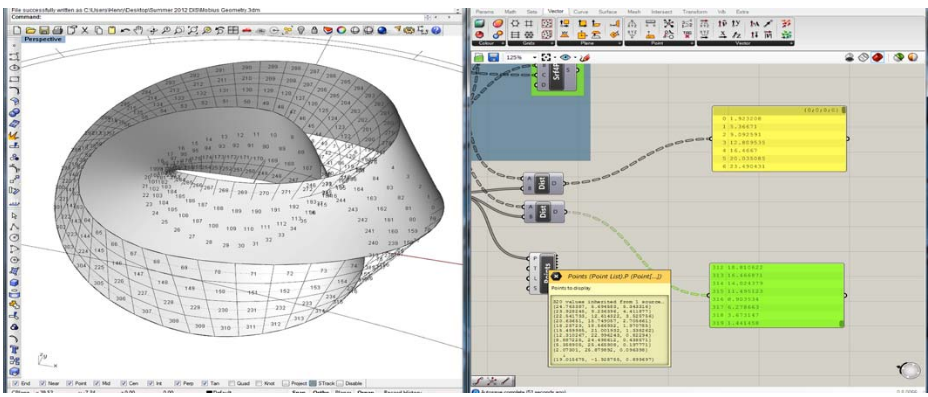


Figure 10: Panels labeled with simulation results

Dynamic platform

To take this method further, and match the process automated by Revit®/Vasari® in the static model, we use the GECO® component to export the model to Ecotect® as a mass without reactive panels and then run building performance simulation. Simulation options include energy use intensity, life cycle cost, emissions, heating and cooling loads. These available simulations are exactly the same as those available in Revit®/Vasari®. Essentially, Autodesk Ecotect® is available in both methods. It is built into the Revit®/Vasari® platform and linked to Rhinoceros®/Grasshopper®. With the dynamic method, the model remains available for output of panel information and environmental calculations as long as Rhinoceros®, Grasshopper® and Ecotect® are running. For practical applications these platforms are running the simulation at regular intervals to create dynamic data lists to inform the final constructed mechanisms of a façade. Additionally the simulation can be run at intervals and saved to create a spreadsheet, ideally organized with variables such as time of day, panel aperture, location of panel, and panel number. **(Fig 10)**

CONCLUSION

This work has examined possibilities for integrating simulation and design tools to optimize performance of sunscreen designs. It explores three different workflows combining different software and plug-ins including parametric modelling and performance assessment tools. BRPH communicated to us the needs to develop digital design workflows which allow for flexibility and iterative design process while being designer friendly. The three workflows identified in the study include static, dynamic and cross-platform approaches to investigate static and dynamic screen configurations. The static platform is more suitable for simple design evaluation as it does not allow for sophisticated parametric control. The cross-platform is linear in terms of data exchange. Evaluated models cannot be imported back as parameterized model. Finally, the dynamic platform increases possibilities in both modelling and simulation taking advantage of interoperability across platforms. A combination of tools from cross-platform and dynamic platform can yield a more efficient design workflow. We believe that both the design output and the flow of information are equally important within this investigation.

FUTURE DEVELOPMENT

The current stage of development aims to enhance the control of parametric definitions and refine the parameters to better reflect the constraints and necessities of design problems. According to **Fig. 3** this research's primary goal is to develop workflows that consider the expansion of all platforms to include more tools for performance assessment. The expansion will lead to the necessity to implement multi-criterion evaluation. Moreover, designers intend to test the current findings through hardware integration and detail construction development in a manufacturing process.

ACKNOWLEDGEMENTS

This project was the result of collaboration between Academia and Practice. We would like to thank BRPH for their initiative to develop solutions for integrating design and performance and approaching the FAU School of Architecture for this endeavor.

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ENDNOTES

[1] http://aedasresearch.com/features/view/advanced-modelling/project/al-bahar-towers
[2] SHoP: 2003, *Introduction,* in Versioning: Evolutionary Techniques in Architecture, Wiley-Academy, West Sussex, UK.
[3] GECO® has been developed by [uto].
[4] Weaverbird® for mesh topologies: http://www.grasshopper3d.com/profiles/blogs/weaverbird-mesh-topologies-in
[5] This type of geometry was selected due to its differentiated surface orientations. Other architects have used the form (i.e. BIG's Astana National Library in Kazakhstan) and so we believe it is worth examining its performative potential.

Making Sustainability Visible: Two Early Childhood Education Centers

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ABSTRACT: This post occupancy evaluation compares two early childhood education centers built in 2007 in two very different parts of rural Oregon by two independent Head Start organizations. Making sustainability visible was a goal for both these projects at multiple scales: building facilities that gave stability and visibility for programs for early childhood education, fostering environmental awareness and reducing energy costs. Research involved two cycles of evaluation: one in 2008 – a year after occupancy - and a second in 2012 – five years out. Methods included interviews with architects, clients and users, parent surveys and site visits for walk-throughs, observations and collection of environmental data. Findings validate key design principles necessary to the success of both projects that can inform future projects.

KEYWORDS: Head Start, preschool, post-occupancy, sustainability, children

INTRODUCTION: COMPARING TWO CENTERS FOR EARLY CHILDHOOD EDUCATION

Redwood Early Education Center and Harney County Early Childhood Center are projects of similar scale built for similar budgets - but for different clients in different contexts resulting in buildings of very different character. Both opened in 2007, designed by the same architect, using principles derived from earlier research, to support social sustainability (connecting to context and community, legible building organization, welcoming entry, open, generous and flexible classrooms, support for staff), environmental sustainability (direct classroom-playground connections, daylighting, pools of light, natural ventilation, ceiling height variety, thermal comfort, special windows) and economic sustainability (energy efficiency, straightforward, cost-efficient construction). In the wet coastal mountains of western Oregon, the Redwood Early Education Center (Fig. 1) is the result of a cooperative venture by Southern Oregon Head Start, Rogue Community College and Josephine County Early Intervention Services. Located on the wooded Redwood campus of Rogue Community College in Grants Pass, the building houses two Head Start classrooms and a multipurpose room and provides a practicum site for Rogue Community College students earning associate degrees in nursing or early childhood education. In the high desert of eastern Oregon, Harney County Early Childhood Center (Fig. 1) provides the only public preschool education in the county, drawing children from both the county seat of Burns and from scattered farms and ranches. The programs include Head Start (two classrooms), Great Start (for slightly higher income groups), and programs for Infant/Toddlers and Home-based Head Start (formerly Rural Outreach). This study compares how similar design principles are applied to different projects and evaluates how the buildings are meeting their purposes, to find out what is successful and what is not, and to inform future projects.

Figure 1: Redwood Early Education Center (left) and Harney County Early Childhood Center (right)

1.0 METHODOLOGY

Research involved two cycles of evaluation, a project review one year after occupancy and a strategic review, completed five years after occupancy (Guide to Post Occupancy Evaluation, 2006, 9). Methods were primarily qualitative with some quantitative collection and analysis of enrollment numbers, staff retention, utility bills, number and location of furnishings and environmental data.

Initial methods included literature review, background research and documentation and interviews with the architects. This was followed by two full-day visits to each project: Redwood EEC (Thursday, 11/1/2007; Tuesday, 2/26/2008); Harney County ECC (Tuesday, 11/27/2007; Monday, 2/11/2008). The fall visits included interviews with staff, walk-through and photographing the facilities and classroom observations. The winter visits also included furniture inventories, environmental data collection (light levels – illuminance readings, glare – luminance readings, temperature – HOBO data loggers, sound levels – decibel readings), child interview activities and parent interviews. Parent surveys were left for distribution and then returned. Five years later, one full-day site visit was made to each project: Redwood EEC (Thursday, October 25, 2012); Harney County ECC (Monday, November 5, 2012). The investigation techniques in 2008 were repeated except for child interview activities, which had not yielded useful data.

2.0 KEY FINDINGS

The projects were analyzed and compared at multiple scales: community impact, site and building organization, classroom design and furnishing, playgrounds, specialized rooms and support spaces, economies of construction, maintenance and durability.

2.1. Stable Head Start Programs

Primary goals of both organizations were to increase stability for their early childhood education programs and improve their community outreach. Comparisons of student enrollments over the past five years, analysis of staff retention numbers and interviews were used to assess whether these goals have been met. Over five years, both Redwood EEC and Harney County ECC have had stable enrollments – Redwood at 80 students in four classes, Harney with 60 Head Start students in four classes, 34 Great Start students in two classes and multiple clients for Home-based Head Start and Healthy Start programs, which include out of facility site visits and socialization groups within the center. In 2008-9 Redwood converted its multipurpose room into a full day classroom, increasing enrollment to 100, but for administrative reasons that program was not continued. Both Redwood EEC and Harney County ECC advertise openings at their front door as outreach, so parents know they are there. Harney County usually has a wait list, but if anyone comes in off the street and needs services, both programs will find a space. Both directors reported low staff turnover. At Redwood EEC staff retention was 30% (5/17), although staff turnover was reported lower than among other sites. One new teacher with experience at other sites in Grants Pass and in California reports she "really love[s] [this center]" (Aviles, 10/25/2012). At Harney County ECC, retention was 80% (12/15). Harney County is much less populated than Grants Pass with very few family wage jobs, so this high number is not surprising. The Harney County director reported that the building draws people in. "People drive by to look at it. Some ask for tours" (Schnitker, 11/5/2012). Another teacher stated, "We're the envy of the town – we have a nice building" (Stampke, 11/5/2012). The relationships among Redwood's consortium partners have changed. Josephine County Early Intervention no longer runs programs in the multipurpose room but still sends specialists to work with special needs children in the classes. The partnership with Rogue Community College has grown to 38 nursing students, four early childhood practicum students and four regular volunteers who come to the center. A Rogue Community College faculty member uses a center office three times a week to meet students. The observation room, the only one of its kind in the agency, is an asset valued by the college and is used by Head Start teachers and family advocates to reassure and educate parents and for teacher supervision and evaluation. From the administrators' perspective, the room is underused and may not warrant the investment in equipment and space. The room could be smaller, because no more than two people observe at a time.

2.2. Welcoming | Child and Family Friendly

Welcoming children and their families is a primary goal for these facilities. Overall parent comments in 2012 (9 from Redwood EEC; 3 from Harney County ECC) were as positive as those in 2008 (15 from Redwood EEC; 13 from Harney County ECC). In all surveys from both centers, parents stated their children "love" their schools. At Redwood parents liked the entrance security systems (5), the natural playground (4), the child-size fixtures, the child-size door, that it is well-built and planned (3), that it is clean, friendly (2), the size of classrooms, having two children's bathrooms and many different learning tools (1). Parents desired playground improvements, more parking, more security cameras and a bigger room for parent meetings. They disliked having "to go to the classrooms by going outside when it is cold." Respondents from Harney County ECC liked the open / "simpleness" of the plan, the low windows to the outside, the large amount of natural light, the playground (2), the good size of classrooms, the bike path in the playground, and that the building looks clean, new (1). Improvements desired included finishing the playground, adding a diaper changing station in the men's bathroom and planting more trees for shade.

A welcoming entrance is achieved in both projects by front and back porches with fully glazed windows for seeing in and out. Redwood EEC incorporates three special elements: a child-sized door, a tower room off the entry and a visible parent room. The "little door" is beloved by children and parents. Observing the little door in action for an hour in 2008 and again in 2012 showed similar patterns. Children enter through the adult door, and then go back to come through the little door; parents go through the little door; children hold open the little door for their sibling; a grandfather holds open the little door for his grandson. At the time of the building's construction, staff had concerns about the little door and the glazed nook to its side, but fears about pinched fingers and children darting out have not materialized. The tower room at the entry has been refurbished since 2007 to include seating and books, making it much more friendly and inviting. The parent room has a good location with an interior corner window along the entrance hallway. Staff report the parent room is well used, and the corner window "brings style." Harney County's budget precluded the child-size door, but the front porch and lobby are welcoming and wide enough for areas for parents to sit and chat.

Both buildings have rooms for family programs and parenting classes that support their community outreach mission. Redwood has converted the motor room to a multipurpose room for monthly parent meetings, parenting classes and training sessions. Harney County uses the Home-based and Infant-Toddlers' classrooms for parent-child socialization groups and for parenting classes. Both buildings have commercial kitchens that allow food to be served at all parent events, which is a big draw.

2.3. Understandable and Functional Layout

Redwood EEC and Harney County ECC (Fig. 2) have contrasting organizations, but both work well in the context of their sites and staffing patterns. Circulation patterns are clear. Parking for parents is adequate, and there are clear paths to the front doors. Redwood's office wing is separated from the classroom wing, with only the problem that an adult bathroom is needed in the classroom wing. At Harney County, the organization with staff offices and workspaces on one side of the hall and skylit alcoves for classroom entries on the other works equally well. The flow at Redwood has required doors with alarms, so that parents and children enter the classrooms from the back porch but can only exit through doors to the north. In Harney County, children enter from the playground as well, but then exit down the hall to the lobby.

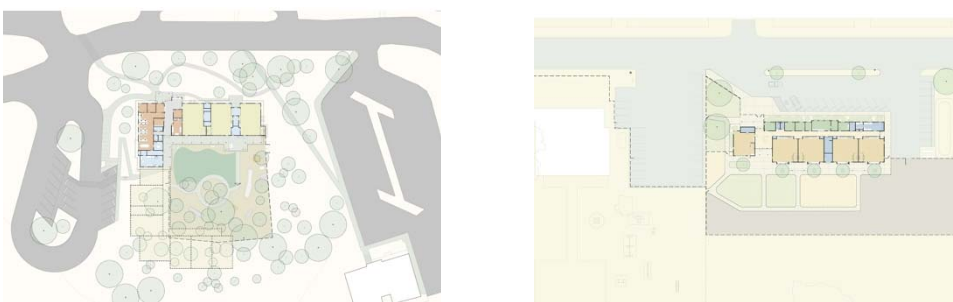

Figure 2: Site plans: Redwood EEC to the left, Harney County ECC to the right

2.4. Well-proportioned, Open and Child-centric Classrooms

Multiple characteristics are important in ensuring open and child-centric classrooms.

2.4.1. Size

The size of both classrooms at around 93 m^2 [1000 ft^2] is good – not too large and not too small. At Redwood one teacher reported that the classrooms are large enough tor putting out more activities than in other centers, but not so large as to get "runners" (Wilson, 10/25/12). The Head Start Performance Standards of 3.25 m^2 [35 ft^2] per child would have allowed classrooms of 65 m^2 [700 ft^2] (Redwood) or 49 m^2 [525 ft^2] (Harney County) that would have been much too small (Head Start Design Guide, 2005, 39).

2.4.2. Daylight | Ceiling Height | Views

Daylight is admitted in both classrooms from both the north and south (Fig. 3), and because of their height both classrooms have clerestory windows to maximize daylight penetration. Both classrooms have windows with low sills that are scaled for children. Redwood's triple hung windows reach the floor with the first bar just above the scale of a child standing. One Redwood teacher, who prefers the "Green Room" because there are more windows, added a birdbath outside and writing tables by the window, so children can write about what they see. Another teacher "likes the corner view: when a child is upset, they can look at and commune with nature, see something that takes their mind off it. … It is gorgeous when it snows; the kids have seen rainbows" (Wilson, Wonsyld, 10/25/2012). Harney County's low window seats on the south side are favorite places. One teacher made a "WOW" window through which children can see outside in all directions (Lovelady, 11/5/2013). Teachers use low windows as special places for reading, science, writing and art.

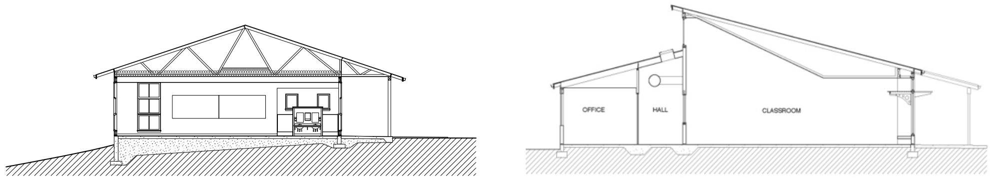

Figure 3: Sections north to south: Redwood EEC on the left, Harney County ECC on the right

2.4.3. Child-scaled Bathrooms and Sinks in the Classroom

Having children's bathrooms with child-sized fixtures in the classroom is essential. At Redwood EEC staff felt two toilets were necessary, but privacy has been an issue. In the "Yellow" classroom, fabric drapes were added to increase privacy in 2007, but by 2012 these were replaced with cabinets on top of the wall between the stalls. At Harney County ECC teachers agree one toilet is adequate, and they have turned the inboard toilet stalls into activity areas. Adult toilets down the hall are easily accessible if a second toilet is needed. Teachers at Harney County ECC also debate the privacy issue. The latched doors are hard for children to pull open – pushing would be easier. In both centers sink countertops are too wide, so children cannot easily reach the soap or paper towel dispensers. The plastic laminate counters have not worn well. One narrow trough sink, with space for two and paper towel dispensers at the side above waste cans, might be easier for children to use and improve durability.

2.4.4. Surfaces | Color | Special Features

Teachers in every classroom display on every wall surface, including some of the windows, and hang many kinds of things from the ceiling. Balancing the number of windows and the amount of tackable wall area is a challenge. Colors in both centers are intended to be calming. The "Yellow" and "Green" rooms in Redwood are pale. The interior room with fewer windows has the lighter, yellow color. In 2012 the yellow is lighter and the green a paler blue-green than in 2008. The Head Teacher reports the nature-like colors keep things calm (Broome, 10/25/12). At Harney County the classrooms remain painted a stronger blue, but in a climate with stronger light, the color unifies each room as a calm background. Harney County was designed with interior windows and Dutch doors between the classrooms and the hallway. The interior windows are appreciated for allowing parents and staff to preview before entering the classroom. The Dutch doors are particularly useful for the Infant/Toddler and Home-based Head Start classrooms, where the lower door contains the younger children while the upper door remains open.

2.4.5. Teacher Support and Storage

The teacher's 2.4 m [8 linear feet] of counter space in Redwood EEC is workable, even though it is split in two levels – one with the sink and the other higher. The 1.2 m [4 lf] in Harney County that includes the teacher's work sink is inadequate. Teachers from both centers say there is never enough counter space. Built-in cabinets in both centers provide storage for supplies. Redwood has 2.4 m [8 lf] of above-and below-counter storage. Teachers also have access to two shared storage closets, one between the two classrooms and the other used for dramatic play costumes. In 2012 closed cabinets were added above the wall separating the two toilet stalls, adding 3 m [10 lf] for supplies. Harney County classrooms have 4.9 m [16 lf] of full wall built-in storage. Each classroom also has a closet for additional materials, but these can only be accessed from the hall. Teachers would prefer direct access from inside the classroom.

2.5. Playgrounds Directly Connected to the Classrooms

Direct playground-classroom connections are highly valued in both centers. Children typically enter their classrooms from the playground. In both programs, classes go outside to play almost every day, and in good weather teachers keep the doors open and use the porches outside for activities such as easel painting. The two playgrounds are similar in size but very different in character. Redwood EEC was built in a forested site, and the playground feels embedded in the woods. Construction saved as many trees as possible, and playground elements are integrated with nature: grass swales, a sand pit framed with cut logs, a stone creek bed with pumped water, playhouse cabins, a tree house area, birdhouses and a manufactured "boulder" with fall area all around. The playground was volunteer-made and funded and remains well loved by staff parents and children. From 2008-2012 the playground has continued to be improved while increasing its natural character. The trike path from 2008 was extended, and a gate added at the top of the rise to prevent trikes from barrelling down the hill. The gate itself is a fun open/shut activity.

One new shed for gardening tool storage and several planter boxes were added. Water issues have been fixed with the grading. The sandbox needs a roof to protect it from the rain and for shade on hot days.

The Harney County ECC's playground was not part of the construction budget, and the center opened with a minimal playground: fenced dirt, one deciduous tree in front of each classroom's bay window, sidewalks for trike riding, two sections of grass and a sand pit. Since then the center has raised $121,000 in grant money for playground development. One large section now sports a large play structure on area filled in with soft-fall padding. Wood benches have been added, and three mulch areas with plantings are beginning to take hold. Most noticeably, the trees planted in 2007 have thrived – although they have yellow jacket traps hanging from them. The Harney County ECC playground was designed with a separate infant/toddler zone. That has not been further developed. Although the infant/toddlers use the playground at every session, parents accompany them, so there is lots of adult supervision. The long playground allows age separation just by distance (Yunker, 11/5/2012).

2.6. Versatility and Flexibility

Both projects were designed with a strategy for expansion, but neither has expanded. Within each building, some rooms have been used in new ways. The motor room of Redwood EEC was designed for easy conversion to a classroom, which happened during 2008-9, when the bathrooms were built out. After the full-day program was discontinued, staff were glad to have a multipurpose room back for parent meetings, training sessions, family day activities, parenting classes, rainy day recess and small group break-out activities. The large storage closet has been converted from ball storage for the motor room to an art studio. Furnished with both adult and child-size tables and chairs and audiovisual equipment and accessible from both the classrooms along the back porch and the lobby, the room works well as a multifunctional space. At Harney County ECC, the parent room, originally located at the front door, was moved down the hall, and the director's office moved into the original parent room. The lobby is large enough for parents to socialize, and the parent room was largely unused. The new parent room is smaller but outfitted as a Parent Coop with a computer, Internet access and open shelves with a lending library, clothes and canned goods. One parent was in there most of the day, using the computer (11/5 2012). The Director's office is in better location to welcome parents and children, be closer to the administrative assistant, and particularly in the summer, when she is the only employee on site, this location lets her control the door.

In both centers, the classrooms are designed as simple volumes for easy teacher supervision, while maximizing the flexibility for children to engage a variety of learning activities that can change with different furniture arrangements. Within each classroom, the Head Start curriculum has a set of activity areas: circle, writing, reading, blocks, art, dramatic play, computers, manipulative play, math, science. Interviewing teachers and recording in photos and maps the different ways different teachers have laid out the activity areas measures the flexibility of space. Teachers in 2007/8 and 2012 reported finding the classrooms in both centers had enough flexibility for them to change furniture groupings.

Figure 4: Furniture layouts: on the left, Redwood EEC Head Start classrooms in 2008 and 2012 | on the right, Harney County ECC Head Start classrooms for the 3's and the 4's in 2008 and 2012

Mapping activity areas and furnishings in 2008 and 2012 gives evidence to suggest there is more flexibility in the rectangular Redwood EEC classrooms than in the square rooms of Harney County ECC (Fig. 4). At Redwood EEC cubbies remained unchanged in the welcome area (3 m [10 lf] with two tiers of cubbies), and wet activities remained along the south wall. However, the location of circle shifted in both classrooms, and six of the eight activity centers changed location. At Harney County ECC there is less flexibility in the furniture placement, because of the position of the teacher's corner, determined by Internet connections and outlets, and its relationship with circle. The only circle that had changed was in the Home-based Head Start and that room was observed between socialization classes. To supplement the 2.4 m [eight lf] of built-in, single-tier cubbies on the north wall, each teacher has added additional cubbies in different positions around

the welcome area. The loft in the 4-years old Head Start room remains in the same place in 2012 as in 2008. It is remarkably effective in zoning the cubbies area and taking advantage of the height of the room.
When first observed in 2008 the number of pieces of furniture was greater in classrooms in both projects than the architects had anticipated. In 2008 each Redwood classroom had 32 pieces of furniture. In 2012 that number had only grown to 35. In Harney County the number of pieces of furniture has generally increased. In 2008 classrooms had 20-30 pieces of furniture, but in 2012 the range goes from 32-44. While some pieces have been removed, it has proved more common for pieces to be added. Most of the additional pieces are shelves and filing cabinets for storage.

2.7. Daylighting | Pools of Light

Each of these projects was designed to maximize daylight in the classroom with balanced light from the north and south. At Redwood EEC a 3.1 m [10’3”] high ceiling allows for tall, triple-hung windows, three ganged together along the south wall and two along the north wall at opposite ends. Four pendant fluorescent troffers and a ceiling fan with a light provide electric light. At Harney County ECC the lower flat ceiling over the wet activities zone along the south wall has five in-ceiling fluorescent fixtures, and the ceiling sloping up to the north has two pendant fixtures and a fan.

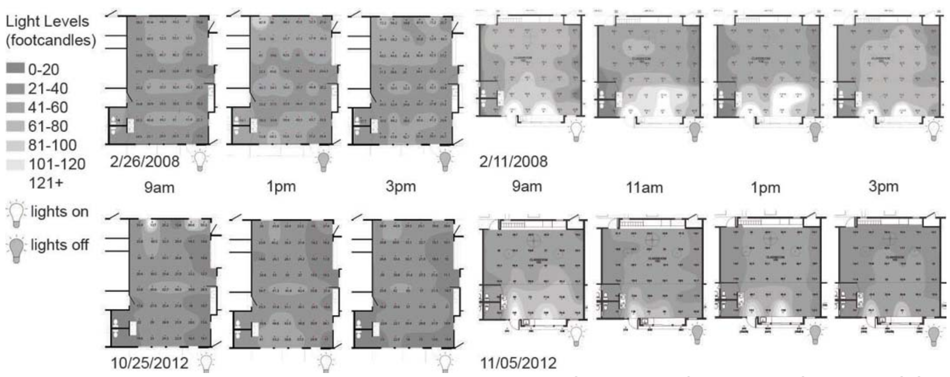

Figure 5: Illuminance measurements: Redwood EEC on the left, Harney County ECC on the right

In 2008, Grants Pass was overcast with some sun. Burns was sunny all day with snow on the ground. In 2012, both locations were overcast in the morning and sunny in the afternoon. Light levels in the main areas of the rooms were at or slightly below the recommended illuminance levels of 300-1000 lux [28-93fc] for preschool activity areas (Head Start Design Guide, 2005, 134). In both centers, light levels were lower in fall 2012 than in winter 2008 (Fig. 5), possibly because of the increased quantities of things, intended to make the room feel more “homey,” covering the windows, and in Harney County, the light shelves. Ironically, light shelves designed to maximize daylight penetration work equally well for display. Teachers reported that they prefer natural daylight and use electric lights to vary lighting conditions for pedagogical reasons. At lunch and rest times, lights are off. During free play, the lights are on, and teachers turn them off to get students’ attention. Teachers at Redwood reported that they usually only turn on half the troffers. Harney County ECC wanted blinds for the clerestory lights, because there are times they would like to darken the rooms more completely. Except for darker pockets near the walls and brighter pools next to the windows, light distribution in the classrooms in both centers was generally within a 3:1 ratio and did not exceed 5:1. Although creating pools of light with independent switchable lights was an earlier concept not realized in the final design, the only activity that seemed to need a focal light was circle. The windows create natural pools of light that vary throughout the day.

Figure 6: Luminance measurements: Redwood EEC on the left, Harney County ECC on the right

In Redwood EEC, the covered porch significantly reduces the potential for glare. The maximum luminance ratio measured was 24:1, well within the recommended maximum 40:1 luminance ratio for anywhere within the normal field of vision (Kwok, 2010, 512). In Harney County ECC the interior Venetian blinds reduce the potential for glare, and the maximum ratio measured between the main windows and the darkest part of the wall was 33:1. Two areas exceeded the recommended maximum: the windows above the light shelf, which are not within the normal field of vision of a child in the room, and the glazed door and adjacent window, which do not have blinds and had a maximum ratio of 161:1 (Fig. 6).

2.8. Thermal Comfort and Reduced Energy Usage

The coastal climate of Grants Pass is mild and rainy, and skies are often grey. Redwood EEC heats October-May and cools August-October. The exterior HOBO readings taken over one week ranged from 2-18°C [35-65°F] in February 2008 and 6-32°C [42-89°F] in October 2012. The Head Start Design Guide gives a guideline of 21°C [69.8°F] in winter (2005, 132). With classroom thermostats set at 21°C [70°F], the interior range during hours of occupancy in 2008 was 16-22°C [60-71°F]; in 2012 it was 19-23°C [66-74°F]. Complaints about thermal comfort came from the few rooms that did not have local air vents (manager's office, interior conference room) or local thermostat control (parent room). Although the building was originally planned for radiant floor heating, value engineering resulted in a high efficiency heat pump with forced air. Ceiling fans and operable windows allow for cross-ventilation and more air flow when desired.

In contrast, the high desert climate of Burns is one of extremes with very little precipitation. The exterior HOBO readings reflect its greater range of exterior temperatures: from -7-12°C [20-54°F] in February 2008 and -11-32°C [12-89°F] in November 2012. Harney County ECC heats October-May and cools August-October and late May-June. The heating was planned with passive solar strategies - all the classrooms and their windows face south. A radiant floor system supplements passive strategies. Because the system takes six hours to heat up, it is left on with a thermostat set at 20°C [68°F]. The interior range measured in 2008 was 20-23°C [68-74°F]; in 2012, it was 21-24°C [70-75°F]. Children and staff love the warm floor and that there is little dust. Teachers frequently use the ceiling fans and operable windows for cross-ventilation. Additional cooling is needed in the hot early fall and late spring. A passive system with louvers for night flush was designed, and a swamp cooler installed. When first tried, the low louvers let in the dust of the undeveloped playground. Teachers also expressed security concerns about having low vents and have taken over the floor area near the louvers, making them inaccessible. The swamp cooler did not work for the first five years, until someone local was found who could fine-tune its motor. The night flush now works with air coming from the swamp cooler and exiting the clerestory windows. The exterior sunshades at Harney County were value engineered out, and this may contribute to heat gain. However, trees planted along the south edge of the building have grown a lot in five years and offer shade. The only classroom that really overheats is the Infant-Toddler classroom, which has windows to the south, west and north, no exterior sunshades and only one modest tree. On an early November afternoon, the room was noticeably warmer than the other classrooms. To make passive heating and cooling strategies work, they need to remain a priority throughout construction, and fine-tuning and educating the users are critical. The decisions to cut the sunshades, use a VCT floor rather than exposed concrete, and not to use the night flush vents have eroded the potential efficiency of the systems.

Table 1: Energy consumption and cost

	Building	**Time Period**	**Energy Sources**	**Area** m^2 [ft^2]	**Annual Energy** MJ [kBtu]	**Annual Site Energy Use Intensity** MJ/m^2[$kBtu/ft^2$]	**Annual Energy Cost** $	**Annual Cost/Unit Area** $\$/m^2$ [$\$/ft^2$]
Grants Pass	*Merriman*	10/2011-09/2012	Electric and Natural Gas	678 [7300]	719,212 [681,681]	1,060 [93.3]	14,244	13.4 [1.95]
	Redwood EEC	10/2011-09/2012		650 [6992]	583,053 [552,628]	897 [79.0]	9,344	14.4 [1.34]
Burns	*Old Building*	07/2005-06/2006	Electric and Oil	698 [7509]	474,001 [449,267]	679 [59.8]	7,913 (8,793*) **adjusted*	11.3 (12.6*) [1.05 (1.17*)] *for inflation*
	Harney County ECC	07/2011-06/2012	Electric and Propane	799 [8600]	515,826 [488,909]	646 [56.8]	10,657	13.3 [1.24]

The energy costs of the two buildings were compared after analyzing utility bills (Table 1). The Redwood EEC building achieves a 51% energy reduction from the median energy consumption of a building of similar size, location, use, and equipment (EPA Energy Star Target Finder; using k-12 as the basis for comparison since there is no category for pre-k) and a 15% reduction in energy use compared to the Merriman building, another Head Start building in the agency. The Harney County building achieves a 70% energy reduction from the median energy consumption of a similar building and a 5% reduction in energy use compared to the old building. At Harney County propane was selected as the source of heating fuel, because of its low price at the time, but since then the price has skyrocketed.

2.9. Economies of Construction | Maintenance and Durability

Both of these projects were designed with very lean budgets. Redwood's sloped and wooded site with a lot of ground water meant higher construction costs for excavating and replacement with new select fill. At Harney County, the budget was even tighter, but the relatively flat and treeless site with utilities in place kept down site costs. Both projects used repeating trusses and standard construction. Redwood EEC used trusses with one plate height, except for the tower and deep roof overhangs to the south. Harney County used inverted trusses with two different plate heights, and the higher 3.7 m [12'] interior wall required additional sheer capacity. The Redwood staff was not pleased with the contractor. After five years, there is truss lift at the ceiling in the entry hall that results in periodic cracks in the sheetrock. The sprinkler system needs constant maintenance and it costs $2,000 each time to drain the system to repair leaks. Harney County after a second bidding process was very satisfied with their contractor's performance. However, the swamp cooler that was planned to save dollars cost more to install, because it required two different subs, and only in the last year has it been effective. Both projects have regular twice-daily cleaning protocols and weekly and seasonal floor waxing and window cleaning standards. The larger carpets are shampooed and smaller carpets come in and out. Redwood EEC has repainted the interior four times, while Harney County ECC has not yet needed to repaint.

Having a kitchen at both centers has allowed them to save dollars and provide organic, low salt and low sugar meals that the children like. The kitchens prepare breakfasts, two lunches (am and pm) and afternoon snacks and also serve dinners for parent and family events. In each building design, square footage for the kitchen competed with space for classrooms, and both kitchens ended up undersized. Redwood had already expanded its kitchen subsuming an adjacent closet by 2008, but the space remains too narrow and too small. In both kitchens the need for cooling and ventilation were underestimated. Redwood's cooling problems are exacerbated by its location facing south. The overheating of the kitchen stresses the refrigerator and freezer and makes it hard to make bulk food purchases without danger of their spoiling. By 2012 Redwood had added a swamp cooler to help with kitchen's cooling. Harney County's kitchen was not outfitted and operational until 2009. Before then, food was brought in from the Youth Prison. By cooking their own meals, Harney ECC is saving enough money to use organic ingredients. The location on the north side of the building helps keep the kitchen cool, but the refrigerator and freezer had to be moved into the main space, because they generated too much heat and needed a bigger area with adequate air flow. This makes the kitchen even hotter and louder, and the swamp cooler situated to cool the kitchen has never worked. Planning for appropriately sized kitchens with adequate ventilation and cooling has long-term savings.

CONCLUSION

The federal government has been doing longitudinal studies for years on the effectiveness of the Head Start program on the lives of children. Although the government has not done post-occupancy evaluations of Head Start facilities, there are design guidelines. This post-occupancy evaluation supports many of the existing guidelines and provides evidence for design principles that can add value in their application to future projects. It makes a case for new facilities that will make Head Start programs visible and increase their sustainability as resources for children, families and communities. Both these centers demonstrate how new buildings can integrate goals for social, environmental and economic sustainability, giving Head Start programs presence and stability, fostering environmental awareness and reducing operating costs.

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URBANISM

Technology, Connectedness, and the Urban Environment

Re: Tool-Kit for Detroit

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ABSTRACT: Detroit is a city defined by making. The refrain “You can get anything made in Detroit” is often quoted today even after the decline and relocation of the automotive industry. Given the condition of Detroit, the state of American manufacturing, and the fact that the city and its fabrication networks are illegible to newcomers and industry outsiders, the *Re:Tool-Kit for Detroit* research project questions the veracity of this claim. The project asks what can you *really* get made in Detroit *today*. Who are the makers operating in the city today? Where are the fabrication shops? How does fabrication shape the city today? And how is the culture of making in Detroit evolving in response to the changes in manufacturing, the rise of digital fabrication, and an influx of artist and craft based making?

By mapping the fabrication landscape of the city, and packaging the research in a way that is accessible to designers, and students of art, architecture and design who may not be fabricators, the research seeks to create new opportunities for the under utilized fabrication capacity that already exists in Detroit and to encourage new collaborations between university and city, design and fabrication. Research for this study was gathered through 47 interviews conducted with a range of fabricators. Interviews were recorded and analyzed. Fabrication shops and fabricators were documented photographically and mapped.

The research findings have been exhibited at the University of Michigan and will be available in the form of a website and a printed (and printable) “toolkit” both of which contains a map, directory, journalistic case studies, and a series of historical vignettes documenting previous examples of industrial production collaborating with art and design in the city of Detroit. The research project has also entered into a partnership with a non-profit “designed to support Detroit’s growing creative economy” called the Detroit Creative Corridor Center.

KEYWORDS: Detroit, fabrication, making, interviews, toolkit

INTRODUCTION

Even before the invention of automobile, Detroit was a city that made many things. It was a city defined by making and what was made there.[1] The refrain, “You can get anything made in Detroit” is still heard frequently even today in the face of a relocated automotive industry and rapid population decline, indicating that making is still the identity of Detroit even if what is being made is no longer the automobile, and what will be made in the future is yet to be determined. The *Re:Tool-Kit for Detroit* research project sought to answer the question, “What can you *really* get made in Detroit *today*?” By creating a map of what can actually be made in Detroit today, who is doing the making, where things are being made, the project sought to expose how the culture of making in Detroit is evolving at this moment after the restructuring of automotive industry but also in response to the proliferation of digital fabrication and the rise of artist and craft based entrepreneurialism. Data collection efforts were aimed at creating a snap shot of a shifting moment in time – capturing information about how old-school fabrication shops are changing as well as information about what kinds of new shops are forming. To that end, research for this study was gathered through interviews with 47 Detroit area fabricators ranging from long-standing tool and die shops that do not use digital tools, to hi-tech service based fabricators working for military and medical clients, craftsmen fabricators, start-up artisanal fabricators, and collective maker spaces where tools and resources are shared among multiple members.

The *Re:Tool-Kit for Detroit* research project, which is ongoing at this time, deals with the visibility of research in its core objectives, its method of research collection, and the format of the research output. From the outset of the *Re:Tool-Kit for Detroit* research project, mapping the fabrication capacity of the city was seen as a way of rendering both the city of Detroit and its fabrication network visible to a new audience. The desire to make the knowledge of one community visible and accessible to another literally drove decisions about the design and content of the research products. The form of the products produced by the research incorporated a graphic design agenda that sought to present the data in a way that was insightful, useful, communicative, democratic and compelling to an audience that was not necessarily already familiar with

Detroit or fabrication. The decision to employ interviews as the research method served to further connect the research with a larger community as the outreach and organization required to contact, select and conduct the interviews required. This paper will begin by describing in detail the final products produced by the *Re:Tool-Kit for Detroit* and then discuss the research methods, findings, modes of distribution and future potential.

Figure 1: Street views of operational Detroit fabrication shops, Fall 2012. Source: (*Re:Tool-Kit for Detroit*, 2012)

1.0 TOOLS

The *Re:Tool-Kit* is a collection of information gathered, organized and designed to facilitate collaborations with Detroit area fabricators. The tool-kit targets an audience that is either partially or wholly unfamiliar with Detroit and the state of fabrication and provides readers with practical tools and information that would be needed to engage the fabrication community. It is also aspires to inspire readers to imagine new ways that Detroit area fabrication techniques and modes production can be incorporated into design concepts and projects. By providing insights into the character of the Detroit fabrication community, in conjunction with the tools needed to connect with the human capacity and fabrication know-how that already exists in Detroit, the tool-kit aims to facilitate collaborations between a new generation of designers and existing fabrication sectors of Detroit for mutual benefit. To that end, the tool-kit takes the form of a guidebook, a website, and an exhibit. Each product targets a different audience and is anticipated to have a different circulation and life span. This section will describe the intentions, design, character, and considerations of each product as well as the subsections of the guidebook.

1.1 Guidebook

Although the bulk of the guidebook takes the form of a directory, it is not designed to function as a traditional directory such as Angie's List or the yellow pages. It does not exhaustively cover what can be made in Detroit nor does it aspire to be a how-to guide for learning about local fabrication technologies.[2] Rather, it is envisioned as a guidebook or window into the world of Detroit fabrication. It provides an overview level understanding of Detroit's fabrication network, the character of the fabricators, where they work, how to find them and how their work has changed over time. Directory style information is contextualized with graphic symbols, maps, photographs, and stories from the present and past. The guidebook is organized into nine sections: a series of introductory essays, a symbol guide, a map of shops, the directory of shops, case studies, historical vignettes, a timeline, photographs of interviewed shops, and a reference bibliography covering fabrication technology, creative economy, graphic design, and Detroit fabrication history.

1.2 Graphics

Communication graphics were a critical component of all components of the Re:Tool-Kit. The guidebook, website, and exhibit employ a series of unique symbols developed specifically for this project. The symbols create a unified graphic identity for the various components of the project, simplify complex content for a non-expert audience, and provide an efficient means of keying the various sections of the guidebook to one another. Symbols were developed for each fabrication shop type, materials, client types, and a number of other categories aimed at describing the scale, level of finish, and capabilities of each shop included in the directory. The symbols are intended to be a entertaining, non-verbal method of organizing and visualizing a range of information and can be added to and adapted over time. The guidebook states,

> The symbols act as a friendly guide through the material, in much the same manner that familiar pictograms help us navigate foreign places. The symbols in the *Re:Tool-Kit* offer distillations of complicated arrangements – easy to recognize and easy to recall, they are the breadcrumbs that mark a trail through the book and through the city. Though inherently reductive in form, in spirit they aspire to reach out and pull viewers into an evolving story already in progress.[3]

1.3 Directory

The directory allots two pages to each of the 47 shops interviewed (Figure 2). The information presented was selected to do two things. If a reader is simply curious about fabrication or Detroit in general, they can easily see the similarities and differences between various fabrication shops. If a reader is looking for a fabricator that can provide a specific fabrication process, the directory is intended to provide the basic level of information that would be needed to make contact with a fabricator and discuss a possible project. It is our aspiration that once a reader understands the capabilities of various fabrication shops, they might incorporate that mode of production into a design project.

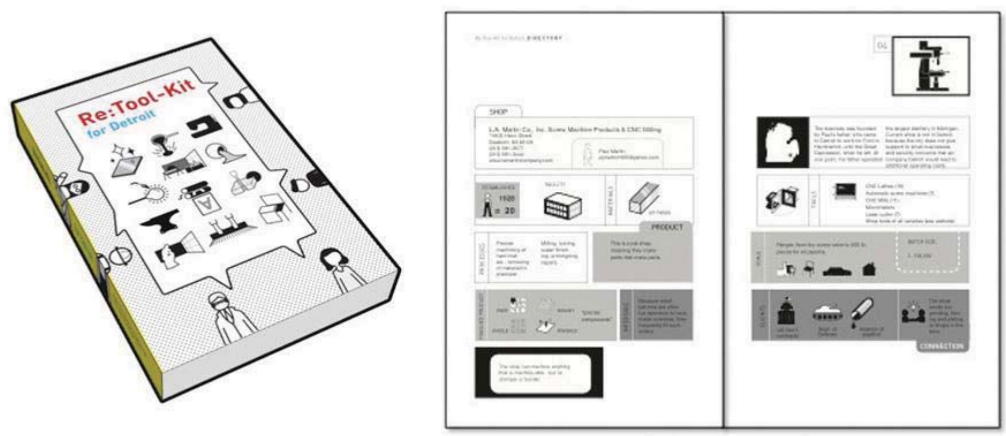

Figure 2: Guidebook cover and typical two-page directory spread allotted to each shop. Source: (*Re:Tool-Kit for Detroit*, 2012)

In addition to contact information, the founding date of each shop and number of employees, there is an icon indicating whether or not the shop occupies its own building or shares space with others. Materials used in the shop are indicated with icons where as processes and tools, which become complicated or too numerous and varied to illustrate graphically are indicated with words. Typical and unusual final products are listed. The scale, typical batch size and level of finish of the final product is indicated. Client types are listed so it becomes clear if a shop will work with individuals, architects, or strictly with other industries and businesses. The symbols are also used to key shop locations to the city map which, when fully populated, will show industrial corridors, and how new and old shops are inhabiting different city zones.

1.4 Case Studies

In addition to including anecdotes and quotes from fabricators on directory sheets, the guidebook included several journalistic case studies that go into greater detail about the history and production of a spectrum of shops. They rely heavily on quotations so that personalities and opinions are as true to character as possible. The case studies cover: 1) a 23 year old artist/entrepreneur who started a sewing production non-profit that employs homeless women to make sleeping bags that convert into coats, 2) an experimental prototype firm doing high-end, low-volume production for military and aeronautical clients, 3) a plastic injection molding company located on an empty street directly across from Chrysler, 4) an furniture maker/sculptor who makes high end custom sculptures and furniture out of metal, wood, and glass, 5) a recently established blacksmith shop which moved to Detroit specifically to educate others about their trade and participate in the making culture, 6) an architectural metalwork shop specializing in pre-welding technologies and education of traditional craft based techniques through a European guild model, 7) an investment casting company started in 1961 that has shrunk from one hundred and twenty to twelve employees in the last twenty years, and 8) metal tube bending shop which was established in 1905 and was the oldest shop covered in our research established to convert ship engines from steam to gas prior to the rise of the automobile.

1.5 Historical vignettes

Ten vignettes dealing with historical partnerships between Detroit designers and manufacturers are included in the guidebook as a means of providing a context for re-tooling and unlikely collaborations. These vignettes show that Detroit's industrial sector has historically been adaptable, diverse and open to outside influences. The vignettes include examples of the art world and automotive industry working together as well of examples of artists using industrial production processes, factories using the same tools to produce craft and industrials products, and examples of retooling during war times. These vignettes are intended to inform readers about how technologies have historically evolved in an effort to spark ideas about how current tools and technologies might be adapted and developed through new collaborations between design and fabrication.

1.6 Website

A website was to developed as a compliment to the guidebook. The online medium has the potential to reach a larger audience. It is more adaptable than print and could accommodate a more extensive directory or be developed to track the changing fabrication landscape. Information from the tool-kit is reformatted and edited for the digital format, but largely the same in content (Figure 4). It is built upon a familiar Google map, but is intended to not simply direct viewers to specific locations or supplant the physical world, but rather, like the book, to complement and deepen one's understanding of a non-visible network.

Figure 4: www.retoolkitdetroit.org. Source: (*Re:Tool-Kit for Detroit*, 2012)

1.7 Exhibit

An exhibit of the *Re:Tool-Kit* was held at the University of Michigan in November of 2012. The exhibit was designed to make the research, website and guidebook available to the public and the university community. Interviewed fabricators were also invited. The exhibit included large scale versions of the symbols developed for the project, a map of all interviewed fabricators, objects from fabricators showing what can be made in Detroit today, and a large number of photographs collected during the interview process. Photographs taken from the street of the exterior facades of the 47 shops were grouped together and contrasted with interior photography showing people, tools, space, details, and activity of the interiors (Figure 5).

2.0 RESEARCH METHODS

This section of the paper will describe the research methods, selection of interviewees, and questions asked.

2.1 Database

Research for the project started with the creation of a database of four hundred shops collected via internet directories, driving around the city looking for fabrication shops and asking for recommendations from local fabricators and people who make things and get things made. This database was added to over the course of the project as interviewees continued to recommend other shops that they considered "first class," successful or remarkable for any number of reasons. The final 47 interviews were selected based on a combination of who was willing to be interviewed and an effort to reach a spectrum of different shop types, fabrication processes, tool lists, business structures, locations, and products.

Figure 5: Research on the City Exhibit at The University of Michigan, November 2012. Source: (Taubman College of Architecture and Urban Planning, 2012)

2.2 City limits

The majority of the shops interviewed were located in Detroit, but several were located in surrounding areas. For the purpose of creating a defined data pool, the original intention of the project was to look exclusively at the city of Detroit, but in order to achieve a spectrum of processes and shop types, ten of the 47 interviews were with shops located outside of the city limits. Many of these shops had originally been located in Detroit. One moved during the course of the project. For many reasons, the fabrication networks of Detroit do not stop at the city limits. Industrial hubs tend to form near their source of materials or business. Many fabrication shops that formerly provided parts to automotive manufacturers are located in close proximity to their primary source of business and customer base. Other shops are located along transportation corridors, or in areas where city services best benefit business needs. Although the city of Detroit is 139 square miles, Metro Detroit (also referred to as the Detroit Tri-County Area) encompasses 1,337.16 square miles. Business and residential areas have long been interconnected and interdependent with the surrounding areas. It could easily be argued that a true map of Detroit fabrication needs to include shops both inside the city limits as well as shops located in the Detroit Metro Area, and to compare the types and success of the two groups, but given the size of the city, that was outside the scope of research at this time.

2.3 Interview

Interviewing fabricators was determined to be the best method for collecting information about fabrication shops because it produced qualitative and inclusive information. What and how things were made was wrapped up in personal stories about the city of Detroit, the particular business, and attitudes about craft and expertise. The interviews provided insight into the spirit and character of the people that make things in Detroit and the difference between one machine shop and another might have more to do with the personality and history of the business owner than with the list of tools, location, clientele and typical batch size. In order to capture the character of the shops and in keeping with the guidebook aesthetic, bits of anecdotal information and quotations collected during the interviews are interspersed with factual information to provide insight into the character and particularities of each shop.

Interviews consisted of thirty-five questions and took approximately one hour. Questions were developed and tested through a series of initial interviews over a period of three months. In the final version, the questions were grouped into eight categories: making/products, history, tools and skills, business, networks and communication, Detroit, and the *Re:Tool-Kit*. Questions asked included 1) what is made 2) what tools and skills are required, 3) how does the business work - number of employees, batch size, scale and finish of products, and customer base, 4) when did the shop start and how it has changed over time, 5) does the shop "collaborate," 6) is the shop capable of making something different than they make today, 7) how does one find the right fabricator for a job in Detroit, and 8) how does being in Detroit affect the work.

2.4 Photography

Every shop that was interviewed was also photographed in the following categories: exterior street façade, signage, entry, interior space, people, tools, materials, and objects made. The city of Detroit and its many ruins have been extensively photographed in recent years. What has been less documented is the interior of the city.[4] The exterior photographs collected as part of the research are not distinguished from much of the recent photography of Detroit. What is significant is the contrast between exterior urban appearance and interior life. Photographs of the people, tools and interiors of studios and workshops taken during the interview process show another side of Detroit busy at work but not visible from the city streets (Figure 1, 3).

Figure 3: Examples of interior photography of interviewed shops. Source: (*Re:Tool-Kit for Detroit*, 2012)

3.0 OBJECTIVES ASSUMPTIONS AND FINDINGS

This section describes in greater detail the objectives, assumptions and findings of the research. It also outlines questions and areas of future work raised by the research done to date.

3.1 Fabrication capacity

From the outset, the *Re:Tool-Kit* suspected that despite the state of American manufacturing and Detroit's present day economy, there is still a wealth of knowledge, know-how and fabrication capacity in the city. Knowing that many small-scale fabrication shops that were once part of an extensive network of automotive feeder industries have been hard hit in recent years, the research project sought to access and quantify the knowledge, skills, craftsmanship and tools. If the existing fabrication capacity and making network could be identified, mapped and rendered visible to a larger audience, a new generation of designer/makers, and a developing movement toward craft-based entrepreneurialism, making could become not only the identity of Detroit, but also its future.

3.2 Illegible city

The appearance and distribution of fabrication shops in Detroit follow similar patterns that exist in many similarities with other American cities. Fabrication businesses concentrate along transportation corridors in light industrial areas populated with durable workshop buildings, often windowless. The invisibility of making and fabrication may not be unique to Detroit, but it could be argued that the once booming fabrication industry and extensive presence of large and small scale manufacturing within the city limits, has added to the illegibility of present day Detroit—especially given the fact that many of these businesses have gone out of business, relocated outside of the city, or have greatly reduced hours of operations and fewer employees. The research also brought to light other reasons that fabrications shops seem opaque and hard to find. In the heyday of the automotive industry, many small-scale fabricators produced specialized products in large batches for recurring clients and did not need to advertise. We learned that most business was done through well-established business-to-business relationships and marketing was not needed. Our interviews revealed that many fabrication shops still rely primarily on word of mouth for finding new clients and many that are used to large contracts and dealing with familiar entities are not interested in walk-in and low volume business. In addition, due to safety concerns regarding the theft of tools and materials, many shops are completely barricaded by security fencing. It is possible to see where buildings are missing or in a state of disrepair, but its much harder to see any clue as to what is going on inside these buildings, not to mention what is being made inside.

3.3 Definition of fabrication

The definition of fabrication used for this project was purposefully inclusive. The term fabrication was often used interchangeably with making and was determined to include old-school shops that do not use digital tools, to hi-tech service based fabricators working for military and medical clients, craftsmen fabricators, start-up artisanal fabricators, members of collective maker spaces where fabrication tools and resources are shared among multiple members and artists who are skilled at techniques that might have traditionally be classified as fabrication—such as metal work, machining and assemblies.

The decision to interpret fabrication very broadly had two purposes. The first was simply in an effort to understand what is being made in Detroit. The second has to do with the difficulty of setting parameters given the computerization and democratization of tools and processes. The proliferation of digital-based fabrication tools has led to the disintegration of the traditional division between design and making. Artists, architects and designers can now produce design and fabrication drawings simultaneously in a single digital file. Sophisticated modeling tools allow multiple differing skill sets such as those of designers, consultants, and fabricators to all work together simultaneously on a project from the very beginning, rendering illegible the moment when the design ended and construction began. This collapse of design and fabrication/construction is changing both design and fabrication. It increases the pressure on designers to understand the potentials and limits of fabrication before the design process even begins. What might better unify the data pool than the term fabrication is a qualification about the scale of making. All of the shops interviewed can be classified as small-scale as opposed to large-scale manufacturing. This scale of making is more likely to be of interest to the design sector. Both old and new shops included in the interview process, were dealing with low volumes of production whether by intention or lack of business.

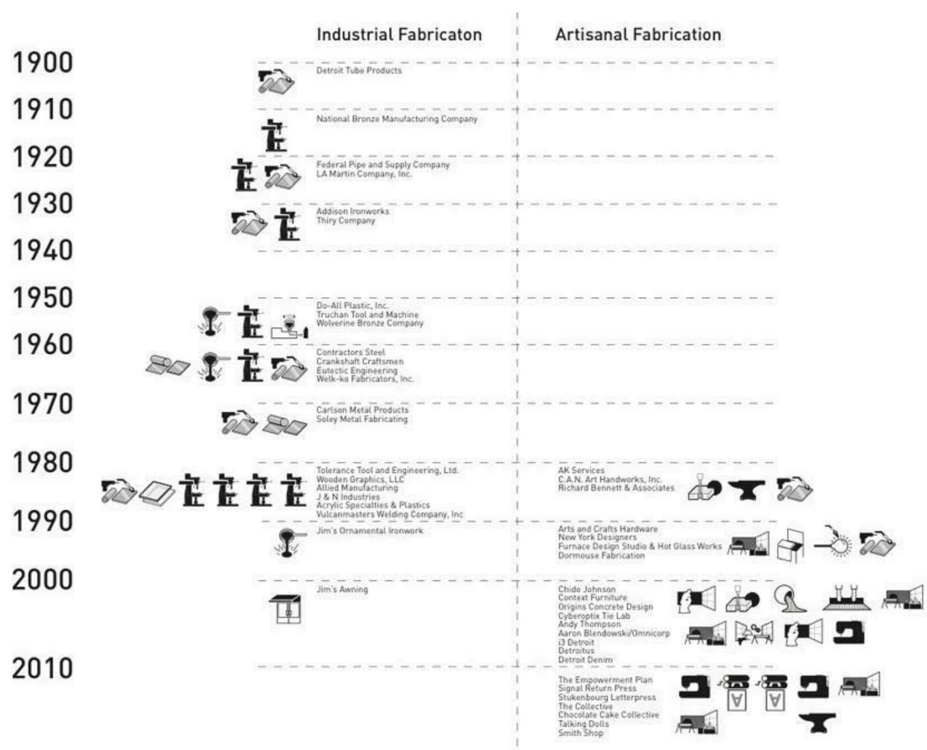

Figure 6: Timeline of interviewed shops. Source: (*Re:Tool-Kit for Detroit*, 2012)

3.4 State of transition

The data collected shows that the culture and business of making in Detroit are indeed changing. Older shops are closing while a new breed is forming and moving in. This moment includes both old school and brand new shops, but the number of old-school shops is diminishing every day. A timeline of the 47 shops interviewed organized by fabrication type shows a clear shift from industrial fabrication to artisanal fabrication. All of the shops in our data pool that started before 1980 focused on industrial production. After 1980, there is a clear shift toward more designing and a designer/fabricator hybrid (Figure 6).

While many older shops were passed down through families from generation to generation, new shops tend to be started graduates of art and design schools – many of whom are originally from Michigan. Both new and old shops often started in a basement or a garage. There was a wide array of tools and skills. Some of the shops we interviewed use state of the art tools and specialize in prototypes and low volume production or high-tech work for aerospace and defense. Other shops had not purchased a new machine in forty-three years—but told us these machines are increasing in value as reliable back-ups to computer operated machines. Many shops were working at less than 20% capacity. Several said they never wanted to work for the Big Three ever again.

4.0 DISTRIBUTION

The distribution strategy for the *Re:Tool-Kit* is based upon a genuine desire to make connections between designers and Detroit area fabricators. To that end, a website was created which will link to a version of the guidebook that can be downloaded or printed on demand. The study initially focused on connecting students of art, architecture and design in the South Eastern Michigan region with Detroit's fabrication capacity because there is a growing educational interest in fabrication technologies, but many students seek work outside of Detroit. Information about the guidebook and research will initially be advertised via 300 printed copies, paid for by research grant funding, and distributed to all 47 interviewed fabricators as well as professors at the University of Michigan in art and architecture. The intent is that faculty will refer the books to students and that fabricators will refer the book to possible clients and other fabricators.

4.1 Partnership

In order to increase circulation of the research as well as continue the process of mapping Detroit's present day fabrication capacity and network, the *Re:Tool-Kit for Detroit* team has entered into a partnership with a non-profit "designed to support Detroit's growing creative economy" called the Detroit Creative Corridor Center (DC3). DC3 will add an essay to the guidebook, publish and circulate additional books in South East Michigan. They will also provide assistance for maintaining and possibly growing the website to include a greater number of directory entries. This partnership will increase the visibility of the research locally as well as insure the initial objective of the project of providing a platform for new collaborations and business.

CONCLUSION

The *Re:Tool-Kit for Detroit* aspires to connect a new generation of people to the existing fabrication network in an effort to contribute to the revival of post-industrial cities in a way that acknowledges with their historical character but also open the way to new opportunities and modes of production. The research captured a snapshot of what can be made in Detroit today and packaged the research for maximum distribution. The research team currently seeking to partner with economic researchers to situate the qualitative data collected within an economic context. In addition, although the *Re:Tool-Kit for Detroit* was developed in response to a specific place and a specific set of conditions, the project is seen as a proprietary set of research tools and forms of output that can be abstracted into a framework and applied to other cities.

ACKNOWLEDGEMENTS

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Determinants of Urban Energy Use: Density and Urban Form

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ABSTRACT: With a particular focus on urban energy use, this study investigates the implications of mixed-use high-density development in a small urban community to curb sprawl in terms of the relationship of urban form and urban density. Every building as a part of the urban core not only affects the urban form but also modifies density, microclimate, and energy use. These relationships are location specific. The interconnected nature of these physical, spatial and environmental characteristics is untangled by investigating individual building form and functions as well as their relationship with other buildings as a function of urban spatiality and density. The first part of this paper explores the potential for increased urban density employing Ralph Knowles' seminal Solar Envelope Concept. The second part investigates the relationship between development density and urban energy use intensity. The microclimatic modifications of increased density development are then compared with the existing urban form and their impacts on energy use are studied employing a simulation approach. In conclusion, the suitability of energy implications of a mixed-use development as a part of urban form and density are suggested. The outcome of this investigation provides insights on building and urban form, achievable density and urban energy needs. This research is relevant to the community and local government that will decide on a new development paradigm. This study also provides a platform for future integration of the socio-economic aspects of introducing high-rise, high-density developments.

KEYWORDS: Urban Energy Use, Urban Form, Urban Density, Mixed-use Development, Microclimate

INTRODUCTION

The population of Bozeman, MT is growing at the rate of 3% to 4% per year and is expected to double in next 20 years from 40,000 to 80,000 (US Census Bureau, 2010). This increase in population and the towns currently adopted low-rise development guidelines may potentially lead to urban sprawl in an ecologically sensitive area. The negative impact of sprawl threatens to replace fertile land with impervious surface areas and will expose the community to increased vehicular traffic, environmental pollution, social segregation, and increased infrastructural cost. However, using smart growth principles (CNU, 2010), the mixed-use high-rise density development will not only help accommodate the growing population but also provide an opportunity to live and work in close proximity. Further, the population can be within walkable distance from the amenities they need and enjoy like retail, co-operatives, banks, schools, museums, libraries, theatres, parks, trails, outdoor activities and more. This will be crucial as 70% of the future population is expected to be retirees, students and professionals and, nuclear families who will seek an urban experience per the Bozeman Community Plan (2009).

The major drawback of dense downtown areas is that they consume a significant amount of urban energy within a small area (Steemers, 2003). Also, tall buildings may potentially prevent solar access in habitable spaces. Further, the downtown area is warmer than surrounding areas due to trapped urban heat and as a result modifies microclimates (Oke, 1988; Mills, 2006) as well as urban climates (Cleugh and Grimmond, 2012). It particularly affects urban air temperature which increases space cooling energy needs (Bhiwapurkar and Moschandreas, 2010). However, a cold and dry climate can benefit from reduced heating energy needs. In order to explore the suitability of mixed-use high-rise developments, this paper seeks answers to the following questions;

- What is the relationship between urban form and density?
- What is the relationship between urban density and energy use intensity?
- How does urban form influence microclimate?
- How does microclimate modify building energy use?

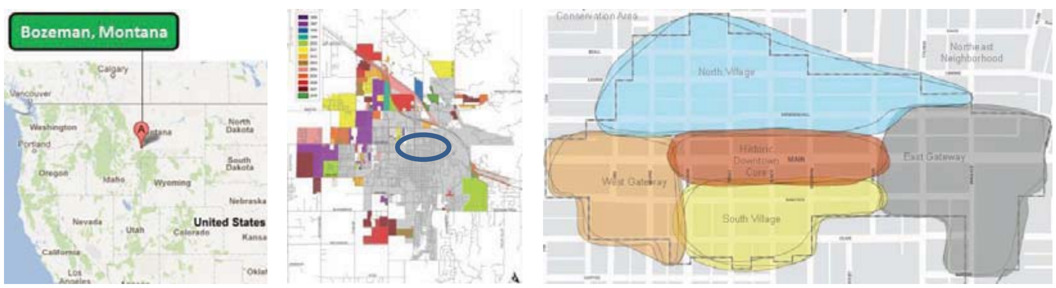
in the context of Bozeman, MT as a case study.

1.0 METHODS

In order to investigate the relationship of urban form, urban density, urban energy and microclimate, this study was divided into four parts. The first part of this paper employs Ralph Knowles' (1985) seminal Solar Envelope Concept to explore the potential for increased urban density. The second part investigates the less explored energy potential of the solar envelope (Knowles, 2005) towards urban densification. The third part focuses on the investigation and comparison of the energy implications of increased density for single use development and mixed-use development within the existing downtown core. This part constitutes a major component of this paper. The fourth part explores the microclimatic modification of increased density development. The microclimatic conditions of an existing urban form is compared with proposed new urban form and its urban energy modifying characteristics are analyzed. In the conclusion, energy implications and warming trends of a mixed-use development are suggested to inform evolving urban form and urban densification. Adopting a simulation approach for microclimatic investigations as well as whole building energy studies, this paper focuses on the eight blocks of the historic downtown core of Bozeman, MT.

1.1 Urban form

The Bozeman Community Plan covers the City as well as nearly two-mile area around the city. The city is approximately 50.50 km² (12,477 acres) and the planning area is 171.71 km² (42,463 acres) including the City (Figure 1). Over the past decade, a significant amount of land has been annexed because of population growth and hence urban sprawl is inevitable. At the core of the city, is the historic downtown spread over 3.92 hectares (9.7 acres) of land, which consists of 8-urban blocks along the East-West axis formed by the Main Street. This area has been studied for potential increase in development density as the majority of urban commercial activities are located here. Each block is approximately 43 meters (140 feet) long and 24 meters (80 feet) wide, although most of them vary marginally in sizes. Particularly, the Eastern blocks (Figure 2) are wide and are averaged as 168 meters (550 feet) and 24meters (80 feet) deep.



(a) (b) (c)

Figure 1: (a) Location map (source: Google maps) (b) Development map (c) Downtown Bozeman, MT consists of five distinct zones; Historic Downtown Core, East Gateway, West Gateway, North Village and South Village (Source: Downtown Bozeman Improvement Plan, 2009)

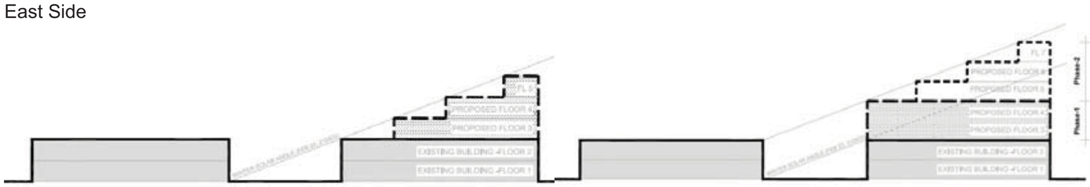
Buildings in the downtown core are 2-story high and the Main street façade is characterized by a combination of brick walls and storefronts. A majority of the buildings are late 19th century buildings with wood frame construction, which host a variety of functions including offices, retail shops, restaurants, local services as well as convenience stores with a few apartments. There is a mix of building uses in each urban block, most of which are locally owned, which makes it very special for the community. These blocks are symmetrically organized along 24 meter (80 feet) wide E-W oriented Main Street. 4-blocks along the Main Street are separated by N-S oriented arterial roads of 18 meters (60 feet) wide (Figure 2). The street width includes sidewalks

1.2 Density

The density of the downtown core is estimated by calculating total land area divided by the actual built area. As most of the development is commercial, its density is represented by square meters/hectare (m²/ha) and dwelling units/hectare (du/ha) represents density of residential units. The historic downtown core covers 3.92 ha (9.7 acres) of land area and there is 59,030.60 m² (635,400 sf) of built area, which gives a density of 15,058.82 m²/ha (65,505 ft²/acre). The few residential units that exist in the core are not accounted for this study. In order to accommodate the growing population, the city is considering increasing the density of the downtown core, an opportunity explored in this paper. As local climatic conditions are primarily cold and dry, solar access to each urban unit is very important. Therefore exploration of the Solar Envelope Concept (Knowles, 1985) is considered useful for this study, keeping in mind the streetscape and construction feasibility of a proposed new development.

(a) (b)

Figure 2: (a) Block view of the study area (b) Historic Downtown Core consists of eight urban blocks and are equally divided by the Main Street along East-West axis and are bounded by Grand Street on West side and Rouse Street on East Side



Option-1 Option-2

Figure 3: Increased development density using the solar envelope concept. Option-1 provides year round solar access to existing commercial units on north side of the street. Option-2, explores the possibility of further densification on south side of the street considering that north side commercial development are internal load dominated building that mostly depend upon artificial lighting. As a result, the solar cutoff angle begins at/is the roof level of north block. Two alternatives are considered under this option. Phase-1 proposes two additional floors of exactly same size on existing building. Phase-2 includes addition of three more floors within solar envelope.

1.3 Energy Use Intensity

The energy use intensity (kWh/m² per annum) is estimated by dividing total annual energy use by all buildings types of the eight blocks divided by the total built area. The energy use intensity of the existing urban block provides a "Baseline" for comparative analysis of proposed new urban form. Amongst above densification alternatives, Phase-2 of Option-2 is considered most relevant for such comparison in this study which is expected to provide insights on densification. For the purpose of evaluating energy performance, this option is further developed as a single-use (Baseline+1) and a mixed-use development (Baseline+2) to explore applications of the solar envelope concept beyond recent studies of Niemasz et al. (2011) for a cold climate. The single-use development, by addition of two floors on existing two story buildings, would result in a total build up area of 118,061.18 m² (1,270,800ft²). The mixed-use development considered residential development for an additional two floors, which would result in total commercial, build up area of 59,030.59 m² (635,000 ft²) and total residential build up area of 59,030.59 m² (635,000 ft²). This comparative urban energy use analysis of urban form focuses on total energy use as a result of a combination of uses and densification and the other building parameters are kept constant during the course of the study.

On-site building surveys are conducted to identify building use, construction type, surface thermal properties/R-values, and occupancy schedule in order to identify and establish representative/prototypical buildings used in energy simulations (Table 1), similar to some previously completed studies (Bhiwapurkar and DeBaillie, 2007). The identified building types are office, retail-bar and lounge, retail-local stores, and restaurants with complete menu as well as fast food services. The utility data would have helped in order to make the energy model of existing urban blocks more realistic and the author wishes to incorporate it in future works. This simulation model acts as a test run for further developments, and provides strong foundations for seeking answers to the research questions posed in this paper as demonstrated in some previous works of Bhiwapurkar et al. (2007).

Table 1 provides accumulated values of various individual units of each building type, which are conditioned by a packaged single zone DX system with furnace. The efficiency of packaged units is averaged to EER of 8.5 and furnace efficiency average of 80% is most appropriate considering the age of these installed units and partially available nameplate data. Also, the natural gas non-residential domestic hot water system is modeled at 80% efficiency. The set points – 24.4ºC (76ºF) for cooling and 21.11ºC (70ºF) for heating are kept constant through the study. A whole energy simulation program, eQUEST 3.64 (DOE, 2009) has been previously validated for its algorithm and published elsewhere, and is considered suitable for this study (Bhiwapurkar and Moschandreas, 2010).

Table 1: Building prototypes and characteristics.

	Building Type/Function	Total Area (m²)	R-Values		Roof Albedo	Glass Properties		Lighting Power Density [W/m²] (W/ft²)
			Roof	Wall		SHGC	U-Value(W/m²K)	
A	Office	16,648	R-21	R-6	0.5	0.63	0.48	16.14 (1.50)
B	Restaurant-Bar/Lounge	16,648	R-14	R-6	0.5	0.8	1.04	16.14 (1.85)
C	Retail-Departmental Store	8,324	R-21	R-12	0.5	0.8	1.04	25.61 (2.38)
D	Retail-Service Station and Convenience Store	17,410	R-21	R-12	0.5	0.8	1.04	25.61 (2.38)
E	Residential (proposed)	59,030	R-38	R-20	0.5	0.35	0.48	5.38 (0.50)

1.4 Microclimate

In order to perform microclimatic simulations, urban texture (Figure 4) is analyzed based on the information gathered from Google images and compared with GIS shape files provided by the city of Bozeman. This information on urban texture includes parcel size, building footprint, roof surfaces, parking lots, street and pavement surfaces, and vegetation as shown in Figure 4. The Majority of the urban surfaces are hard pavements (around 90%); mostly asphalted roof surfaces, some of which are painted white although they are in a deteriorated condition. The asphalt surface area also includes roads and parking lots. Most sidewalks are made of paved concrete (2%) along the street. Vegetation in this study area is less than 5% although parks, creeks, farmlands, and mountains surround the downtown core. Vertical building surfaces are two stories high with mostly red brick surfaces and storefronts, which are more prominent at street level. The average roof and wall albedo values for this study is considered as 0.4 and 0.3 respectively based on the existing surface types and their condition that are visually inspected and compared with thermal properties of the material mentioned in the literature (ASHRAE Handbook, 33.3, Table 3: Properties of Solids). The prevailing wind direction of N-NW as a starting condition, urban roughness of 0.1 and total simulation time of 18 hours which provided the required starting conditions starting at 3:00 am is considered for this study. The urban climate simulation program, ENVI-met 3.1 Beta 4, used for this study has been previously validated (Bruse, 1999) and is commonly used for similar studies.

Figure 4: Surface texture maps of historic downtown core distinguish paved surfaces; streets, sidewalks, parking lots and vegetated surfaces.

2.0 RESULTS AND ANALYSIS

2.1 Urban form and urban density

The application of the solar envelope concept to increase density of the buildup area in the downtown core is demonstrated in Figure 3 along with possible new urban forms. This paper looks into two densification scenarios. The Option-1 considers increase in built area by addition of three floors on the existing building in order to allow year round solar access to commercial buildings on north side of the street. Option-2, especially Phase-1, is developed to benefit from thermal behavior of commercial buildings and these internal heat-load-dominated buildings would be shaded during day time to minimize solar heat gain. Both these options propose new developments over existing buildings and retain open spaces for future use, although most it is currently used as parking lots.

Using Option-1, the built-up area can be increased to 95,787 m² (1,031,040 ft²) which is an increase of 36,756 m² (395,640 ft²) add percentage over an existing urban core as shown in Table 2. This percentage increase in built-up area increases existing development density from 71,748,544 m²/ha (65,464 ft²/acre) to 116,376,568 m²/ha (106,183 ft²/acre), made possible by the addition of three new floors to the existing building that follows winter solar angles and are recessed from the street side. Adopting Option-2 increases existing built-up area by 83,917 m² (903,280 ft²) as a result existing density increases to 173,675,448 m²/ha (158,463 ft²/acre). This option can be implemented in two phases. Phase-1 adds two floors on existing buildings that increase existing built-up area by 59,031 m² (635,400 sf) and existing density increases to 173,675,448 m²/ha (158,463 ft²/acre). The additions of three more floors in Phase-2 increases existing built-up area by 83,917 m² (903,280 ft²) and raise existing density to 173,675,448 m²/ha (158,463 ft²/acre). Option-2 provides few development scenarios that include targeting specific blocks to be developed over others. Both these options provide maximum densification with controlled solar access to the neighboring buildings with a possible addition of floors over existing buildings.

Table 2: Densification of downtown core using solar envelope approach.

	Land Area (hectares)	Built-up Area (m²)	Increase in Built-up Area (m²)	Density (m²/ha)
Downtown Core	3.92	59,031	-	71,748,544
Option-1	3.92	95,787	36,756	116,376,568
Option-A (Phase-1)	3.92	118,061	59,031	143,586,960
Option-B (Phase-2)	3.92	142,948	83,917	173,675,448

The current densification proposal per the Bozeman Improvement Plan includes 20 du/acres in the downtown area with residential unit sizes ranging from 93 m² -139 m² (1000 ft²-1500 ft²). Adopting Phase-1 of Option-2 would add two floors per block and comfortably meet suggested density which needs 194 dwelling units in the downtown area by considering maximum unit size of 139 m² (1500 ft²). That provides extra built-up area of 56,883 m² (612,280 ft²) for other urban functions like community places, retail shops and other community needs including parking structures. Thus, the solar envelope provides enough flexibility not only to build residential units of various sizes and parking structures but also accommodate other community needs and provides solar access to urban buildings.

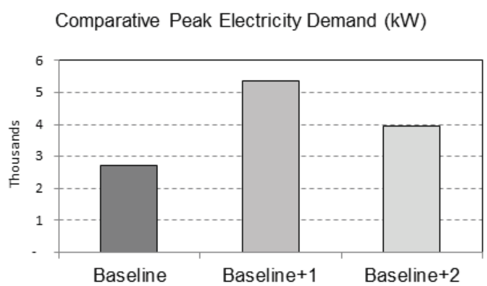
An increase in residential development would also complement new retail activities in the downtown core to meet growing urban demands. For example, a convenience store of 1858-2787 m² (20,000-30,000 ft²) and a neighborhood center of 5574.2-7432.24 m² (60,000-80,000 ft²) require a density of 600-800 du/ha (6-8 du/acres) in order to be financially feasible (Farr, 2007). This suggests possible additional retail development. In this manner, increased numbers and varying sizes of residential units for sale, rental and ownership in the downtown core will support retail investment and vice versa. Thus, encouraging financial investment in the downtown area will not only boost the local economy, as observed by the community in the past, but also help curb urban sprawl. Most importantly, the proposed residential units will have a close proximity to amenities like banks, grocery, schools, parks, post office and so on that are already a part of the downtown core and are commonly suggested for smart growth. In this way, urban densification would contribute towards completeness of the urban neighborhood by providing flexibility in urban building functions to meet changing needs of the community. In addition, downtown densification will help generate more tax revenues compared to the suburban development (About Town, 2012) and the city invests additional revenues earned beyond 1995 tax regulations in the development of the downtown core (City of Bozeman Economic Development Plan, 2009). Recently built public library, town hall, parking structure, and street furniture are examples of this scheme and the community benefits are evident. The following section looks into the implications of mixed-use development on urban energy usage intensity that is crucial for deciding the power infrastructure.

2.2 Urban density and urban energy use intensity

In order to understand the additional energy infrastructural needs of urban densification, this section compares the energy needs of the existing urban form with the proposed new urban form. This comparison is based on a peak electric demand as well as annual energy generation capacity of the power plant required to meet the urban energy needs.

Using simulation results, the Baseline (existing urban form) peak energy demand is 2700 kW that occurs at 3:00pm on August 2 and the annual energy need is 8.7million kWh (Figure 5). Using this data, the estimated energy use intensity of the existing downtown core is 131.52 kWh/m²-year (12.3 kWh/ft²-year). This energy usage is in the acceptable range when compared with the Commercial Building Energy Survey Consumption Survey data for Climate Zone-1 (EIA, 2013). The Baseline+1 represent a single use but doubled density of the downtown area per Phase-1 of Option-2. The simulation results shows that the peak electric demand of Baseline+1 is increased to 5,355kW and it is shifted to July, 12 at 3:00pm whereas annual energy need is raised to 17.5 million kWh. This is an increase of 98% and 100% in the peak energy demand and annual energy use respectively. Thus, doubled peak demand and annual energy trends are observed as a result of doubled density development.

The Baseline+2 shows a change from a single-use development to a mixed-use development in the existing urban downtown area per Phase-1 of Option-2. The peak electric demand, total energy use, and energy use intensity of the Baseline+2 is reduced by two thirds (67%), half (53%), and one third (37%) respectively, compared to the Baseline+1. The Baseline+2 electric demand peaks at 3,929 kW, consumes 12.13 million kWh annually and energy use intensity is 91.46 kWh/m²-yr (8.5kwh/sf-yr) as shown in Figure 5. Thus, a single-use densification proposal causes 98% increase in peak electric demand compared to a 45% increase by mixed-use densification in the existing urban area. It indicates that the electric demand for a single use development can support twice the size of mixed-use development. Similarly, the total electric energy use of Baseline+1, a single-use development, is increased in the order of 100% over the Baseline scenario. However, a mixed-use development suggested in the Baseline+2 can sustain within 39% increment over the Baseline. Importantly, urban energy use intensity of Baseline+2 is decreased by 31% due to mixed-use development over the Baseline.



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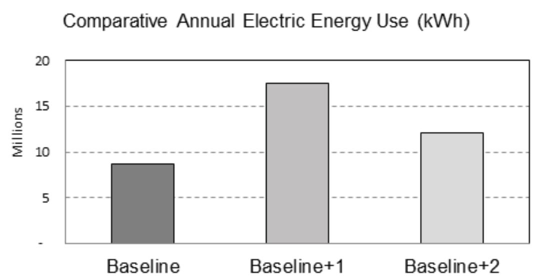

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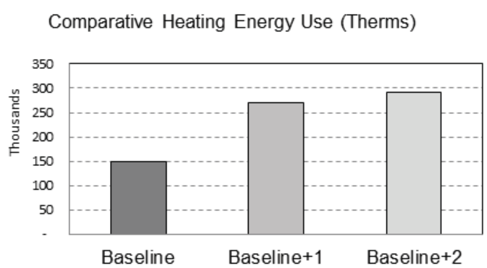

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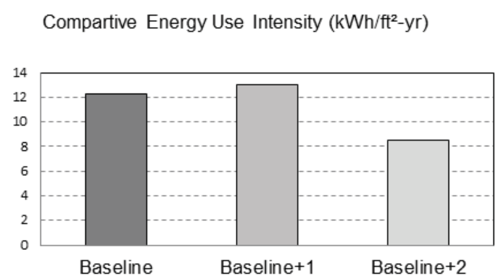


(d)

where;

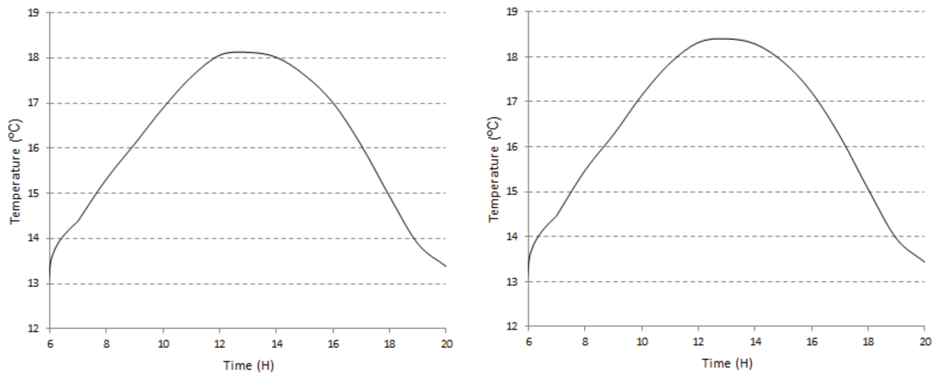
Baseline	Existing Downtown Core
Baseline+1	Option-2, Phase-1 (existing downtown Core + a single-use development)
Baseline+2	Option-2, Phase-1 (existing downtown Core + a mixed-use development)

Figure 5: Comparative energy performance of the existing urban form (Baseline) with a proposed single-use density development (Baseline+1) and a mixed-use density development (Baseline-2) (a) peak electric demand (b) annual electric energy need (c) annual heating energy (d) energy use intensity

It is also observed that the heating energy use is increased with the increase in the density of the downtown area. The Baseline+1 showed an increase in heating energy use by 82% over the Baseline scenario, which is proportional to the increase in the build-up area. The Baseline+2 heating energy use is increased by 97% over the Baseline. So, there is a difference of 15% in the annual heating energy needs of a single-use and a mixed-use development. This difference is a function of the increased internal volume and envelope surface area of residential units compared to commercial units, which increased heat losses to very low outdoor temperatures during winter months. Also, a change in time of use of residential and commercial buildings is considered as the main reason for this change in heating energy use. The peak energy use in residential buildings occurs in the morning as well as in the evening hours when outside temperature is either warming up or cooling down respectively, compared to the single use internally-dominated buildings that peaks around afternoon hours.

2.3 Urban form and microclimatic changes

The existing downtown core of eight blocks (Figure 4) separated by 24 meters (80 feet) wide E-W oriented Main Street and 18 meters (60 feet) wide N-S oriented streets are analyzed using urban microclimatic simulation program, ENVI-met 3.1 Beta 4, on July 12, 2012. The mean air temperature of an urban canopy, an imaginary urban void formed between two urban blocks on 24.38 meters (80 feet) wide street bounded by the ground plane and a roof height, is recorded at every 1.0 m from ground level to the top of the urban canopy at 10.0 m. This temperature data is then averaged to get temperature graphs presented in Figure 6. The Baseline (existing downtown) and the Baseline+2 (existing downtown + additional 2-stories) conditions are used for this analysis. The comparison between the existing and a proposed new urban form shows maximum change in the mean air temperature of 0.4 C during 1 pm as shown in Figure 6.



(a) (b)

Figure 6: (a) Temporal variation of mean canopy air temperature of the existing downtown core (Baseline) on 07/12/2012 (b) Temporal variation of mean canopy air temperature of the proposed densification of the downtown core (Baseline+2) on 07/12/2012.

The changes in the mean air temperature shown in Figure 6 is much lower than expected, however while analyzing microclimatic changes, it is important to note that the only change in the baseline and the proposed model is of increased wall surfaces with fixed a albedo value of 0.3. So, the observed changes in microclimatic conditions are due to increased vertical wall surfaces, which are exposed to solar angles of 60º at noon and 40º at 9:00 am and 3:00 pm. Also, only the South facing urban canyon surface is exposed to the sun while street surface is shaded by low solar angles. Further, high Sky View Factor (Oke,1988) of low rise structures provides higher exposure to sky that helps in radiative cooling of a heated surface after the sunset, however if the ambient air temperature is lower than the wall surface then it helps constantly release heat to the outside environment which may affect canyon air temperature. This phenomenon, daytime temperature differences among various built environment, as a function of street geometry could be significant by creation of urban heat island or cool islands (Svenson and Eliassson, 2002), is considered as one of the reasons for low temperature differences observed in this study (Golany, 1996).

2.4 Microclimatic changes and urban energy use intensity

The modified air temperature changes due to increased surface areas of the Baseline+2 are incorporated in the weather file used for energy simulations. No significant change is observed in the energy use of the Baseline+2 conditions. The internal heat load dominated buildings and a low occupancy of residential units during daytime are considered as major reasons for this. The microclimatic changes during winter days is not modeled due to current limitations of the ENVI-met program to incorporate snow surfaces, typical of winter condition in the study area. So, energy changes during winter conditions are not estimated. However, it is expected that the compact urban development with high-density development would help retain urban heat and thus, this warming effect may benefit cold climates as observed in the studies conducted in Switzerland, for example (Frank, 2005).

Based on the work completed so far, it is evident that this work would benefit from the field measurements in order to validate urban climate simulation models as well as be able to test winter benefits of compact development. Also, field measurements would help account for the anthropogenic heat sources like the heat released by building forms and automobiles that could not be included in the microclimatic simulations. Further, establishing a rural climatic condition to explore microclimatic effects of the urban form in a small community would be helpful. Nonetheless, this study provides direction for future works.

CONCLUSION

By exploring urban form, urban density, urban energy use intensity and microclimatic conditions, this paper provides new insights on urban development process for small communities. Employing Knowles' seminal Solar Envelope approach, the first part of this paper performs solar analysis of existing urban form to increase the urban density and current development density of 71,748,544 m²/ha (65,464 ft²/acre), which can be increased to 140,877,452 m²/ha (130,927 ft²/acre). The second part of this paper investigates changes in the urban energy use intensity due to increased development density. Doubling the build-up area with a single-use development doubles the simulated urban energy use intensity of the downtown core. However, mixed-use development significantly reduces energy needs of increased density development in the third part of the investigation. The peak electric demand, total energy use, and energy use intensity can be reduced by approximately two thirds (67%), half (53%), and one third (37%) respectively indicating that the electric demand for a single use development can support twice the size of mixed-use development. Importantly, urban form with mixed-use development decreases urban energy use intensity by 31%, from 131.52 kWh/m²-year to 91.46 kWh/m²-year. The fourth part of the investigation focuses on microclimatic modification of increased density and compares it with the existing urban form. The average dry bulb temperature of the downtown core canopy is reduced by 0.4ºC on a summer day and a very marginal change in the urban energy use is observed at this time.

The significant outcome of this study is that there are urban energy implications and microclimatic effects of the solar envelope approach. Combining both these interconnected effects, it is critically important that the mere addition of new urban surfaces potentially modifies microclimatic conditions and this influences energy and environmental needs of the community. Further, this investigation indicates that small communities can benefit from microclimatic conditions it generates, especially in cold climates. Thus, by increasing development density in a compact manner can help balance urban growth and minimize negative energy and environmental impacts. Most importantly, the adopted approach in this paper is relevant to the community and local government that will decide on a new future development paradigm.

FUTURE DIRECTION

A current limitation of urban climate simulation model to simulate snowy conditions limits the heating energy investigation. The microclimatic conditions presented in this paper can further deteriorate by anthropogenic heat sources like heat released by the built environment and related vehicular traffic, which can be accounted by exploring the density and transportation relationship in future works.

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The Future of Urban Design: Opportunities of a New Pragmatism and the Disappearance of the Client-Expert

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ABSTRACT: In a similar way as for architecture, the client demands for urban design have considerably changed over the last two decades. Since its official founding in the post-war era practiced as a form-oriented design discipline that focused on the medium scale somewhere in between architecture and regional planning, it is now understood as an evidence-based management discipline that steers a gradual process of change and adaptation. This paper elaborates on the thesis that visibility in terms of traceability and accountability will become an increasingly important feature for the profession. The point is made that the urban designer has to convey and prove his knowledge to a decision-taking client that does not necessarily have the technical competence to decide, nor a clear program to follow. Functional considerations and their fulfillment are still key, but are complemented by far more strategic demands that have grown in relevance through the recent emphasis on the urban condition as a main driver of economic competitive capacity.

It should be clarified that the author, due to his origin and research experience, often uses European references and that he focuses on an analysis of the profession in the developed rather than developing world. The content of this paper is predominantly based on the knowledge gathered during the writing of three comparative books about housing typologies, high-rise in the urban context and planning methodologies. This knowledge has been applied to the professional sector following a research consultancy mission in a campus planning agency during the summer of 2012.

KEYWORDS: urban design, profession, process, strategic management, master planning

INTRODUCTION

Main part:

The reasons for the above-mentioned mutation of the urban design profession are manifold. For the sake of simplicity they can be attributed to three major realms: the one relating to questions of supply and demand, the ideological one and the process-oriented one.

1. In terms of demand, we just do not experience the same need for hygienic living space as was the case in the century after 1870, and especially after WWII. Housing shortages are still of preoccupying scale in many urban agglomerations, but due to a lack of political pressure the topic rarely gets on top of the federal government's agenda. This situation stands in contrast to the instability of the late 19th century in several European countries, when the improvement of living conditions became a major argument in order to prevent social unrest. Public agencies, forced to deal with the situation, were willing to implement grand urban interventions which stand at the origin of "urban design" in the narrow sense of the word: in the most extreme case, built under a single ownership and designed by a single hand, large areas were developed in the suburbs of the historic cores, and suggested the birth of a design discipline that could not just be considered as an "accumulation of architectures". Though not at the center of the paper's preoccupation, this differentiation is relevant, and exemplifies how crucial the understanding and possibility of a holistic approach is to the birth of its denomination as a new profession. The actual ingredients of urban design - buildings, the spaces in between or in the middle of buildings, streets and squares - had obviously not changed, but what had changed was the fact that they were planned and implemented on such a large scale, in fairly short time and by small planning teams. This was a historic novelty, especially for working class residential structures that had only on an exceptional, philanthropic and usually paternalistic base been in the planning powers' center of interest. Famous case-studies are Claude-Nicolas Ledoux's Royal Saltworks in Arc-et-Senans (1775), or - less glamorously - Emile Mueller's Cité Ouvrière in Mulhouse (1853). Due to the country's old age and its relative economic and political stability, the urban history of France in general offers an at times almost cliché-like vision of central planning and its consequences. In the post-war

period, it will be difficult to find another democratic country that has implemented as rigorously as France new urban paradigms such as the Grands Ensembles, the archetype of mono-functional housing estates, built between the mid-50s and mid-70s on cheap land on the outskirts of the larger cities. Despite the often bleak outcome, it should not be underestimated, how quickly a very efficient machinery had been set into motion that satisfied social, political and economic demands. The creation of desperately needed residential space was a welcome opportunity for the business community to modernize the whole building sector and to establish a new network of infrastructures. Today, the demand situation is quite different, and in many places, especially Japan and some European countries like Germany and Italy, we even have to cope with decreasing rather than increasing populations. This does not mean that there is no more building activity in the residential sector, at times even in the form of megastructures, but it does mean that there is less need for public control and coordination. Budget cuts hence make large-scale expropriation by the state almost impossible. The result is a far more slivered market, wherein it is difficult to recognize any clear models and parallels, a factor which is however also linked to the lack of historic distance. In ten or twenty years it might be easier to identify the commonalities of projects that are currently ongoing. An atomization and liberalization of the market can be recognized on two levels, the first one being a larger amount of market players, a thesis that - due to the increasing observance of oligopolies - would have to be verified, and the second and more important one, being the fragmentation of land ownership and its consequences on development models and initiatives. A research topic on its own, this latter point marks the major difference between state-urbanism versus private initiative, as much as intervention outside urban cores versus intervention in central location. Another way of expressing this opposition of development philosophies is the confrontation and comparison between a tabula-rasa urbanism on the one hand, best exemplified by Le Corbusier's Plan Voisin for the reconstruction of Central Paris, and infill and retrofit strategies on the other. What this paragraph is trying to convey is the simple assessment that the type of demand has an impact on the work definition of an urban designer, directly, but also indirectly through the legal tools that the public sector is willing to put in place in order to satisfy this demand. The Roppongi Hills development in Tokyo is a recent case-study that perfectly illustrates how difficult the assembly of scattered city-center ownership can be without the use of eminent domain through the state. In order to build the new district, it took even one of the largest and best connected private fortunes in Japan over 17 years to buy up the necessary land. In contrast, for the construction of Stuyvesant Town in Manhattan, the earliest example of post-war urban renewal in the US, the city prepared the ground, displaced over 10.000 inhabitants, and, in late 1945 demolished structures on over 60 acres of inner-city land. All this happened in less than 2 years on the base of a new law (the Hampton-Mitchell Redevelopment Companies Law of 1943).

2. Regarding the question of ideologies, urban design has followed a similar direction as many other societal issues after the 1989 Fall of the Wall. The dissolution of the east-west dichotomy in the aftermath of this event had a fundamental impact in our way to lead political discourse, and it ended a phase during which essentially all decisions were somehow linked to the defense from the Communist threat and the anxiety of a nuclear war. The consequence of this in principle positive development - in which pragmatism has taken the lead over enforced unity - has been a general loss of "cheap utopias" and big ideas. The events after 1989 eventually only emphasized and accelerated a long ongoing process in which the grandeur of the nation-state became gradually replaced by a multi-nodal reality of globalized urban networks. Today, the political discourse about urban questions has not vanished, but a new generation of citizens (and voters) expects more than a "for me or against me" rhetoric that - often in a politically convenient manner - veiled the complexity of the actual problems. The author's German background might overestimate this notion due the country's geographic location and its unfortunate role in WWII, but periods like the McCarthy era in the US suggest that the - allegedly artificial - simplification of public discourse was not limited to this specific geographic zone. As much as we like to refer to them in desultory efforts of grandiosity, the mindset of the Plan Voisin, Broadacre City, but also Stuyvesant Town and Sarcelles seems to be gone. Overwhelmed by an infinite amount of "smaller" issues, very few professionals or academics are concerned with comprehensive visions of the future, may they refer to spatial questions or mankind as a whole. An excellent, though extreme example of the overlay of urban and political issues can be found in the history of Stalin-Allee (now Karl-Marx-Allee) and the Hansaviertel in Berlin of the late 1950s. The former one came first and was built by the communist regime in East-Berlin in the form of a monumental axis as an architecturally very traditionalist demonstration of power. The latter one, initiated as a purely pragmatic reconstruction measure, eventually grew into an equally ambitious marketing campaign, and received the status of an "Internationale Bauaustellung", just like the famous Weissenhof-Exhibition in 1927. Now considered one of the most important examples of post-war avant-garde urbanism, it showcases masterpieces of residential architecture from influential modernists like Aalto, Niemeyer, Beaudouin, Taut or Eiermann. Also from an urban point of view, the conceptual contrast with the pompous Karl-Marx-Allee could hardly be more pronounced, and the Hansaviertel masterplan in an almost forced manner denies any symmetric order or relation to the street, influenced by Scharoun's ideas of a new "Stadtlandschaft" (urban landscape). Coming back to questions of landownership, it is highly revealing to notice that private

ownership of the Hansaviertel was only reinstated in order to highlight the political refusal of measures that could have appeared similar to the nationalization of land in East Germany. In reality, many western planners were actually in favor of a similar approach, and the resulting plot structure was a redistribution that had little in common with the historic situation. In order to implement the project, all land had temporarily been gathered by a public development company, ignoring and erasing the small-scale plot structure of the former 19th century "Gruenderzeit-viertel", which had almost entirely been destroyed during the war. Though an extreme comparison, this case-study is meant to underline the thesis that urbanism and politics can hardly be separated, and that the relatively recent, but fundamental changes in world politics do have an impact on how we plan the built environment.

As a general remark, one that might help us not to focus too exclusively on political issues, there is a link to be made with the preceding explanations surrounding the question of demand, as it can be assumed that the birth (and death) of urban ideologies is somehow triggered by the demand for a certain product and the media attention that it produces. It seems for example improbable that « Existenzminimum » had become an important notion in the history of architectural modernism, as part of the New Objectivity movement, if there had not been a material need for very modest accommodation. Today, just to mention the main driver, it is very difficult to imagine progress in the field of urban design without sustainability at the center of attention. Ecological and social needs have forced us to densify existing urban fabrics, rather than to further expand on greenfield territory. The above-mentioned polarization between large- and small-scale development can hence be seen as much as a demand question, as one of ideologies. What came first, becomes essentially a hen-and-egg problem.

Whatever the reasons are, the opportunities for Grand Design are minimized, or exported to new markets in the Middle and Far East. This point, the impact of large-scale planning activity in foreign markets on the self-conception of a whole profession, has in the author's opinion been largely underestimated: in the boom years until 2008, all major design offices have proudly been focusing their efforts on markets that had little in common with the situation in their home-countries, preventing the here presented changes to become more often publicized and discussed. Everybody was fascinated by 3D-renderings of artificial islands and new high-rise districts, the less prominently situated ones being awkwardly reminiscent of the most extreme cases of post-war slab urbanism. Is it by chance that we now, in a humbler economic climate, read more about New York's High-Line as a spectacular example of re-use, than about new city projects in China or Abu Dhabi? In the dense urban context of the western world, the theories of a Sitte, Wagner, Hilberseimer, Geddes, or even Koolhaas and Krier, might still be important and helpful, but the real challenge is to adapt them to a context that now usually inhibits the implementation of a comprehensive masterplan. As a closing comment for this paragraph, it might be useful to re-emphasize that this paper is concerned with the self-understanding and future development of a profession, rather than the reality of what actually is built. The fact that urban sprawl in the form of low-density and car-dependent residential developments is a still ongoing urban disaster, potentially the 20th century's most relevant planning and urban-design phenomenon, does not necessarily mean that it is the question that best defines the profession's major preoccupations. For the good or for the bad, most of us - those working in academia and publishing - do not consider ourselves as being linked to this phenomenon.

3. Last but not least, the process-oriented questions surrounding urbanism and urban design have experienced a major change through the erosion of the client-expert in a postmodern environment that challenges the logocentric paradigms of the Enlightenment Project. Once the built environment is not seen any more as a consequence to a specific problem, but as one of many parameters for the creation of an innovative and very competitive economy, the definition of the program and measure of success surpasses the capacities of the corporate client and his focus on the reaction of the end-user. Emphasized through an ever growing need for flexibility, an evidence and survey-based approach becomes the only way to communicate, and the visibility of this approach a vital need for accountability. The content of this paragraph dwells on the assumption that the form and existence of the city, and built artifacts in general, is not just a consequence of other, "more tangible and important" factors, but a driving force in itself. Today, we – the city administration or private entities – increasingly do not just plan or build factories, because we need work-space, or residential quarters, because we need more dwellings, or sewers, because we are afraid of diseases, but we build museums in order to attract talent, or student centers in order to provide more efficient communication space. In a constant effort for economic optimization, growing competition and hence aggressive marketing, architectural and urban features are becoming subjects, rather than objects. It could rightly be claimed that this phenomenon always existed - think of all major monuments, or, City Beautiful as a whole period -, but it seems as if we had reached another scale, one that has encompassed the private sector. The difficulty of such a non-quantifiable role, in which space allocation loses its dominance over allegedly secondary parameters, is the definition of the program, the selection of the best proposal and the measure of success. With this in the back of the mind, who could be such an omniscient

expert-client, and if there is one, would he like to be accountable for potential failure? These are the circumstances under which the urban designer has to prove his added-value, in giving evidence - visibility - to his suggestions and architectural choices. The technological advances of the last years and the widespread use of social media have drastically altered and improved the opportunities to - almost instantly - identify dysfunctionalities and unsatisfied desires, as much as to test design alternatives and measure reactions to the built result. Through these tools, programming, participation and competition can be revolutionized, a process that is already ongoing through the implementation of digital city government. A radical counter-example to these complex efforts of democratic process-management can be given through an analysis of the structure of many 20th century social housing agencies, the London County Council as an extreme case internally employing hundreds of designers. A lack of differentiation between architecture, landscaping and urban design - allegedly an inherent component of modernist design philosophy - was accompanied by the fusion of the client and service provider roles, a mode of functioning that since has almost completely disappeared.

Another interesting case-study is provided by the university campus. As a small version of an ideal (and almost autarchic) city, it offers an environment that particularly well documents the above-mentioned changes and opportunities. With the rare exception of some major extension projects and new university foundations, the urban design challenge of such entities is not any more primarily one of implementing a specific formal order between architectural artifacts, but the ability to adapt the institution's growth vision to its physical features, potentially even to help define the vision itself. The simple question is how to guide and control a continuously ongoing process of transformations that will raise the university's profile and income. A decision and comparison regarding such proposals has become increasingly doubtful without the delivery of evidence. Taken to the scale of the profession as a whole, a previously internally-led discussion about design principles, often more philosophical than scientific, will hence be externalized with the client as major addressee. A simple example of these changes is the « results-menu » on Sasaki's website (www.sasaki.com), highlighting not building images, but the research outcome and socio-economic impact of their implemented projects. In the middle and long term, it will be very difficult for practices to enter this market without a clearly articulated research strategy, something that is not easy to do for small structures.

CONCLUSION

What does all this mean in more practical terms? There are two ways to evaluate the consequences of these radical, but gradual changes, and the difference between them depends on the reaction of the professionals. The changes can be considered as a threat, if designers do not manage to adapt their toolset to these new demands, but they can also become a new opportunity to finally take the key role that often has been given over to project managers or real-estate consultants. The question therefore is, how education can prepare students for this new situation, and how much design-orientation and -knowledge they need? If too much emphasis is given to urban design in the traditional and heroic sense, dealing with the actual design of new districts or even cities, too little time might be spent on the above-mentioned process-management issues that represent a growing market. The opposite can lead to a situation in which fundamental urban principles are overseen. The evaluation of artistic principles in urban design hence remains a major issue, as much as the question, if these can be conveyed to students without comprehensive studio work. A review of the curriculum of urban design master programs documents this quest, a particularly clear example being the New School's new Master of Design and Urban Ecologies, in which the students are taught to design « processes for urban transformation ».

The main motivation to write this paper was not that much the presentation of new market tendencies, as these have now been ongoing for several years, but rather the wish to ground them in a historic perspective of the urban design profession, and its always problematic delimitation towards the architectural and planning fields. An interesting and somehow surprising byproduct of this research for the author has been an updated view on the differences between 19th century, modern and contemporary urban development, and its main driver for change. In this context it is interesting to note that the assumption of a radical break between « traditional » and « modern » design features, in the sense of a deliberate design decision, eventually steps back in importance compared to the differences in the development set-up. Seen from this perspective, the future of urban planning - at least in terms of organization - might have more in common with Regent's Street (1814-1825) in London or some of Baron Haussmann's (1853-1870) Parisian breakthroughs, very complex in terms of implementation, than with more recent highlights of the 20th century, like the Hufeisensiedlung in Berlin or Stuyvesant Town in New York. What role will the urban designer play in this system? And will his toolset still identify him as a designer?

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Methods for Integrating Spatial Analysis in Assessment of Community Sustainability

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ABSTRACT: Faced with a large amount of data, obtaining useful information and providing effective support for urban planning is a new and increasingly difficult challenge. The effectiveness of planning decisions can be greatly enhanced by providing planning professionals, policy makers, and other stakeholders with methods and tools to evaluate the different impacts of proposed planning decisions on urban sustainability at the neighborhood, city and regional scales. These methods and tools should rely on quantifiable metrics and indicators that can be easily measured and tracked over time. Incorporating interactive forms of decision making in planning processes using Geographic Information Systems (GIS) is an approach that provides an effective means to address this challenge, and GIS applications are increasingly being used to develop such metrics and systems. Existing capabilities of GIS systems can provide effective strategic decision support to planners and private and public organizations and assist them in enhancing their information infrastructure. This paper provides a review of two recently completed studies utilizing GIS applications and related tools in assessing different aspects of community sustainability in the City of San Antonio and the South Texas region. The two case studies, conducted by the authors, are used to illustrate the capabilities of spatial analysis using GIS applications at the neighborhood and regional scales respectively. The paper presents and analyzes the methodologies used in the two case studies as a means of illustrating different approaches in utilizing GIS capabilities in the assessment of urban and community sustainability. Policy implications for local governments and recommendations for future utilization of the models and metrics developed in both studies are also identified and discussed.

KEYWORDS: Sustainable Development, Spatial Planning, Neighborhood Analysis, Workforce Housing.

1.0. Spatial Planning and Decision Making

Faced with a large amount of data, obtaining useful information and providing effective support for urban planning is a new and increasingly difficult challenge. Currently there are three main technological platforms that are used to provide support to planners to complete their specific objectives (Anthony, et. al. 2006; Ning-rui, D. and Yuan, L. 2005):

- *The Planning Support System (PSS)*: This system was proposed by the American scholar B. Harris in 1989, and followed by other scholars and planning officials who made it widely used. This system intends to provide support to the whole process of planning. It covers not only the ultimate decision-making, but also discovery, analysis and evaluation of the planning problems.
- *The Expert System (ES):* This system is also known as a knowledge-based system, and is an intelligent computer program that uses artificial intelligence technologies to simulate the decision-making process of experts and solve problems in some specialized fields using existing knowledge and experience. Without differentiating various types of users, it aims at the optimal or ideal decision rigidly aided by knowledge and experience provided.
- *The Decision Support System (DSS)*: This is an interactive information processing system used to help decision-makers use data or models to solve unstructured or semi-structured decision-making problems using computers. It provides a good environment for policy makers to formulate policies through the man-machine dialogue. It can analyze problems, establish model, simulate the decision-making process and results, and help the policy makers improve the quality of decision-making by making full use of information resources. It requires users to identify clear rules of judgment and objectives. It usually provides several options, and lets users make the final decision for themselves. (Zhana, et. al. 2008).

In addition to urban areas, Planning Support Systems (PSSs) have been applied to urban-rural planning for the past 20 years. Developed countries with advanced economies, societies and technology, perfect systems and laws, mature method and skills of urban-rural planning are also in an advanced status regarding the data, technology and software of PSSs. The main idea proposed by Harris (1989) was to combine information technology with methodology of urban planning to provide decision-making in every step during the planning process (Mao, et. al. 2008).

Another area where spatial planning was integrated into decision making is growth management and sustainable development. The significance of this area is discussed further in two case studies presented in this paper. Additionally, in the Netherlands both the fourth National Environmental Policy Plan (Ministry of VROM 2001a) and fifth National Policy Document on Spatial Planning (Ministry of VROM 2001b) emphasized the responsibility of local authorities for creating a sustainable environment, stressing that spatial planning at the local level has direct impacts on the urban and rural environments. In practice, this means finding a sustainable balance between the influences of present and proposed human activities and the sensitivities of the urban and rural environment. This requires coherence between spatial and environmental policies and an integrative, area-specific planning approach at the local level. It is essential for this integrative approach that environmental aspects are incorporated into the planning process at an early stage, instead of being evaluated afterwards. To do so, local authorities and urban planning officials need tools that enable them to review the potential environmental impacts of spatial plans quickly and indicatively, as exemplified by the Neighborhood Sustainability Assessment case study, and to explore alternatives in an iterative and interactive way. Another example of this approach can be found in a research project started at Wageningen University in 1998, which aimed to develop a GIS-based Strategic Tool for integrating Environmental aspects in Planning Procedures (STEPP) (Carsjens et al. 2002). The objective of STEPP was to support interactive spatial planning processes at the local level, especially with regard to identifying options in the early phases of the process.

Subsequently, the benefits of incorporating interactive forms of decision making using GIS applications have developed from an operational support system into a strategic decision making support system (Grothe 1994; Cornelius and Medyckyj-Scott 1991). These systems take advantage of GIS' ability to bundles time and efforts to improve the position of private and public organizations by enhancing their information infrastructure. GIS applications are contingent upon the use of spatial data, progress in information technology and computer science and engineering, availability of digital geo-information, and importance of its implementation. GIS is therefore a vital technology that has important applications not only on the neighborhood level, as illustrated by the first case study, and on the regional level as shown in the second case study, but also on the national level. It deals with information on people (demography), facilities, businesses and land (use and planning), zoning, employees, customers, facilities and the market (Huxhold and Levinsohn 1995; Saleh and Sadoun 2006).

2.0. Spatial Analysis Applications AND sustainability

Compared with STEPP and similar tools, newer generations of GIS offer more sophisticated and extensive database management and display capabilities, and are much more user-friendly (Malczewski 2004). These new trends have stimulated the development of geo-technology tools to support different aspects of the planning process, particularly tools in which participation is a key element (Geertman 2002). These participatory GIS tools have materialized under the generic term Planning Support Systems (PSS) (Harris 1989; Brail and Klosterman 2001; Geertman and Stillwell 2002; Geertman 2002). PSS are spatial decision support systems (SDSS) (e.g., Jankowski and Richard 1994) that have primarily been developed to support planning processes (Geertman 2002), based on the assumption that an increase in access to relevant information will lead to a greater number of alternative scenarios, and thus a better informed public debate (Shiffer 1995). (Gerrit and Ligtenberg 2007).

Additionally, GIS as a spatial analytical tool has been noted to be very useful in monitoring, appraising, and updating urban sustainability assessments. GIS has the capability to link location data with attributes and also perform spatial analysis on these data. Urban sustainability, as well as site suitability assessments, involves measurement and evaluation of spatial data that can be handled to some extent by GIS. Apart from data manipulation, integration, and analysis, GIS could be used in visualizing different scenarios of the indicators of sustainability... Experiences from empirical studies (Blaschke 1997; & 2001; Lautso et al. 2002) have shown that GIS and related technology could be very useful in urban sustainability assessment and in the quest towards achieving sustainable cities. Indeed, the operationalization of sustainable development locally and globally requires spatial thinking and spatially explicit approaches (Blaschke 2001) that consider the spatial heterogeneity and interdependency of developmental processes and impacts. The trend of sustainability assessment studies is towards the development of holistic approaches that will integrate the different aspects of spatial planning into the appraisal (Bond et al. 2001). Therefore, there is clearly a need to integrate the evaluation of the planning process with the appraisal of the process outcomes in order to improve understanding of how planning could foster sustainable cities (Alshuwaikhat and Aina 2006).

3.0. Background of the two case studies

To illustrate the use of GIS applications in spatial analysis and planning decision support, this paper presents a review of two recent studies utilizing GIS software and related tools in assessing different aspects of community sustainability and identifying the common approaches and methods used in them. The paper presents and analyzes the methodologies used in the two case studies, conducted by the authors, as a means of illustrating the different approaches in utilizing GIS capabilities in the assessment of community sustainability, and the different scales such studies can address.

The first case study (Rashed-Ali, 2012a & b) addresses the issue at the neighborhood / city scales and involves the use of the INDEX PlanBuilder software (Criterion Planners, 2011) to develop a neighborhood sustainability model for the City of San Antonio, Texas. This model aimed to provide support for sustainability-oriented neighborhood planning activities across the city. The model was based on 29 sustainability indicators, and was used to calculate an overall Neighborhood Sustainability Index for each of 275 neighborhoods within the city. This overall Neighborhood Sustainability Index consisted of seven component indices, six of which were based on the six livability principles developed by the Partnership for Sustainable Communities[1], while a seventh was developed for Environmental Impact. In addition to the quantitative indices, maps representing the spatial distribution of each indicator were developed for each neighborhood. This Neighborhood Sustainability Index aimed to provide support for neighborhood planning activities across the city with the aim of reducing energy and water consumption, vehicle miles of travel, pollution emissions and the overall carbon footprint of the city. This index will help planners, policy makers and other stakeholders evaluate the long-term environmental impacts of their decisions, compare available planning alternatives, select optimum ones, as well as develop new alternatives to address issues identified in the analysis and generally make more informed planning decisions.

The second case study (Kamal, 2012) focuses on the regional scale and consists of a site suitability analysis, which utilized GIS spatial analysis functions and other statistical models for assessing areas for residential developments to accommodate the workforce required for the oil and gas production in six counties located in South Texas: Dimmit, Frio, La Salle, Maverick, Webb, and Zavala. Since the 2008 discovery of Eagle Ford Shale, the South Texas region, which extends over 24 counties, has experienced extensive economic growth estimated to have 20 to 30-years lifespan and is ranked among the largest 10 US oil fields. The counties identified for this study are responsible for more than50% of the drilling activities of the entire shale, and are surrounded by the cities of Eagle Pass, San Antonio and Laredo. The purpose of the site suitability analysis was to provide a systematic method that could aid policy makers in allocating local and state resources needed to meet the housing supply of workforce over the next 15 years (from 2010 to 2025). It also aimed to provide the developers and local housing authorities with proposed locations with appropriate commuting range to oil and gas drilling sites. The influx in demand for workforce housing arose amid the 2008 discovery of an oil shale field in the region.

4.0. Developing the GIS Methodology

4.1. Neighbourhood Sustainability Assessment Study

The methodology used in the first study relied predominantly on quantitative methods focusing mainly on the processing and analysis of preexisting GIS data in deferent agencies at the city, county and regional level. The methodology consisted of the following:

- *Indicator selection:* The selection of neighborhood sustainability indicators for the study was based on a thorough review of similar sustainability assessment studies in a variety of US cities. Notable studies reviewed include a sustainability framework for the Twin Cities Region (Kaydee-Kirk et al, 2010), and the STAR Community Index (2010). Several case studies of the use of the INDEX software in different US cities were also reviewed including studies in Portland, Kansas City, Redwood City, Austin, and Grand Rapids (available at www.crit.com). Based on the literature review, an initial set of more than 50 indicators was identified for further evaluation. This set was then compared to the sustainability indicators available in the INDEX software, which resulted in the selection of a smaller set of 35 indicators. 3.The availability of citywide GIS data and other required inputs for the indicators was then investigated, which resulted in a final set of 35 indicators.
- *Indicator score calculation (INDEX PlanBuilder):* Raw scores for selected indicators were calculated using the INDEX PlanBuilder Software. The Process involves loading the GIS data collected from various sources as well as other needed data and defaults into INDEX. When available, required data and defaults representative of local conditions used (Author reference). If this data was not available, national level data or INDEX software defaults (also representing national level averages) were used.

- *Neighborhood sustainability indices*: As previously stated, the selected indicators were combined into seven sustainability indices. Six of those indices were based on the HUD/EPA/USDOT livability principles discussed earlier, while the seventh related to the environmental impact of the neighborhood. Each of the seven indices was based on a subset of the indicators calculated within the study based on the relevance of the issues addressed by each indicator to the focus area of the index. To aggregate the indicator raw scores, scores were standardized so that they all fall on scale from 0-1. The standardization was achieved by comparing each indicator's raw score to a maximum and minimum threshold score for it. Indicators were assigned equal weights in calculating different index scores. However, several indicators were used in more than one index thus resulting in increasing their relative weight. All index scores were calculated on a scale of 1 -100. The approach of relating neighborhood sustainability indices to livability principles was based on the Twin City Region study discussed earlier. Finally, an overall *Neighborhood Sustainability Index* was calculated based on the seven component indices. Different relative weights were assigned to each component index based on the relevance of the issues it addresses to the environmental performance focus of the project. Accordingly, indices relating to environmental impact, housing equity, and transportation were assigned higher relative weights than other indices. This resulted in further modifications in the relative weight of each indicator in the overall *Neighborhood Sustainability Index.*
- *Pilot neighborhood*: To test the capabilities of the INDEX PlanBuilder software and the effectiveness of the developed neighborhood sustainability model, the model was first applied to two neighborhoods with contrasting urban sustainability characteristics, a neighborhood with high urban density, high use mix, high street connectivity, available amenities, and good transportation coverage and one with low-density mostly single use neighborhood with low street connectivity, low public transportation coverage, and low availability of amenities. The results of this initial assessment were consistent with expectations and clearly exhibited the contrasting sustainability characteristics of the two neighborhoods
- *Citywide implementation*: The model was then applied on a city-wide scale. To achieve this, the city was divided into 10 zones based on geographic location and the major highway network (see figure 1). Each of these 10 zones was then divided into its constituent neighborhoods based on the boundaries of registered neighborhood association. In total, 275 neighborhoods were assessed within this project. An assessment of existing sustainability conditions was conducted for each of the 275 neighborhoods identified within the city. Results generated for each neighborhood include scores for all indices (the overall Neighborhood Sustainability Index and the seven component indices), raw scores for the 29 indicators used, as well as maps describing the geographical distribution of some of those indicators within the neighborhoods (figure 2). All project results were made available to the public on the project website (author reference).

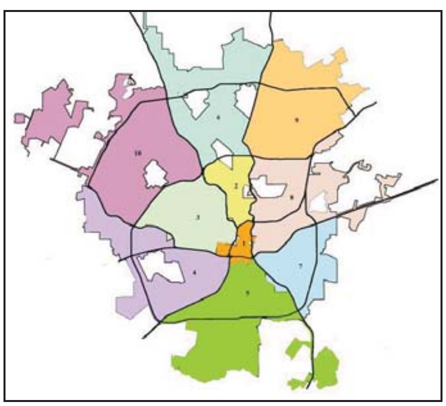

Figure 1: Geographical zones used in the study

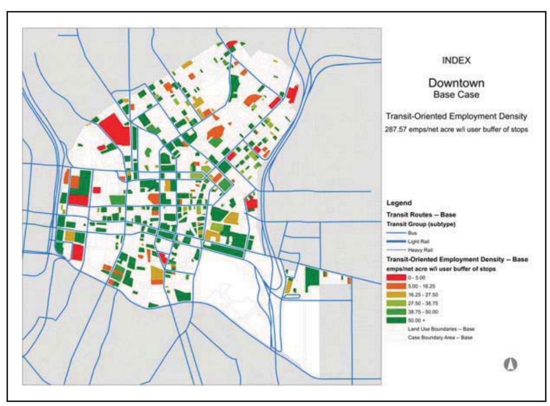

Figure 2: Indicator map for one of the neighborhoods within the study.

4.2. Site Suitability for Workforce Housing

In contrast, the methodologies used in the second study included both quantitative and qualitative methods including: 1) interviews with professional to establish a workforce metric, 2) six focus groups with local stakeholders to identify the study parameters, 3) Population projections (from 2010-2025), 4) projection of housing demand by tenure and by type in the six counties, 5) GIS mapping for site suitability analysis to identify development sites for oil and gas workforce housing, and to identify existing housing vacancy and foreclosure stocks. The following are the methodology stems:

- *Identifying workforce metrics:* Interviews with oil and gas industry professionals and geologist were used to develop the workforce metrics. The metric was based on drilling footprint and its impact on well counts and rig counts; the latter was used to calculate the number of jobs needed to run each rig and Total number of jobs per rig was estimated to be 105 jobs divided into 94 transient jobs, and 11 permanent jobs; both types are shown in figure 3.
- *Projecting population and households (2010 to 2025):* Projection of current population was conducted by applying Hamilton-Perry (Smith, et. al. 2001) projection model, which accounts for aging existing population, and considering birth, mortality and fertility rates in the county. Adding permanent rig-related jobs and households to the natural population growth model in the community from 2010 to 2025 according to the following considerations: 1) Adding newcomers (permanent jobs in each community) at a ratio of 25 percent in cohorts 45 years and older, and 75 percent to cohorts 0- 44 years, 2) An assumption was made that the major unincorporated communities will absorb the entire permanent jobs created in each county.
- *Projecting households and housing units (2010 to 2025):* Total population adjusted by adding the incoming workforce was used to create household model through three household categories: age 15 to 44 years, age 45 to 64 years; and retired householders: 65 years and older. Texas household size, 2.75 (US Census Bureau 2010) was used to estimate household counts. Two classes of tenure[2] (10% Owner-Occupied Household, and 90% Renter-Occupied household) were used to estimate future housing demand per each household category. Housing projections by type[3] excluded RVs, vans, and boats, and was normalized to the pre-launch year of 2010, before intensive drilling activities took place in Eagle Ford Shale area.
- *Mapping convenient commuting range:* Locating areas within each of the six counties where potential development was based on identifying optimum driving distance to and from existing oil and gas drilling-on-schedule wells. Various publication and studies show that the average commute range is between 15.5 miles in rural areas (Transportation Research Board 2000) and 45.6 minutes for the average two-way trip per day (The Gallup Poll Briefing, Carroll 2007). Based on results from both studies, we identified the optimum driving distance for the workers from all drilling sites as 15.5 miles, as shown in figure 4. This distance was incorporated into GIS buffer analysis, to identify the ranges from current active wells to define potential sites for residential workforce development.

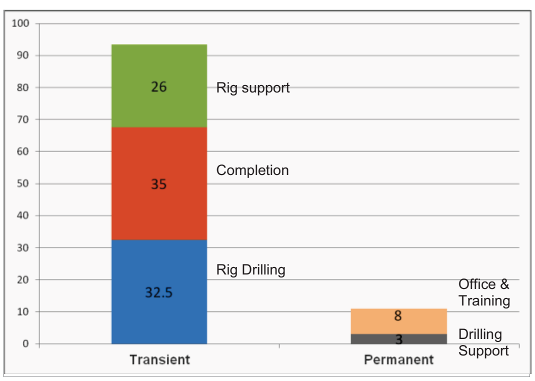

Figure 3:. Job counts and types per rig

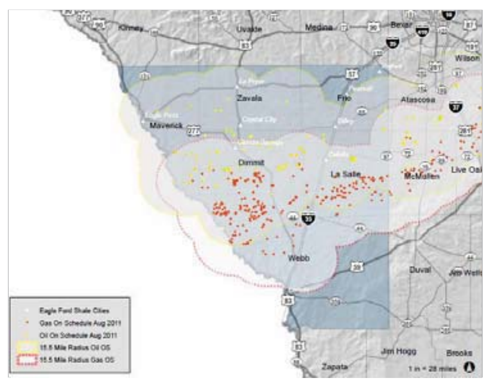

Figure 4: Commuting ranges identifying potential residential development

- *Mapping vacant and foreclosed housing stock:* Location of vacant housing units was mapped in each city where wells are active and the community has an increased workforce population within the study area. Vacant units data was extracted from the Census block groups data (US Census Bureau 2010). Foreclosure counts by county and by community were retrieved on November 17, 2011. List of housing units on foreclosure were categorized by city's available properties on foreclosure, as well as the mean and median price of the property. All RVs, vacant land, and other uses were excluded from the list. Data was integrated into GIS map, which manifests the foreclosure count in each of the communities and counties. The analysis concluded that an estimated 6,509 units are available within the jurisdiction of the unincorporated communities in the six counties.

5.0. Discussion: A Metric for Future Studies

5.1. Neighbourhood sustainability assessment study

The results of the neighborhood assessments conducted in this project are in themselves very valuable for different stakeholders in San Antonio including planners, policy makers, neighborhood associations and the general public. They provide these different stakeholders with a detailed and quantified assessment of different sustainability metrics and issues. However, the larger benefit offered by this study lies in the considerable potential it offers for future work that would further build on the advantages offered by having such an assessment system in place. First, the assessments conducted in this study represent the existing conditions of different neighborhoods and are based on GIS data available at the time of conducting the analysis. Repeating this assessment on regular bases would offer the city the ability to track progress towards achieving its sustainability objectives as well the potential for evaluating the success of different sustainability and other initiatives, at both the city and/or neighborhood levels, in improving sustainability. Second, the comprehensive nature of this model results in it overlapping with several existing models in different sectors (e.g. emissions models, transportation models, etc.). While most of these models work at a higher level of aggregation than the one addressed in this project, comparing the results of the neighborhood sustainability assessment project with those of other existing models can result in further improvements in the accuracy of the neighborhood model. Finally, the existing conditions results offer a valuable starting point for neighborhood associations to evaluate existing and future development plans they may have and to compare different alternatives and identify the ones achieving the best improvement in neighborhood sustainability.

5.2. Site suitability for workforce housing study

Since oil and gas drilling activities in Eagle Ford Shale area are dynamic, they need to be studied periodically in order to integrate the facts about population, workforce, and drilling activities that unfold within the projection scenario for the 15 years' time span included in this study. Accordingly, policy makers in the Eagle Ford Shale area need to integrate the developed workforce metric and to utilize it in updating the overall estimate of population, households, and housing units. The advantages of this metric is that it allows addressing changes in housing demands emerging from the dynamic nature of drilling activities in the statistical model and its adjusted ratios for both population and housing units. The metric as well as the qualitative data analysis of the interviews and focus groups provided concrete evidence that the following unincorporated communities could represent a workforce hub:

- Carrizo Springs, located in Dimmit County, TX
- Crystal City, located in Zavala County, TX
- Dilley and Pearsall, located in Frio County, TX
- Cotulla, located in La Salle County, TX
- Laredo, located in Webb County, TX.

The results of the spatial analysis is that within optimum community ranges of 15.5 mile from drilling sites, vacant parcels located in the jurisdiction of the identified workforce hubs are suitable for new residential developments, the design of which needs to be adaptable to accommodate local residents upon the end of oil and gas lifecycle. Finally, the potentials for incorporating existing vacant and foreclosed housing units exits due to the large stock of both.

CONCLUSIONS

In conclusion, while the two case studies presented in this paper address different community sustainability issues, as well as different scales, the analysis presented clearly illustrates the value that GIS spatial analysis tools can bring to sustainability assessment both at the neighborhood / city scale as well as on the regional scale. In both case studies, GIS tools were used both to process large amounts of data, which would not be possible if these tools were not available, and then to use this processed data to develop usable, quantifiable, and trackable metrics that provide valuable support to the planning decision making process at the two different scales addressed. Through having these quantitative metrics, planners, policy makers, and other stakeholders will be able to evaluate the long term environmental impacts of their decisions fat the neighborhood scale and to make strategic decisions in identifying developable sites in economic boom regions at the regional scale. The large potential offered by these two models also lies in the potential they offer to planners and policy makers to compare available planning alternatives, select optimum ones, develop new alternatives to address issues identified in the analysis, and generally make more informed planning decisions that lead to reductions in energy use, emissions, and other environmental impacts benefiting neighborhood(s) or regions in question. Local and state policy makers can also make decisions to allocate resources such as rehabilitation funds and home repair programs to areas with high vacant and vacant and foreclosed housing units. The outcomes of the process can also be used to inform the general public and solicit their involvement in the decision making process. The availability of the tools used within the two case studies, the existing conditions assessments conducted within both of them, and the expertise developed through them will facilitate this process and provide valuable assistance to neighborhoods, counties and regions in their planning activities. These decisions would be flourished by a continuous updates of already-established metrics that aid future decisions, assessments and allocation of resources.

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ENDNOTES

[1] The livability principles were developed by a partnership between the Department of Housing and Urban Development (HUD), Department of Transportation (DOT), and the U.S. Environmental Protection Agency (EPA). Available electronically at: http://www.sustainablecommunities.gov/aboutUs.html

[2] Tenure refers to owner occupied units and renter-occupied units.

[3] Type includes single family, multifamily, and mobile homes.

Can IT Industry Regenerate Mill Towns? Holyoke's Revitalization through Land-Use and Urban Design

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ABSTRACT: Mill towns of New England have been under distress for several decades due economic decline and depression in small manufacturing industry. These economic challenges contribute to the decaying urban environment and impoverishment of the communities. Information technology (IT) intensive industry has been touted as a panacea that can revitalize declined post-industrial economies. However, revitalization of a historic mill town with IT intensive industry may present unforeseen challenges and limitations to sustain the prosperity of local communities and vibrancy of urban environment. This paper analyzes to what extent the fostering of IT intensive industry in historic mill towns facilitates sustainable revitalization and aid the regeneration of the communities. This analysis focuses on recent developments in Holyoke, MA along with a brief review of economic redevelopment in Maynard, MA in the past based on high-tech industry. Holyoke is engaged in a major revitalization process catalyzed by the recent opening of a high performance computing center and subsequent development of the innovation district. We examine these revitalization efforts through the lens of smart growth strategies focusing on sustainability of the local urban environment. The investigation identifies urban morphology changes that are needed to create a synergy with the implementation of the IT intensive industry for the creation of vibrant nodes withy mixed land-uses and a cohesive community.

KEYWORDS: Urban morphology, mixed uses, IT-innovation districts, local communities, economic development

INTRODUCTION

For past several decades, economic decline and depression in small manufacturing industry have been the source of decaying and deteriorating urban environment and impoverishment of the communities in the mill towns of New England. As these poor conditions create a burden for regional economies, strong revitalization plans became crucial for the declining mill towns to regain a competitive edge in regional economies and improve the tax base. Economic redevelopment is considered the most critical step towards revitalization of the historic mill towns, therefore the local governments concentrate their efforts on attracting new industries that can contribute to job creation and economic redevelopment. Recently, fostering information (IT) intensive industry has been one of the leading approaches to attempt economic redevelopment in declined industrial cities. IT intensive industry has gained publicity as a potential catalyst for revitalization, most probably due to the lucrative economic returns and social prestige of IT business. In addition, IT intensive facilities are often considered appropriate for being hosted in retrofitted mill buildings; existing mill town infrastructure is economically efficient with competitively lower property values which benefits IT companies at the start-up stage. However, reliance on the promises of the IT intensive industry for revitalization presents some problems. This is mostly because the IT industry may have a limited effect on bringing economic and social diversity transforming the local community and other urban form to support the economic regeneration.

This paper explores opportunities and challenges presented in mill town morphologies for revitalization through IT intensive industry. IT based economic redevelopment alone may bring only limited benefits to local communities as compared to the transformation needed for a revitalization within the physical environment changes intrinsic to economic and social development. For a sustainable revitalization, economic redevelopment should be supported by social capital and economic diversity, along with physical environment changes to facilitate diversity of social groups and uses. In comprehensive urbanism studies, revitalization process is considered a "place-based people strategy" which involves "improving the lives of residents within a designated area through investment incentives, local hiring clauses, empowerment zones, some beautification projects and similar policy tools" (Sutton 2008). As can be implied in this definition, physical environment is in fact an integral part of revitalization. The role of physical environment for revitalization can be further understood with analysis of urban morphology and its properties intrinsic to human spatial activity that concerns economic and social transactions.

With a motivation to inform revitalization through morphology and land-use changes, this paper investigates the following:

(1) What challenges does the current morphology of mill towns present for revitalization?
(2) To what extent can IT intensive facilities regenerate the local urban environment?
(3) What kinds of changes in urban environment can contribute to connecting new land-uses with the existing neighborhoods?

These questions are explored in the case of Holyoke, Massachusetts which provides an interesting example with its rigid morphology and recently formulated revitalization plans based on innovation economy. Although our analysis mainly focuses on Holyoke, we also discuss another mill town, Maynard, which went through a number of redevelopment cycles extensively driven by high tech industry. In the case of Holyoke, this paper examines the implementation of an IT intensive facility and plans for the innovation district in the framework of smart growth principles that can transform the existing morphology.

1.0 URBANISM WITH SMART GROWTH STRATEGIES FOR DECLINED CITIES

Urban revitalization projects for declined cities have been informed by smart growth strategies that promote compact built environment with mixed uses, housing choices, walkability and transit oriented development. These principles promote shaping of urban environment to facilitate social and economic transactions and community connectedness, and thus bring environmental, social and economic benefits (Yang 2008; Downs 2005).

Smart growth principles were derived from urbanism theories and criticism to the Modernist large scale and top-down planning decisions and divisive zoning rules that have been formulated since the 1960s. As explored by several urbanism theorists, certain spatial elements of urban environment can promote diversity of people, functions and land uses and contribute to economic vitality and social cohesion (Alexander 1965; Gehl 1987; Hillier 2009; Jacobs 1961; Newman 1972; Whyte 1980). Jacobs (1961) advocates for smaller building blocks as they create frequent intersection of streets and thus facilitate chance interactions and subsequent development of economic activity. Alexander and Gehl point to programmatic conditions such as overlap of the occupied areas of different facilities and optional activities, which create the mixed uses in natural patterns of people (Alexander 1965; Gehl 1987). With a greater emphasis on morphology, Schumacher (1978) elaborates that urban space can maintain density of movement if a sense of closure is defined by building blocks and if streets are continuously connected like in “network-like” structure instead of being segregated away from major arteries (“tree-like”) like in cul-de-sacs (Schumacher 1978).

Consistent with the insights of Schumaher (1978) and Jacobs (1961), space syntax theory suggests that streets segments that are reachable from all other segments by involving the fewest number of other streets attract movement (Hillier et al. 1993). Therefore, streets with greater number of intersections are more likely travelled by people, and streets that can be reached by traveling through only few others are places of social encounter, co-presence and commerce. Space syntax framework claims that land-uses such as retail, commerce, passing trade, are in fact economic entities also migrate to hierarchically important destination or through-fare places. In return, these economic entities such as shopping centers operate as attractors of movement. Therefore, people’s spatial activity are predicted within the synergy created between street networks and programmatic attractors (Hillier 2005). Resonating with Jacobs (1961) Peponis et al (2008) explore that the denser the street network, the greater chance that people deviate from routine movement and explore unfamiliar places and convenient shopping (Peponis, Bafna, and Zhang 2008). Hillier furthered this argument by suggesting that higher density of streets and frequent intersections form economic centers in large metropolitan areas. Hillier argues that the street networks that form economic centers are distinguished from streets for residential areas which may have a more homogenous segment structure (Hillier 2009).

2.0 CHALLENGES AND OPPORTUNITIES IN THE MORPHOLOGY OF MILL TOWNS

Within rigid morphological characteristics, historic mill towns present some challenges along with some opportunities for revitalization. The proposition that hierarchical relationships of street network predict concentration and passing behavior of people and thus associated economic and social transactions can be true only to a limited extent in declined mill towns. Despite intact street layouts and even a compact build environment, the towns lack various land uses and strong economic structure, to help generate human spatial activity. Without these elements, the streets of these mill towns are like an infrastructure without any substantial purpose. Revitalization efforts aim to provide economically regenerative and socially vibrant public realm. An essential factor transforming “place” is the implementation of new market sectors in the built fabric of mill towns. This implementation should not focus on a single market sector; however, the economic redevelopment should generate social and economic diversity and make a regenerative effect on local communities. New market sectors should ideally motivate other sectors in the local site, with demands for housing, retail and other commerce. New market sectors thus should be able to motivate the growth of new economic centers in time, along with planning and construction of the physical environment. However, sectors that are alien to the local community, such as shopping malls and casinos may have a detrimental effect on community and alter traffic patterns drastically and in undesirable ways.

Information technology has been considered as a potential source for economic redevelopment in declining cities (Harris 2013; Gospodini 2006). Old industrial cities with intact physical infrastructure and tax incentives provide attractive sites for information technology start-up companies. However, it still is an open question whether information technology businesses could have a regenerative effect on declined mill towns and their communities. Given the specific skill base used in IT firms, economic development through IT intensive industry may also alienate the mill town communities and thus present challenges and limitations for revitalization. This is because IT facilities today extensively utilize virtual operations with high skilled labor not present in local communities, thus can be less generative of new land uses in local environment, as portrayed by technology theorists and sociologists (Castells 1991, 2000, 2000; Gibson 1984; Mitchell 1995, 1999; Sassen 2007).,Recent developments show that in IT operations does not entirely diminish the physical dimension of interactions (Gospodini, 2006); on the contrary IT may induce new kinds of relationships with urban land and new spatial activity and travel patterns (Wheeler, Aoyama, and Warf 2000).

In the wake of attracting new industries to declined cities, urban form will have to support multiple market sectors and create diverse social and commercial transactions in order the economic regeneration to be sustained. The urban form adaptability is partially defined by the pattern of property ownership that determines how the land is divided into individual parcels. Scheer (2010) points out that as cities grow and change in response to economic, political and cultural conditions, the urban block parcel, so-called “tissue,” remains relatively constant (Scheer 2010). She argues that a fine grained tissue with small parcels and multiple owners in the urban blocks create challenges for adaptability as each building will change individually and different times, the overall structure and character of the place remain the same because a small parcel framework dictates certain types of buildings (Scheer 2010; Campoli 2012). Depending on the physical and fiscal conditions of the declined town the urban block and tissue define both challenges and opportunities for adaptability to new and multiple industry sectors and housing choices, As discussed by Campoli, vacant land in former industrial sites offers larger footprints for new industries, while intact remaining mill buildings may open up the entire block only for single use and diminish the diversity of street (Campoli 2012).

3.0 MAYNARD (MA) AND ECONONOMIC DEVELOPMENT THROUGH HIGH TECH INDUSTRY

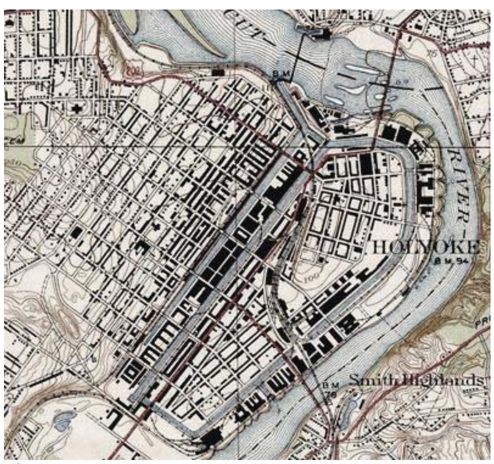
Challenges in revitalization processes have been pertinent to many declining mill towns. A number of mill towns provide provide additional context for our more in-depth analysis of Holyoke and its recent IT intensive industry development. the New England mill towns have been attempted to be revitalized through a wide array of approaches including museums, shopping centers, artist lofts, theatres and software companies as well as housing driven by local and regional assets (Mullin and Kotval 2009).. In Massachusetts, the economic development of mill towns has been influenced by the high tech industry along the major traffic arteries outside the city of Boston. For example, the development of high-tech industry on the Rte.128 corridor has been motivated by research institutions like Massachusetts Institute of Technology, local private equity and the defense industry, which were all established in Boston as a result of the historic financial and economic legacy of nearby mill towns.

One mill town that was influenced by the high tech industry in the region was Maynard, MA, originally established as a wool manufacturing community on the Assabet River. In Maynard, the wool manufacturing mill was major employer of the town community. Following the gradual decline of the mill by 1950; the mill building housed temporarily a number of industrial firms, which were attracted by cheap available space, trainable labor and proximity to Greater Boston. The major economic redevelopment took place once the Digital Equipment Corporation (DEC) was settled in the Maynard mill. DEC later became the largest producer of mini-computers in the world which was, for a time, the primary industry of the town (Mullin, Armstrong, and Kavanagh 1986). The corporation employed not only the worker community of Maynard, but also became a major anchor of the regional IT community, providing some of the critical equipment for the early Internet and computer revolution. Although DEC's presence as an expanding high tech firm was a positive occurrence for Maynard's employment needs, it was not transformative for the urban environment; DEC used only the single, self-contained large mill complex in town. Further, the reliance of the town on a single large industrial corporation did not bring a resilient transformation. After the 1980s, DEC's operations started to decline due to the market shift in the high tech industry towards home based personal computers, and the decline in the use of minicomputers produced by DEC. The corporation bankrupted and left Maynard in 1990s leaving a large trained worker community which could be employed by other high tech firms in the region (Mullin, Kotval, and Karamchandani 2008), but not in Maynard. DEC's transformative effect on the town physical environment remained limited with the adaptive reuse of the mill building, yet DEC transformed the social capital of the town (for a time) and has had a long-lasting impact on the regional economy .

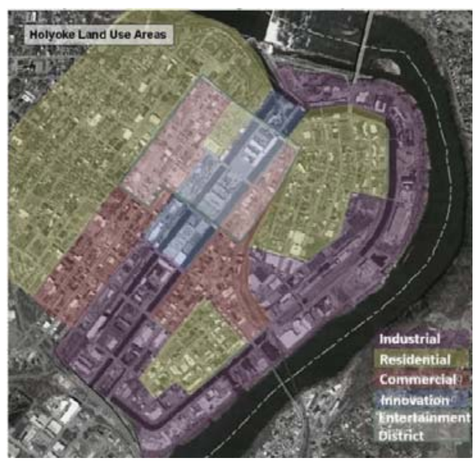
4.0 HOLYOKE (MA): REVITALIZATION THROUGH INNOVATION ECONOMY

4.1. Morphology, Current Land-uses and the Revitalization Efforts

Holyoke, established in 1830s as a paper manufacturing community on the Connecticut river, presents an interesting example to explore how urban morphology could work in concert with new economic development based on IT intensive industry and subsequent land-uses (Fig. 1a). Current land uses in Holyoke include limited retail, small manufacturing, and residential buildings. Blighted areas, empty lots and abandoned buildings highlight urban distress. Recent revitalization efforts in Holyoke focus on economic development through innovation industry and urban renewal through adaptive reuse of historic mill buildings, restoration and beautification of main streets and canals for broader community use. A key move within these efforts is recent implementation of the Massachusetts Green High Performance Computing Center (MGHPCC), which is planned to serve as a data processing node for five major universities in the state. The high performance computing center is considered by the local planning authority as an attractor for innovative and creative start-up companies which will form an innovation district.



a)



b)

Figure 1. **a)** Map of Holyoke Canal System (Holyoke, Massachusetts, USA), c.1938,
b) New land-uses planned for Holyoke today; the area marked as "Entertainment District" is a planned for smart growth rezoning. Source: City of Holyoke

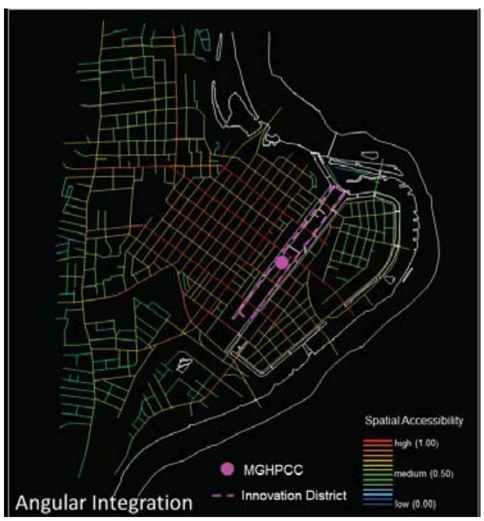
Despite its potential as a cutting edge IT based research facility, the computing center provides a limited capacity for new employment with only 16 positions for non-skilled labor, thus the facility can hardly be seen as a major economic development with job creation capacity. A more profound economic impact on Holyoke's community can only be experienced in occurrence that the computing center attracts other information technology intensive business to the area. At this point there is only limited information on how many new companies may start business in the area. It is yet to unfold whether new IT companies will induce a new social capital, improve the employment basis from the local community and increase the population density and spatial activity that can motivate housing, retail and service sectors. Indeed, along with the high performance computing center, the innovation district is critical for the revitalization due to being a part of the area designated for "smart growth" based on rezoning to allow for mixed use development with a combination affordable housing retail and office development in close proximity (Mass.Gov 2013) (Fig. 1b). The innovation district is envisioned to seed developments for a new economic node in Holyoke downtown with mixed uses residential, retail, and commerce as well as walkability potential, vibrant public realm and a diverse community. However, this capacity may be synergized by necessary changes in urban morphology to support connectivity for walkability, social and economic transactions and to allow diverse building types and uses.

4.2. Capacity of Innovation District for Smart Growth within the Morphology

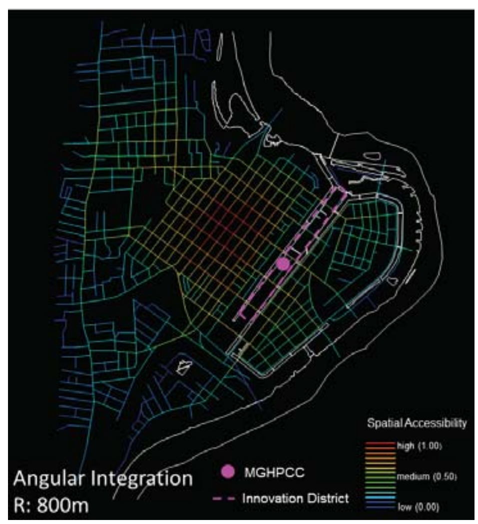
A preliminary analysis of Holyoke downtown reveals opportunities and limitations provided by the existing morphology. Holyoke downtown is shaped by an urban grid of 450x250ft (140x80m) blocks, interlaced with power canals and delineated by the river. The urban block is characterized by mill buildings in large parcels and row-house enclaves for workers, single family houses in smaller parcels, and a few town parks. The mill buildings arrayed along the power canals and the riverfront provide limited penetration for visibility within the block. Street network continuity is partially interrupted by canals along the central arteries of the town. Our further analysis is based on street segment analysis and an examination of urban block and tissue properties. Street segment analysis explores hierarchical relations that may modulate people's movement towards certain areas and create potential for social encounters and economic development. The urban block and tissue properties in downtown including blighted areas reveals opportunities and limitations for morphological changes such as urban block modifications and new building types.

Movement and Concentrations in Street Network

In street segment analysis (of space syntax), "angular integration" measure captures the likelihood that segments are likely destination points due to being reached within the least number of turns and minimum sum of angular change in street network. Streets with high degree of "angular integration" are where human flow is attracted to and thus present potential for frequent social encounters thus a good value for locating commerce and other business activity. To explore this capacity for general movement and pedestrian access, we ran the analysis for all street connections and the connections within the 800m diameter from each street. The 800m diameter corresponds to 10 minute walking distance for pedestrians.



a)



b)

Figure 2: Angular Integration graph of Holyoke **a)** For all street connections, **b)** For connections within 800m diameter from each street. Source: Analysis by author using the map provided by the City of Holyoke.

The angular integration graph run for all street connections indicates that the major street running parallel to the central canals on their west side is the most likely destination in downtown Holyoke (Fig.2). This street in fact is currently the major avenue (High Street) where small street shops, restaurants, the city hall and other public buildings are located. The other segments with high degrees of angular integration are those running perpendicular to the canals, which connect the downtown to the west. However, not all of these east-west arteries present this capacity because of interruptions in their continuity by the canals. Indeed the street network in general would benefit from further densification by the canals area in order to gain greater capacity to attracting people's movement towards the central core. Currently urban blocks around the central canals are quite large determined by the size of historic mill buildings. The angular integration graph based on connections in 800m diameter (Fig.2b) shows that the potential destination points for pedestrians are at west side of the downtown where street network forms a homogeneous and regular grid. This capacity of the current street layout predicts pedestrian walkability, which would be an asset for mixed uses in smart zone areas. However, the planned smart zone area falls in the north side of that highly integrated core shown in Fig.2b. In order to work in concert with densification of land-uses in the overlay district, street layout should facilitate movement towards this area through more frequent intersections.

This analysis suggests that the existing street layout of Holyoke is almost too homogenous to motivate vibrant economic sub-centers; there is very little differentiation in the grid to yield new nodes. In particular, the street layout around the high computing center and the Innovation district area is even more segregated from the entire downtown due to the interruptions by the canals and large mill buildings.

Urban Block, Tissue and Building Types

The street network analysis provides more meaningful insights when examined together with urban block, building footprints and property division characteristics. As can be seen in Figure 3, Holyoke downtown morphology is characterized by almost homogenous urban grid and building types as large mill complexes, row-houses and single family houses. As suggested by properties selected for clearance and rehabilitation. The large mill complexes along the canals and riverfront present capacities for adaptive reuse or new construction. New constructions in the sites of large building footprints areas provide opportunities to implement mixed use buildings within new typologies. A number of other rehabilitation properties are within the smart growth zone. In particular, three rehabilitation property groups are aligned along the artery perpendicular to the canals, which is found to be an integrated in the street segment analysis. These observations suggest the smart growth zone have the potential for further change with new building types and urban renewal of the primary arteries. Despite the rigidity of the urban grid, new building blocks and types may foster mixed-uses and various housing choices. Rehabilitation of the mill sites with smaller building footprints may improve the connections of the mixed used neighborhoods with the proposed canal walk. This connection can attract greater number of people to the scenic canals and thus help build vibrancy around the innovation district (Fig. 4).

Figure 3: Proposed rehabilitation areas and smart growth district within the urban block and tissue properties. Source: Analysis by author using information and map provided by the City of Holyoke.

Figure 4: The Canal walk after the recent rehabilitation (left) and its future projection (right). Source: City of Holyoke

CONCLUSIONS

This paper provides preliminary analysis of Holyoke in the light of Maynard economic redevelopment history. In contrast to Maynard case depending on substantial worker base, the IT intensive facility implemented in Holyoke promises very limited impact on local community in its current state. Holyoke's innovation district planned jointly with the high performance computing center may be regenerative if synergized by physical environment changes guided by smart growth. The changes in physical environment, that foster mixed uses, new building types and better connectivity can accommodate and facilitate new land uses and spatial activity fueled by the innovation district. The current morphology of Holyoke is not conducive for creating economic sub-centers around the high performance computing center and the innovation district due to the street layout that remains too homogenous and strict due to the effect of legacy mill buildings and the power canal system. Our examination of urban block, building types and tissue properties suggest greater potential for essential morphological changes. In central areas, large building footprints may redeveloped in smaller parts in order to create diversity with street and the planned canal-walk. In order to break the rigidity of the street network, areas of large building footprints may even be planned with additional streets to promote chance interactions. Blighted areas that are open for rehabilitations could introduce new building typed that foster mixed uses.

Motivated by a provocative example like the high computing center and the innovation district developments in Holyoke, our analysis and findings are preliminary. As more information on new IT facilities becomes available, our investigation can be furthered with more detailed comparisons of the potential land-uses and the morphology.

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Analysis of Smart City Models and the Four-Foci Taxonomy for Smart City Design

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ABSTRACT: Driven by increasingly complex social, political, economic, and environmental challenges, in the hope of promoting the health, safety, and welfare of citizens in urban environments, the demand for more effective management of immense data resources and easy public access to information is increasing. The notion of a smart city has evolved in recent years to mean a city that is well-endowed by information and communication technologies (ICT) that complement the physical infrastructure, and thereby enhancing the quality of the social and environmental assets. A city may be defined as "smart" or "intelligent" when investments in human capital, social capital, traditional transportation, and modern communication infrastructure drive growth and sustainable physical and economic development. Through participatory governance, managed growth of the smart city is intended to result in a high quality of life and wise management of natural resources. Currently several theories and models for designing a smart city, including hybrid models and new ideas, are emerging. Following an analysis of various research studies, it was possible to group these models in terms of their foci: (1) technological, (2) business, (3) political, and (4) environmental. While the proposed models have made considerable contributions to the field of smart cities, each of these models shares four key limitations: (1) a lack of integration of the local system and global system, (2) a lack of attention to holistic sustainability, (3) a lack of consideration of human factors and human-environment interaction, and (4) an inability to address significant urban changes. The research approach of Takeda et. al. (1990) was adopted for this research project, and has four phases namely: Phase I (Awareness), Phase II (Suggestion), Phase III (Development) and Phase IV (Evaluation). The research will be conducted in several studies. This paper reports on Study 1 which followed an exploratory and conceptual approach in two phases namely Phase I and Phase II, in which an in-depth analysis of several smart city case studies reported in the literature was performed. The purpose was to examine promising smart city models, and to critique their effectiveness, strengths, and weaknesses. The literature review enabled the authors to solidify their understanding of smart city design. A taxonomy of key categories of concern when designing a smart city, called the Four-Foci Taxonomy, is proposed in the paper.

KEYWORDS: Smart city, intelligent city

INTRODUCTION

In this paper we suggest that contemporary smart city models, despite their noteworthy contributions to the field of smart city research, deal mainly with limited foci, fail to sufficiently address significant contemporary urban challenges facing many cities, lack a holistic and integrated approach to city development, and neglect human factors (Hollands, 2008; Deakin & Al Waer, 2011).

More specifically we suggest that in contemporary smart city models, there is (1) a lack of integration of local systems and regional systems, (2) a lack of attention to holistic sustainability, (3) a lack of consideration of human factors and human-environment interactions, and (4) a lack of ability to address significant urban changes.

To address these challenges, we propose that an ideal smart city model should be able to address and overcome (a) a major recession like the current one ("Great Recession") and any significant future recession, (b) public health crises, and (c) a shrinking city phenomenon as well as substantial urban growth challenges.

Finally we suggest ways in which these significant challenges may be handled by drawing lessons from contemporary smart city models and several popular urbanisms or urban paradigms. We also suggest areas of further research in the field of the smart city.

1.0 METHOD OF INVESTIGATION

Study 1 of this research project is theoretical in nature as we use a conceptual approach to analyzing the current smart city models, and to proposing broad recommendations as to how to improve the existing models. We do this by building on their strengths and accomplishments, and the opportunities they create. The main research phases are I. Awareness, II. Suggestion, III. Development and Evaluation, and IV. Conclusion (Takeda et. al., 1990).

To support our positions and recommendations, we conducted Phase I and Phase II in the following way.
Phase I. Awareness

1. First, through an in-depth literature review, we reviewed and analyzed published case studies, and selected several smart city models that are frequently mentioned in the current literature, according to the outcomes of the case studies.
2. We then performed a comparative analysis of the selected smart city models, according to key issues that they address, the primary goals of the models, and the key strategies used to fulfill their goals. During the comparative analysis, we paid particular attention to frequently occurring themes or patterns. As a result, we were able to identify four focus areas in which similar types of smart city models can be grouped together.

Phase II. Suggestion

1. Definition. In this phase we defined each of the four focus areas to which a group of smart city models belongs. We also discuss several important aspects and key characteristics of each focus area.
2. Findings. Based on the outcomes of the comparative assessment of the four groups of smart city models, we have identified areas that need additional attention as well as key challenges that face each of the four groups of smart city models.
3. Recommendations. The results of the comparative assessment form the foundation for our recommendations. We suggest ways to improve the current smart city models, building on what has been accomplished already. We also touch on the areas of further study in the future.

2.0 ANALYSIS OF SMART CITY MODELS

Through an in-depth literature review, we identified several smart city models that currently exist in the literature. These models are chosen primarily because of the frequency with which they are mentioned in the literature, and we analyzed them according to several variables so the models can be compared (see Table 1).

Three general groups of data were chosen to establish baseline information as well as the general characteristics (features) of all models selected for this study: (i) key issues that contemporary smart city models address; (ii) goals of the models; and (iii) strategies that the models employ in order to accomplish the smart city goals.

Following is an analysis and comparison of several popular smart city models according to several key focal areas.

Table 1: Comparison of Smart City Model Groups by Key Areas

Key Features	**Categories of Focal Area**							
	Smart City Model Goup 1 **Technological focus**		**Smart City Model Group 2** **Business focus**		**Smart City Model Group 3** **Political focus**		**Smart City Model Group 4** **Environmental focus**	
Smart city defined, aspiration, common threads	▪ City as a showcase of technological advancements ▪ City that promotes technological advancements ▪ Focuses more on smart city than smart citizens		▪ City as a profit-making, economically sound entity ▪ City that is able to compete in a global market ▪ City as a small nation with autonomy, self-reliance ▪ Focuses on experts and smart people (smart leaders)		▪ City that promotes a civil and participatory society and reasonable behaviors of citizens ▪ Argues that smart citizens lead to smart cities		▪ City that is sustainable, able to cope with climate change, energy crisis, etc. ▪ Smart city as the key player to promote regional sustainability ▪ Requires smart city, smart region, and smart people	
Key proponents, key players	▪ Technocrats	a	▪ Managers	b	▪ Facilitators ▪ Conveners	c c	▪ Regionalists ▪ Environmentalists	d d

Examples of smart city models, primary locations	▪ Models that are based in Asia, especially Far East; led primarily by governments (e.g., Singapore, Japan, Korea, China, Taiwan, etc.)		▪ Advanced countries ▪ Rapidly developing countries		▪ North America ▪ Western Europe		▪ North America ▪ Western Europe	
Key problems that the models are addressing	▪ Deteriorating, outdated urban infrastructure and city services, especially in old and shrinking cities ▪ Lack of coordination among various divisions and jurisdictions in municipal entities	a a	▪ Loss of manufacturing industries/jobs ▪ Population loss ▪ Shrinking city phenomenon ▪ Ongoing "Great Recession" and future recessions ▪ Chronic unemployment in underserved areas ▪ Income disparity	d d d b b b	▪ Lack of interest or participation by citizen in city affairs	c	▪ Shrinking city phenomenon ▪ Extensive vacant land ▪ Declining population, manufacturing industries and jobs ▪ Deteriorating building stocks and traditional urban neighborhoods ▪ Climate change	d d d d d
Key goals of model	▪ Efficiency ▪ Ubiquity of technology ▪ Participation in a global society via technologies ▪ Effective information management system ▪ Keep citizens informed and make them smart via technologies ▪ Civic engagement via user friendly technologies, digital networks	a,b a a,c a,b a,c a,c	▪ Economic viability ▪ Competitiveness in global economy ▪ Profitability ▪ Efficient information management ▪ Sustainability ▪ Rightsizing cities	b b b b,d d d	▪ Civic engagement ▪ Participatory democracy ▪ Collaboration ▪ Sense of community ▪ Social interaction ▪ Building social capital ▪ Informed, active citizens as smart citizens	c c c c c c c	▪ Smart growth ▪ Sustainability ▪ Regionalism ▪ Public health ▪ Rightsizing cities ▪ Responsiveness to energy crisis and climate change	d d d d d d
Key strategies to promote goals	▪ Smart technologies ▪ Experts, smart people ▪ Easy access to Internet ▪ Open source system / open source urbanism ▪ Social media, digital networks	a a a a a	▪ Training of city officials as effective, smart business managers ▪ Branding ▪ Marketing ▪ Creating investment opportunities ▪ International trades with cities around the world ▪ Use of art and design, creative application of art and design in business	b b b b b abd	▪ Social media, digital networks	c	▪ Sustainable urban design ▪ Ecological urban design ▪ Landscape urbanism	d d d
Limitations, challenges	▪ Digital divide ▪ Coordination among different jurisdictions or agencies ▪ Updating technologies ▪ Lack of skilled labor or skilled workforces that can use technologies efficiently and effectively ▪ Lack of regional collaboration ▪ Limited sustainability, lack of attention to sustainability	a,c abc a a,b d d	▪ Social equity ▪ Distribution of wealth ▪ Coordination among different jurisdictions or agencies ▪ Lack of regional collaboration ▪ Limited sustainability, lack of attention to sustainability	b b abc d d	▪ Low level of participation by low income people ▪ Equal representation of diverse communities and groups ▪ Lack of regional collaboration ▪ Limited sustainability, lack of attention to sustainability	c c d d	▪ Suburbanization ▪ Lack of efficient public transit system ▪ Lack of regional collaboration ▪ Deteriorating downtown, old suburbs	d a,d a,d d

(a) technological; (b) business; (c) political; (d) environmental

It is difficult to state that a given smart city model handles only one focal area (of concern) such as technological, business, political, or environmental focus. While many models tend to focus on a number of problems or concerns, the contemporary smart city models have focused on various issues that may be divided among the following four broadly defined focus areas: a technological focus, a business focus, a political focus, and an environmental focus. Table 1 supports this observation. While there are potentially other foci (e.g., Allwinkle & Cruickshank, 2011), the categories we propose above are more prevalent than others. Despite the fact that there are some overlaps among the four foci, and admittedly the foci may need further refinement, we believe that this proposal is a useful step in the right direction. We define each focus area as follows:

(a) Technological focus

Several smart city models (Allwinkle & Cruickshank, 2011; Hollands, 2008) have considered a wide range of technological innovations necessary to make the cities smart or make citizens think or behave intelligently, by being informed about city affairs and the benefits of technologies in city affairs. This may include providing easy access to the Internet in public places, WiFi, information kiosks, digital networks for informing citizens, and the like. These and other web-based platforms that solicit each citizen's perspectives and feedback promote various forms of virtual civic engagement in city affairs.

An area that can definitely benefit from technological advancements is transportation. In our auto-dependent environment, several smart city models deal with technological innovations to redefine and advance transportation. A number of universities (e.g., the University of Michigan, the University of California at Berkeley) and automakers have been involved in research studies to develop a smart highway system in order to address traffic jams and auto-related accidents (Cepolina & Farina, 2012)). Other advancements result from multi-disciplinary collaboration between car makers, city officials, and urban planners. One such collaboration is to develop a smart system through coordinating vehicular technologies, traffic signals, and sensors embedded in street pavement, to reduce fatalities at street intersections that are prone to accidents (Vasseur & Dunkels, 2010). Moreover, given the fact that the elderly population is one of contemporary society's fastest growing groups, it might be necessary for scientists and engineers to investigate how technologies can make our cities and transportation systems work in a smart way to create a physical environment that promotes the health, safety, and welfare of elderly people (Lord et. al. 2011). While some researchers are looking into these issues, more studies are urgently needed.

Wayfinding is another critical area where smart city technologies can be of great assistance (Mitchell, et. al., 2004). Signage systems, environmental graphics, augmented reality (AR) technologies, smart phone technologies, and the Internet, can help residents and visitors navigate and experience the physical environment of cities in a more intelligent, convenient, and enjoyable manner.

Another area where technologies can play an important role is to enable various jurisdictions or agencies to work together more effectively, not just locally but regionally. Technologies can reduce overlapping tasks and bureaucracies. They can streamline review and approval processes, and they can promote more effective community outreach and communication. Moreover, technologies can help municipal employees generate fresh and innovative ideas on matters that concern citizens; technologies can encourage citizens to be more engaged in city affairs, or to volunteer for civic activities. All of these benefits can help promote a smart city by making citizens more informed, active, and responsive.

One of the key challenges in this focus area is determining how to deal more effectively with the so-called digital divide, the gap between those who have adequate access to the Internet, and those who do not. Despite the fact that much progress has been made in this area, closing the gap between haves and have-nots still remains a major challenge (Norris, 2001).

Another key challenge is how to promote an ideal integration of virtual engagement and actual engagement that encourages citizens to visit their city so they enjoy its physical beauty, and interact with other people, not just virtually, and but also physically in public places. This area needs more work in spite of pioneering efforts by William Mitchell and other scholars (Mitchell, 1995, 2000, 2005), which still arguably remain mainly theoretical. Additional practical, implementable solutions are needed.

(b) Business focus

Making cities smart or developing technologically advanced cities cost money and require other resources. Dealing with increasingly complex city businesses require a more intelligent way of running the city. Many smart city models address business aspects of making city smarter (Thite, 2011).

How to run the city businesses in a smart way is a broad and complex issue. Clearly the city is not a company. But many parts of city affairs are business-related. The city has to balance the budget. The city has to generate revenue. Among all the industry sectors other than private businesses, municipal governments (including city governments) are the entities that paid most dearly in the “Great Recession” of the last several years (Rosenberg, 2012).

In the increasingly global market place, cities are competing against other cities locally, regionally, and globally. This changing geopolitical dynamic, coupled with the recent (and ongoing) Great Recession, forces cities to be smarter about running the city businesses, increasing revenues, and balancing the budget by, for example, attracting international investors. We know many examples where cities around the world invest their efforts on branding and marketing their unique products and assets in the global market. For example, Seoul, capital city of the Republic of Korea, has branded a “Design Seoul,” which integrates technologies, art, design, architecture, and business in creating a smart global city (City of Seoul, 2009).

Given the fact that efficiency is one of the key goals of this group of smart city models, one area that needs more efficiency is coordination and collaboration between various agencies or jurisdictions in municipal governments. This is where cities that are technology-focused and cities that are business-focused can collaborate.

One of the challenges of this group of smart city models is learning how to increase operating efficiency, while promoting a culturally rich and diverse city life (Kuk & Janssen, 2011). The policy makers and city officials often run the risk of neglecting or compromising social capital at the expense of running an efficient city or increasing revenues (Caragliu et. al. 2011). In the name of getting things done faster or more efficiently, meaningful citizen participation or civic engagement in city affairs may be diminished or lost. Detroit is a prime example of this phenomenon, because in spite of the city’s honest efforts to increase in efficiency in the city’s public services (e.g., services in fire, police, sewer, water, garbage collection), their efforts failed in a significant way mainly because the city did not do a good job in engaging citizens and soliciting their input and feedback on what the city was trying to accomplish in the face of a shrinking city reality.

Forester (2009) argues that we should take advantage of differences of opinions or different values among different people, even if it may take extra time and effort to do so, because doing so promotes collaboration among people and eventually helps the city move towards a more efficient, productive, and civil society.

One of the challenges that business-focused smart city models face is to reduce the income gap between the haves and have-nots. Studies show that the income gap has been bigger especially during the current Great Recession, with the poor becoming poorer, and the rich becoming richer (Rosenberg, 2012), especially in cities like Detroit (Okrent, 2009). In a similar vein, the lack of social equity and a significantly higher level of unemployment among poor residents challenge efficiency as one of the primary goals of the smart city.

(c) Political focus

In recent massive protests and democratization movements by everyday people in the Middle East and North Africa, we have witnessed that people, no matter where they live, yearn for the freedom of expression and participation afforded by an open society. In an increasingly plural society throughout the world, diversity in terms of race, gender, culture, and ethnicity demands a participatory society, civic governance, and civic engagement in many aspects of city affairs (Healey, 2006; Ellin, 2010). Several smart city models pay particular attention to the complex social and political aspects of making a city smart (Caragliu et. al. 2011). The underlying assumptions of these models are that active and informed residents are smart, and that smart people will work toward smart cities.

In light of such premises, these models focus on how to educate citizens, how to induce citizens to actively engage in city affairs, how to make it easier for them to share ideas about how to make their city better, how to cultivate an environment where new ideas and different perspectives may be nurtured so that citizens become better informed about making their city function more smoothly and serve them better.

Some of these models use technologies to promote more effective engagement of the general public in the design and planning process of city’s physical environment. One of the goals to achieve this is to promote an effective system for successfully soliciting the opinions of residents. In this situation, the success may depend in part on how effectively and how easily lay people can use the system or technology involved.

Dealing with angry or scared residents, who live in a shrinking city like Detroit, however, poses many difficult challenges particularly because a rightsizing or shrinking city policy will inevitably involve relocation of some residents from neighborhoods that have extensive vacant land (Okrent, 2009). In recent years, Detroit has used various civic engagement techniques including technologies in soliciting input and feedback from residents, but the city's efforts have largely failed. More recently the city has been changing its approach and strategies for civic engagement and currently the city is in the process of deploying new strategies (DWP, 2012).

The city has recently developed and launched a web-based community engagement platform (DWP, 2012; Mirviss, 2013). While this is encouraging, such a system might attract certain types of people (i.e., tech savvy residents, younger people). Many residents living in underserved areas may need to go to places like public libraries to use the Internet. A web-based tool is a great way to solicit public feedback, especially from people who are reluctant to express their opinions in front of others in a public place. Making it truly interactive is still a long way away, and the technology is not mature yet (Burd et. al., 2007; Jassem, et. al., 2010; Jassem, 2010).

(d) Environmental focus

In these days of concern for climate change and energy uncertainties the survival of our cities, regions, and even humanity, will require policymakers to explore "smart" ways of using limited resources and "smart" ways of making the physical environment sustainable. Some smart city models (e.g., Phdungsilp, 2011) deal with a broad range of environmental issues and concerns that affect our efforts to make cities environmentally smart. A common thread that cuts across these models in terms of their key assumptions is that to make the city smart will require smart people, smart technologies, and smart growth both locally and regionally, in other words a "smart" mindset (Kourtit et. al., 2012).

Proponents of this group of smart city models (with environmental focus), especially the supporters of the Smart Growth model advocate conservation of natural land, preservation, and effective and careful consideration of vernacular technologies, indigenous materials, local climate, and local assets in placemaking (Daniels, 2001). These elements are intended to promote transit-oriented development, mixed-use developments, and walkable communities.

In a similar vein, New Urbanists (e.g., advocates of New Urbanism) argue that transit-oriented developments expansion that encourage high density residential developments surrounded and supported by mixed-use areas (i.e., areas that are concentrated around the key nodes where major transit hubs are located) can promote a sustainable and smart city and region (Calthorpe, 2001 & 2010). While the transit-oriented development model has been received well by many policymakers and citizens in many cities, New Urbanism has been criticized by many who argue that it promotes more suburbanization, partly because New Urbanist communities have been developed mainly in suburban or semi-rural areas (Freilich et. al., 2010). In response, New Urbanists have been focusing on urban infill projects for some time, but more efforts are needed (Larsen, 2005)..

Another type of urbanism that has received much attention recently is called Landscape Urbanism. The proponents of Landscape Urbanism contend that in the age of post-industrial cities such as the ones in the American Rust Belt region, cities that have extensive vacant land and deteriorating building stock and infrastructure, landscape should be used as a primary means to create a renewed, sustainable city that is healthy, productive, and creative. Such a renewed city would eventually morph into a smart city. Landscape Urbanists argue that instead of building new buildings, abundant existing buildings should be repurposed, and vacant land should be transformed into productive landscape, used for activities such as urban agriculture (Waldheim, 2006). They also contend that newly created urban greens including urban farms should be connected across the city and region to create an ecologically sound system, and that existing nodes such as major community centers or town centers should be strengthened, and connected to landscapes across the city. In the end, as the Landscape Urbanists suggest, the landscapes that currently exist, as well as the new landscapes will become parts of a green infrastructure network that connects all green spaces and preserved natural areas across the city and its larger region. As a result, the city and region will be ecologically healthy. This is, arguably, yet another way of making the city and region smart.

Despite Landscape Urbanism's appeal to some cities in the Rust Belt region, Landscape Urbanism is not without criticism. In cities like Detroit that have suffered from significant shrinkage through loss of population and jobs, and the vacant land crisis in the face of an ongoing recession, landscape-based development or urban agriculture is not necessarily popular among policy makers and citizens who are faced with chronic unemployment. For example, Detroit's unemployment rate is hovering at 40% or higher in many poor neighborhoods. While Detroit is known for small community gardens and reportedly has about 1,000 gardens, Detroit still does not support the idea of large scale or industrial scale urban farms within the city perimeter. Also, there is significant resistance from the owners of small gardens and community residents against large-scale farming in the city (Okrent, 2010).

Given these factors, a major challenge of environmentally-focused smart city models may be explained by asking a two-part question: a) what are the smart and effective ways to promote an ideal balance and synergy between the built environment and green and natural environment in the city; and b) how can both of these be integrated in city-making? Empirical literature on this issue is still scant, and further research is necessary.

3.0 AREAS OF IMPROVEMENT

After reviewing the four categories of foci of smart city models discussed above, several lessons may be learned.

The previous section (Analysis of Smart City Models) suggests that a better smart city model is one that would incorporate more than one focus area. For example, elements from a business-focused model and a technology-focused model could be used if city officials want to promote more collaboration among different agencies or departments. Based on the evaluation and comparison of the four groups of smart city models, we learn that weaknesses of each model may be mitigated by incorporating strengths of other models that have a different focus.

Despite their popularity, a number of popular smart city models that we reviewed seem to employ a limited focus area; one such example is a technology-focused smart city model. We suggest that in order to promote an ideal smart city, it is necessary for city government leaders to address key concerns in all four categories.

Despite the fact that some overlaps exist among the models of the categories of focus, as shown in Table 1, the foci discussed there are useful because they help us better understand the scope, nature, and characteristics of smart city models. We can also use the proposed taxonomy as a way to understand and examine strengths and weaknesses of various smart city models. The classification of the smart city models can help us understand what kind of smart city model is required or desired for the relevant type of city policy or goal. The Four-Foci approach we propose requires further research, but nonetheless is a first step to obtain some synergies in the design of a smart city.

While thee reviewed smart city models have made contributions to the field of research into the ideal smart city or intelligent city, these models share three key limitations: lack of integration of the local and regional systems; lack of attention to holistic sustainability; lack of consideration of human factors and human and environment interaction; and inability to address significant urban changes. A more in-depth analysis is provided in the next section.

(a) Lack of integration of local system and regional systems

While smart city models generally contribute to, or address, a specific local context the models pay little attention to how to make a larger region smart. An argument may be made that, without a smart region, it would be difficult to achieve a smart city (Krueger & Gibbs, 2008). While some smart city models in the environmental focus group in Table 1 deal with regional issues, research on how a smart region beyond smart cities may be promoted and research on the relationship between the smart region and smart cities are still scant (Caragliu & Del Bo, 2012; Tranos & Gertner, 2012). All four groups of smart city models tend to be locally grounded, but their strategies in general lack regional collaboration.

(b) Lack of attention to holistic sustainability

There has been a growing concern among social scientists that, despite increasing attention to sustainability around the world, social, psychological, and political dimensions of sustainability have been neglected (Parr, 2009). It was found in this investigation that all four groups of smart city models address sustainability in one way or another. However, sustainability is defined in a limited way in each group., Despite sustainability claims made by each group of smart city models, a smart city model that advocates holistic sustainability, which incorporates social, economic, political, physical, and environmental domains of sustainability, is still rare.

(c) Lack of consideration of human factors and human and environment interactions

In each of the four groups of models , it is difficult to find mention of a smart city model that addresses how the physical environment of smart cities affects residents' behaviors and attitudes, and in what specific ways. In order to make cities smart, it may be necessary to induce citizens to think and behave in a smart way (smart thinking), as our comparative analysis of the various models has revealed. There is a large body of literature in environmental psychology and related fields that suggest that the physical environment impacts human behavior in significant ways (Gifford, 2002; Kopec, 2012). Research on how the smart city's physical features impact the thinking or behavior of the citizens, or whether the smart city can influence citizens in a positive manner in terms of their attitudes and behaviors, is still scant. We need research on smart cities in terms of human-environment interaction.

(d) Inability to address significant urban changes

While all four groups of smart city models reviewed deal with the evolution of cities in one way or the other, it is questionable as to how effective their approach to unprecedented changes such as the shrinking cities phenomenon is; this uncertainty arises from the fact that the focus or scope of each model is narrow or limited (Bugliarello, 2011). The shrinking city phenomenon has a widespread negative impact on the city like is seen in Detroit, because it affects many sectors (Okrent, 2009). Given the fact that the shrinking cities phenomenon is affecting not only cities in America's Rust Best region, but also cities around the world (Oswalt, 2005).), the role of smart cities in dealing with shrinkage is critical, worth investigating, and ought to be examined in-depth.

The following section suggests how to address the issues raised above, discusses the weaknesses or drawbacks of the models reviewed, and suggests how to develop a more robust smart city model.

4.0 RECOMMENDATIONS

We suggest that a more ideal smart city model should be able to address the following three key concerns or pressing matters of our and future generations: (a) major recession like the current "Great Recession," (b) public health, and (c) the challenges of urban growth or shrinkage.

The following discussion suggests how to address the challenges mentioned above, and how to develop a more robust smart city model.

We suggest that the abovementioned three areas of concern are critical to developing a more effective smart city model. We also suggest that there are several urbanisms that can respond to these concerns and help policymakers improve the current smart city models, building on what has been accomplished by the current models.

(a) Great Recession

Recession has left the design field unable to cope with change successfully. The field of design includes disciplines in architecture, urban design, urban planning, and landscape architecture, all of which deal with city-making.

After enduring several years of the recession that has swept the world, world leaders have begun to talk about a glimmer of hope. Despite some signs of recovery, the current recession has left the design field unable to cope effectively in a timely manner. Many firms went out of business and many people have lost jobs. The design field has been hit especially hard by the current recession.

Several smart city models (Agudelo-Vera et. al. 2011) focus mainly on the business aspects of smart cities, and they deal with smart business strategies such as expanding traditional boundaries of disciplines that deal with placemaking and citymaking.

To handle the current and future recessions more effectively, city officials and policy makers need to do more than what has been done up to now. For example, they need to address the following:

■ An ideal smart city model should be able to help city government leaders develop new programs or urban physical features that use various methods or technologies in an innovative way. Ideally such programs or features are designed to collect data from pedestrians and other users about improving the city's physical, social, and cultural environments (Desouza & Bhagwatwar, 2012). City officials and policymakers should also think about how such programs and features and citizen's engagement can help create jobs. Some of the smart city models do attempt to address some of these issues (Schön et. al., 2001).

■ An ideal smart city model should help city officials educate the public about the benefits of using innovative systems or technologies to address the vacant land crisis, and ways to deal with it such as urban farming, recycling, or repurposing vacant land and properties; creating new nature conservation areas; and cleaning the contaminated soil and water. A side benefit is that all of these tasks would help create new jobs, green jobs, new hybrid jobs, or new kinds of industries that require artistic, design, management, and planning skills (Salle & Holland, 2010). Some of these ideas can be gleaned from Ecological Urbanism (Mostafavi, 2010; Jepson Jr & Edwards, 2010).

■ An ideal smart city model should incorporate a strategy for educating the public, policymakers, and design professionals about the importance of collective intelligence and collective capabilities. For example, we can educate designers about developing systems of design that can help share information and knowledge with others through a network of individuals that have an interest in a similar issue. Participants can then aid in the improvement of these systems of design and possibly find new opportunities for employment. An ideal smart city model would encourage designers to explore social media, or conventional methods integrated with social media, engage the public, and educate the citizenry about design via open source systems and social media, all of which can lead to new job opportunities. Some of these ideas can benefit from incorporating strategies from Open Source Architecture and Urbanism models (Varudouli, 2012; Nijs, 2011).

(b) Health crisis

Many advanced countries face significant health challenges. They include obesity, diabetes, and sedentary life styles, all of which are affecting cities around the world.

Obesity, diabetes, and sedentary lifestyles are increasing, as we rely heavily on cars to conduct our daily business. Childhood obesity is increasing at an especially alarming rate (Frumkin et. al., 2004).

Some of the smart city models examine citymaking from the standpoint of how to make the city healthy. The proponents of these models advocate the idea of smart people for smart cities (Dannenberg et. al., 2011). In particular they focus on educating the public to be smart about their lifestyle and food choices, and they emphasize the environmental aspects of a smart city. In this regard an ideal smart city model should address the following.

■ An ideal smart city model should be able to help people think about the importance of engaging more actively with the space around them, especially open spaces and streets (Frank et. al., 2003). An ideal model should educate the public about the usefulness of technologies; about ways in which they can use technologies to help them exercise while working; and about ways in which workplaces and homes may be redesigned so people can get some exercise while doing other tasks. Some of the smart city models suggest that various technologies such as smart phones, AR technologies, and technologies embedded in eye glasses, shoes, or belts can help people with their health care. For example, technologies embedded in eye glasses, belts, or shoes can measure people's vital signs when walking or jogging in the neighborhoods, parks, or work places. Likewise, kiosks, trash cans, bus stops, and the like can also have technologies that can educate the public about healthy food and lifestyle choices. Policymakers and city officials should think about how to use a smart city model to help educate the public about those opportunities or possible healthy interventions in their daily lives.

■ An ideal smart city model should educate policymakers about the importance of providing ample space within the urban context for recreation, vegetation, and landscape, because they help create an urban oasis that provides cleaner air and lush spaces for relaxation. An ideal model should educate policymakers and the public about the importance of clean and safe air, water, and soil, which help cultivate safe and healthy food and help promote healthy environment. It will encourage people to enjoy, exercise, and explore the outdoors more frequently, and should eventually lead to a healthier lifestyle. We learn some of these ideas from Ecological Urbanism (Mostafavi, 2010).

■ An ideal smart city model should educate policymakers about the fact that the health of an individual can be improved by interaction with others in the public domain. This may be done physically and virtually. We learn that open source systems and social media create opportunities for social interaction. Social interaction reduces stress and other related illness or pathologies (Kopec, 2012).

(c) Urban growth challenges and shrinking city phenomena

Many cities around the world are shrinking (Hollander & Németh, 2011; Haase et. al., 2010). Areas that once held a large population now needs to find a way to be sustainable and productive with a smaller population in the same amount of space, and needs to address the increasing number of vacant properties, and loss of population and manufacturing industries (Leigh & Hoelzel, 2012). An ideal smart city model should address the following:

■ An ideal smart city model should educate policymakers and the public about the importance of the ability to recognize significant changes of growth or shrinkage (Ahern, 2011). To prevent the rise of the extreme and complex urban growth problem that many cities are experiencing, proponents of technology-focused smart city models argue that we need to use innovative technologies that allow us to analyze, synthesize, process, or merge complex data from diverse fields or disciplines, and also to help predict changes (Dodgson & Gann, 2011;Haase et. al., 2010). This would require multi-disciplinary collaborations and coordinated application of some of the ideas from all four groups of the smart city models that have been discussed in this paper.

■ An ideal model should educate the city officials and the public about the importance of or benefits of re-using underutilized or vacant properties for urban gardens and plants that can improve the soil and air quality. In particular, developing urban farming in vacant land and vacant buildings can create nature conservation areas that can keep the built environment healthy. Urban gardens can also be options for future development (Schilling & Logan, 2008). Ecological Urbanism teaches that ecology and nature can help the design of a more sustainable, healthy, and pleasing urban form (Mostafavi. 2010).

■ An ideal model should educate city government leaders and the public about the importance and benefits of developing long-term plans for rightsizing cities, given the fact that shrinkage and urban growth challenges are not only a city-wide problem, but are also regional issues (Barbour & Deakin, 2012). An ideal model should also educate city officials and the public about the importance of or benefits of collective intelligence or collective capabilities via open source systems and social media (Schetke & Haase, 2008). Given increasing global economies, it will be beneficial for people around the world to be able to exchange ideas about best case examples that could spark new ideas. Detroiters, for example, could share ideas with residents of other cities that are facing similar problems of shrinkage, or other significant urban ills.

CONCLUDING REMARKS

The four types of smart city models discussed in this paper can be used as a way to examine current and future smart city models. The proposed Four-Foci taxonomy of smart city models can help city policymakers identify strengths and weaknesses of various models and help them explore ways in which the models may be improved.

What we learned from this stage of our research is that no matter which model is chosen, it will be necessary to incorporate strengths or assets of each of the four proposed foci (groups of smart city models), and address the challenges of each group of the models as relevant to a specific city. Another lesson is that an ideal model needs to promote a 'smart' mindset, which requires civic engagement, collaborative planning and dissemination of knowledge in the process of smart city development. In this way research can be made more visible and the idea of public visibility could be embraced more effectively in smart city planning (Deakin, 2012).

Clearly many variations are possible within the proposed four groups of smart city models. Even if the same model is applied in various locations, different locations may likely yield different results. Thus an international comparison of the same smart city model(s) might be useful, given increasing globalization and interdependence of nations.

Study 1 of our research was primarily theoretical in nature, as it aimed mainly to propose a conceptual model for examining the smart city models in a more holistic way. A follow-up investigation, Study 2, is planned on international comparative research on the research topic. Study 3 is planned and will focus on Phase III. Development and Phase IV. Evaluation and Conclusions. Study 3 would be more empirically-based research on smart city models, focusing on particular locations or cities.

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Bottom-Up Urban Innovation and Growth through Social Technologies

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ABSTRACT: This paper aims to outline new and growing intersections between design innovation, social media and grassroots reclamations of abandoned, under-utilized, or neglected urban spaces, with a particular focus on New York City. Three projects of focus include the High Line, a fully functioning public park on the west side of Manhattan, converted from an abandoned, elevated freight line; +Pool, a proposed engineering strategy that uses new filtration technology to construct a river-filtering floating pool in waters around Manhattan; and finally, the Lowline, a proposed subterranean park that collects natural sunlight through remote skylights and transmits it to underground spaces through fiber optic cable, allowing for photosynthesis and plant growth. While the High Line is the only realized project of the three, all have valuable social and urban similarities that reflect a common thread of grassroots innovation. Recognizing the social potential in neglected elements of the city, the visionaries and leaders behind these projects, fought and are fighting to create life, social function and vitality in what have been underused or unusable parts of New York.

KEYWORDS: High Line, Lowline, +Pool, New York City, Urbanism

INTRODUCTION

A city dweller can often see one's environment in finite terms. A city dweller, especially in a city like New York, can walk to the edge of Manhattan and stand at a river, knowing that the island is not going to grow latitudinally or longitudinally. When space is needed and terms are finite, New Yorkers have to look up, or down, or sometimes even out to expand not the island itself, but to expand its functionality. This is a common theme in many finite urban spaces.

City growth, time and again animated by prosperity and innovation, has historically, in the case of New York, occurred at a breakneck pace, often singularly accommodating the needs of the city's elite, who were also the developers, innovators, policy makers, and government all-in-one. One could argue that the history of the city only repeats itself ad infinitum, but recent trends in urban architecture and design have began to expand the audience and key players in shaping our cities. While heavy-handed development and control of New York was evident in the birth and growth of the city, and it is impossible to deny the tremendous influence industrialists, businessmen, and bankers had on New York infrastructure through their trading, cotton, transportation, and money lending empires, a shift in power seems to be occurring in regard to urban public spaces. These changes seem to be activated, considerably strengthened by, or widely shared by newly galvanized design- and public space-oriented online communities.

While often business and policymakers have dominated the growth landscape of what is one of the most powerful metropolises in the world, the detritus of fast moving growth often has historically left the less individually powerful citizens with architecturally isolated neighborhoods, obsolete infrastructures, and unusable waterways due to pollution and overuse. Technology is universally regarded as a frequent contributor to urban development and redevelopment, but it is often applied to more quantifiable and specific instances of treatment. A recent trend in many creative cities has involved applying innovative new technologies not only to the physical landscape of the city directly, though, but to the social fabric of the city in hopes of instigating involvement and initiating social action in regard to certain proposed urban interventions. These social applications, often arriving in the form of Kickstarter, Facebook, Instagram, Twitter, Indiegogo, blogs and other publicly viewed online forums, has begun to involve a digitally savvy population that is looking to invest in the social and physical future of their urban spaces.

Land development has nearly hit a plateau in New York City, in terms of untouched earth to swell into, and instead of trying to develop quantity, inhabitants are learning about the merit of re-utilizing what is around them to improve immediate quality of life in a non-commercial sense. While real estate prices and viable commercial endeavors are still often the underlying motivation behind most physical action and change that happens in the city, social factors are now becoming more pronounced in a public sense, and this is in part due to the dissemination of widely supported ideas online.

This paper aims to outline new and growing intersections between design innovation, social media and of-the-people reclamations of abandoned, under-utilized, or neglected urban spaces, with a particular focus on New York City. Three projects of focus include the High Line, a fully functioning public park on the west side of Manhattan, converted from an abandoned, elevated freight line; +Pool, a proposed engineering strategy that uses new filtration technology to construct a river-filtering floating pool in the rivers around Manhattan; and finally, the Lowline, a proposed subterranean park that collects natural sunlight through remote skylights and transmits it to underground spaces through fiber optic cable, allowing for photosynthesis and plant growth. While the High Line is the only realized project of the three, all have valuable social and urban similarities that reflect a common thread of grassroots innovation. Recognizing the social potential in neglected elements of the city, the visionaries and leaders behind these projects, fought and are fighting to create life, social function and vitality in what have been underused or unusable parts of New York, supported in large part by social media and other socially minded online networks.

1.1 The High Line

The High Line, a very successfully realized example of obsolete technology giving way to updated ideas and reinterpretation of infrastructural use, had a long history of hard work for the commercial industries of Manhattan. Beginning as a freight line up the West Side of the island, it ran from the 1930s to 1980, when it was abandoned and left wayside. Earlier in the century, this same freight line was found at ground level, but because of safety issues it was hoisted above the city to grow up, because out was not an option. Over time, the vast highway system in the US made the line less relevant, and its closure left a skeleton of the city looming dark over the West Side for years. As developers saw potential in the raw space it was taking up, grassroots efforts began to take hold of the site and after varied attempts at preservation, The Friends of the High Line was finally founded in 1999. This advocacy effort successfully fought for years to preserve the space, and finally in 2009 the first section was opened.[1] The second section has subsequently opened, and the third is currently being developed to open in the next several years.

The High Line not only has a strong presence in the city now, but has also developed a significant online presence as well. On its Facebook page, The High Line has over 65,000 Likes, and over 210,000 people that noted their visit to the park by checking in. Each unique post that The High Line puts up receives hundreds of Likes and dozens of Shares. It encourages New Yorkers and visitors to comment on posts and participate in fundraising efforts, and constantly links to press articles about its own organization as well as similar projects, museums, individuals and businesses that are working toward similar goals. It extends its brand image to support local business and other industries in the city through its own Likes, and shares photos of park-goers to further incentivize participation in the living project.

In its active engagement with the public, it asks urban dwellers (and visitors) to become amateur documentarians, and in allowing these thoughts, photos, and suggestions to be published openly, give the public a forum to overtly participate in the growth of the park. The High Line highlights partners and vendors, even recently sharing with blog readers the plight of one vendor that lost their kitchen through Hurricane Sandy.[2] Though the project itself was unprecedented in New York, the idea of revitalizing something that had been an urban eyesore is not new to urban development. What is unique to this project, though, is the massive amount of effort that went into converting this space into park use instead of residential or commercial real estate use. Thanks to a 2002 study, it was found that tax revenues would outweigh construction costs of the park[3], and the financial value was a significant factor in moving the development of the park forward. The question still remained though, whether it would catch on for use as a public space, especially because it did not live at street level, and was unusually long and narrow for a park. Many factors can be attributed to the success of The High Line as a publicly used park, including lack of green space on the west side of Manhattan, or the power of the officials and fundraisers who were behind the project, but it is undeniable that the extensive dissemination of The High Line brand online, has maintained a relevance in urban culture and planning that shows it is engaged with its users, its city, and the businesses and patrons that help support it. It capitalizes on methods of advertising and commercial methods of marketing to continue to fund and maintain brand identity in a non-profit sphere.

1.2 Unrealized projects

Interestingly enough, two other urban interventions in New York are following a similar design trajectory as The High Line, in that both are setting their sights on unused or underused spaces in New York. In the case of the similarly named Lowline, an abandoned underground trolley terminal in the belly of the Lower East Side is the target, and with the visually-named project, +Pool, the intimidating waters around Manhattan are in the crosshairs. Similarly to The High Line, these projects are relying heavily on their online cultural brand presence to maintain relevance, gain supporters and donors, and most importantly, to start their projects. What is unique here, though, is that these two projects are working in reverse- they do not yet exist. Their fan bases and donor bases are vast, and both projects are already garnering significant public, city, and even international support. What is most amazing, though, is that both are still in fundraising and development stages, and neither has any guarantee of realization.

1.3 The Lowline

The Lowline, a project started by James Ramsey, former NASA engineer and current principal of RAAD Studio, and Dan Barasch, former social innovator with Google and UNICEF, was first publicly presented through a crowd-sourcing fundraising website, Kickstarter. Ramsey had developed a unique technology that allowed for natural sunlight to be collected with solar panels and transmitted to aid photosynthesis in dark spaces. While on a trip to India in 2008, he saw the profound potential of sending natural light to low or no-light spaces, and the possibility of illuminating one of the many subterranean areas in New York became an obvious target.[4] Pairing with Barasch and developing strategy to move forward, the team aimed their sights on an MTA-owned trolley terminal by the mouth of the Williamsburg Bridge, and began a Kickstarter campaign with the ambitious goal of raising $100,000 in one month. With 3,300 backers, the Lowline far exceeded their target, and raised $155,186 in the span of one month, with only a few clear renderings, site photographs, and a promotional video explaining the vision. Subsequent development of the project included a significant free public exhibition on the Lower East Side in September of 2012, introducing a prototyped version of the proposed technology, opening the concept up to the neighbors, students, professors, designers and theorists who were interested. With tremendously positive feedback, the strategic team behind the Lowline is now focusing forward and aiming to have the Lowline included in a significant redevelopment of the Lower East Side, also known as the Seward Park Urban Renewal Area (SPURA).[5] This area, historically low-income because of the highest density of government-subsidized housing in New York City,[6] lacks any significant green space, and the Lowline hopes to capitalize on public support for the project to gain even more political support.

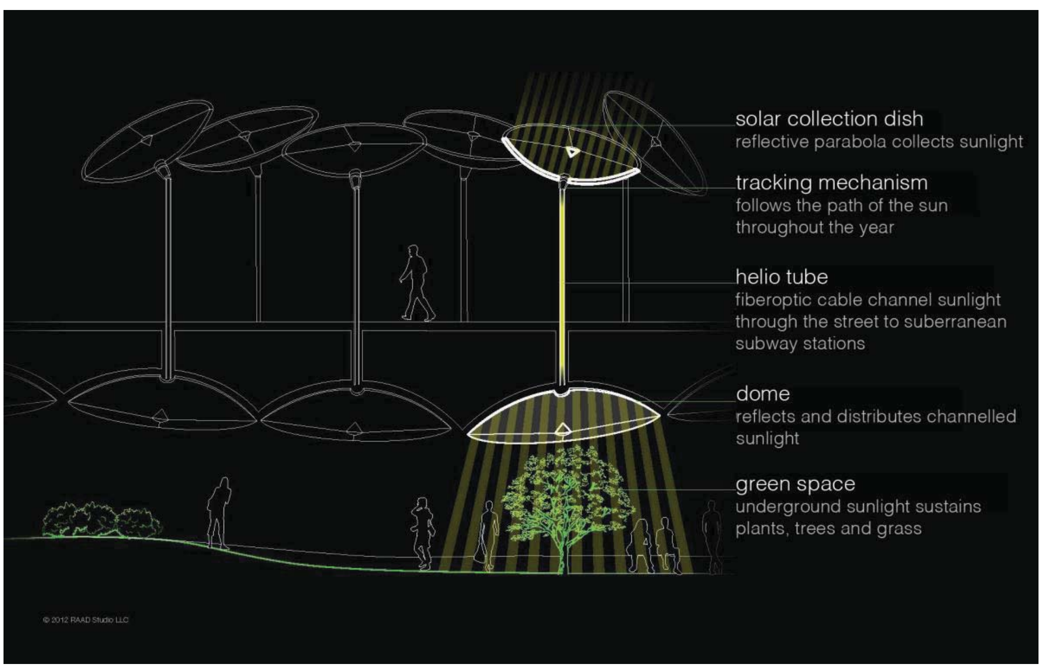

Figure 1: Illustration of proposed “remote skylight” technology for the Lowline. Source: (The Lowline,

Figure 2: Actual photograph of prototype open to public in September 2012. Source: (The Lowline, 2012)

Figure 3: Rendering of proposed Lowline park in abandoned trolley terminal. Source: (The Lowline, 2011)

1.4 +Pool

Finally, + Pool, a project that is tracing a similar arc as The Lowline, also began as a Kickstarter campaign, aiming for a modest $25,000 for initial investigations, and successfully collecting $41,647. The project proposed something simple but profound for the inhabitants of the city- create a floating pool with permeable filtration walls in the formerly feared waters around New York. Utilizing the river water and making it safe to swim in, +Pool proposed a tangible solution to capitalize on even more of the city's resources, in a way that would once again benefit the public. The three founders- Dong-Ping Wong of Family, and Archie Lee Coates IV and Jeffrey Franklin of PlayLab, Inc.- saw an obvious opportunity in the water around the city during one particularly hot summer. Since July 2011 when their initial Kickstarter campaign closed, the +Pool team has moved on to a bigger and better online fundraising campaign, aiming to raise $1,000,000 by April 1, 2013.[7]

Figure 4: Rendering of +Pool. Source: (+Pool, 2013)

Figure 5: Rendering of +Pool. Source: (+Pool, 2013)

1.5 Cultural branding and why social media is significant

In the above-mentioned cases, these significant urban interventions begin on a bottom-up level and are disseminated widely through a number of avenues, not least of which are new forms of online social media, including Kickstarter, Facebook, Twitter and Instagram. This kind of new civic engagement is involving a younger, more socially aware demographic of urban dwellers that span a variety of professions and economic brackets. It is this accessibility to innovation in architecture that is allowing the masses to participate in, inform, approve and support research and trial projects in urban spaces that would otherwise need to initially search for grant funding and other private means of support. While these three case studies are New York specific, the implications of this kind of new, very active social participation can be mirrored and integrated in an unlimited number of urban improvements and interventions.

What is particularly interesting in these cases is that advancing technology made each of these respective urban spaces initially obsolete or unusable. With the successfully realized High Line, years of dedication and community support led to an open public space in place of an abandoned rail infrastructure. In the case of +Pool and the waters around New York City, it was and is a river polluted over the course of the city's significant industrial past, preventing many recreational uses of the waterway. An advanced, river-permeable filtration system technology, in addition to widespread online and financial support, is leading the way for the city to reclaim part of the waterway in the form of a public pool. With the example of the Lowline, an abandoned trolley terminal in the Lower East Side of Manhattan has sat dormant since the late 1940s, a lonely relic of New York's vibrant transportation history. A testament to an ever-changing urban fabric, it is only through a proposed new solar technology that this approximately 1.5 acre underground space may find a second life.

While the levels of new technology vary between these three projects, the common denominator is that architectural and online technology is allowing for a designers and citizens to develop and ascertain the feasibility of certain urban interventions in a direct and open way, democratizing design and demystifying urban planning. These trendsetters are capitalizing on user-generated websites and social networks to execute a publicly accessible and publicly generated project.

Capitalizing on a system that consumers are friendly with in the form of social medias, the means of contributing and means of return are different than standard consumer culture- it is not an individually owned "product", but rather a communally grown project. The product is, in fact, a quality of life product, which subverts the original intent of advertising, creating a product that is free to the public. The accumulated capital is no longer the ability to spend, or the ability to consume, but is post-consumption- the ability to reconstruct and rebuild. Utilizing these advertising tools and methods to promote these cultural and social projects, these social and design innovators are adapting and applying known business methods, and translating them to a slightly different realm.

1.6 Speculative motivations for public interest in shaping public spaces

Such significant public interest in shaping one's own city and space- and in this case, New York City- begs the question of why? While many view architecture and design as historically isolated and patriarchal in relation to the layman, there is a visible interaction between the designer and its users in these specific cases. One could speculate that this is only due to the Internet's power to spread information, but it is worth considering that there are also several more key factors at play here.

Advertising provides a rich background to compare this user participation to, in the sense that now the user in the design term is also a consumer in a capitalist sense. Advertising, or "publicity" as John Berger calls it, as a means to communicate and promote a specific product, is pregnant with expectations and desire. It serves as a frozen moment in time, full of potential energy, bursting with self-expression, excitement, and possible fulfilment of a "need", giving the consumer the power to fulfil their own "needs", though those "needs" were only created at suggestion of the advertisement in the first place.

While not necessarily a consumer that spends money to consume or obtain goods, the user of The High Line or the other two proposed projects is a consumer nonetheless. In this case the currency is culture, and perhaps this cultural currency comes from an oversaturation of personal material goods. American cities are so deep in visual culture that we depend on seeing to know something exists, notable through the rise of print media, then advertising and also television. Because we have become used to the quick gratification of our imposed "needs" by big companies, could it be argued that this desire to support a public urban project is a spill-over from managing and improving the home, and consumers have become over-saturated with products to "improve" their quality of life? Are consumers now looking toward their surroundings to manage and create idealized spaces? At first glance, the public fundraising and support of these projects may seem altruistic and community-minded, because non-profiting places like libraries, museums, and community centers don't revolve around making money, and therefore don't have an investment potential that returns an investor's money. Donations and grants are secured to fund programs for the public, but don't always look to reinvest that money for a financial return later.

These facts would point towards benevolent and benign urban interests on the part of the city dweller, but could there be a deeper, less obvious, slightly more insidious impetus behind the culture consumer that stems from accumulation of cultural currency, similar to accumulation of wealth of material goods? Because the capitalist consumer uses and depends on objects to curate a sense of relevance in their own lives, could it be that this cultural consumption in the form of aiding larger urban projects is just a broader example of consumer culture at work, with the user/investor/viewer accruing culture points for themselves, like dollars? Are these publicly funded projects just the physical manifestations of cultural capital?

CONCLUSIONS

In a Western consumer culture that focuses on and values endless redevelopment of visual identities and material goods, we often discard these same materials at a breakneck pace, in an attempt to be competitive and equally relevant in a constantly innovating capitalist society. Abandoning the notions of utility and design for longevity, we are surrounded by a culture that is programmed to regenerate itself in increasingly smaller spans of time. These ideas of use, disposal and regeneration speak about the social identity of individuals within this wider culture, and can be analyzed and understood through patterns of consumption and reuse. Looking at urban projects that focus on infrastructural renewal, powered by the public, it is interesting to speculate about the state of consumer culture and whether cultural capital follows the same rules as economic capital, or whether consumers are in fact breaking away from expected patterns of consumption and instead investing in socially beneficial projects.

Whatever the motivation, it is undeniable the innovative uses of social media and new technologies are helping to activate and energize an urban public that is excited to get its hands dirty in terms of funding large urban interventions, as well as giving feedback and social support. The joining of social media campaigns and rigorous explorations of urban landscapes with the intention of inserting projects that improve quality of life is a profound statement about the urban dweller and the investment she feels in her surroundings. The city dweller is actively participating in design culture in the same way that a voter would participate in a democratic election, and it is very likely that online information sharing is, in large part, very responsible for this activation.

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OPEN TOPICS

Visibility of Research in Design Practice Current and Future Trends

Ajla Aksamija, PhD[1], David Green[2]

[1]Tech Lab, Perkins+Will and AREA Research
[2]Perkins+Will and AREA Research

ABSTRACT: This paper discusses the current trends in research coming from practice, particularly focusing on the research efforts of Perkins+Will Building Technology Laboratory (Tech Lab). We discuss the processes, types of research questions, selection of appropriate research methods, and applications of results in design projects. We demonstrate these aspects by examining a specific research project as a case study, focusing on the facade energy performance and daylight analysis. Then we discuss the forming of a new non-profit research organization, AREA Research, which was initiated from the existing design practice and the current research activities. The primary objective of this entity is to allow collaborative research efforts between design firms, research laboratories, universities and other research organizations that concentrate on the research relating to the built environment, which may or may not be directly driven by a specific architectural or design project. We discuss the objectives, vision and mission of AREA Research, as well as its organization. These new types of collaborative efforts are aimed to increase visibility of research relating to the built environment, as well as the application of research results in practice.

KEYWORDS: research in practice, innovation, building technology, design

INTRODUCTION

Research in architecture and design is not a new phenomenon. Gradual technological changes, such as new materials, construction techniques and design representations, have accelerated the need for research over time within design disciplines. Today, research is more important than ever and it has become an integral component in the design practice.

Over the past two decades, research in design and architecture has diversified and now often involves interdisciplinary approaches. Topics are wide-ranging, encompassing advanced materials, building technologies, environmental and energy concerns, design computation, automation in construction, design delivery methods, project management and economics. The practical value of this knowledge is enhanced by a new direction, where research originates in practice. Research questions, methods and results must be closely related to architectural/design projects, design processes and services.

This paper examines current and future trends in research coming from architectural and design practice. It first reviews activities and research conducted at Tech Lab, and presents a specific research study as an example of research questions, methods, results, and implementation in architectural projects. Then we discuss the formation and organization of a new non-profit research organization, AREA Research, whose primary objective is to bridge the gap between academic and practice-based research activities, and allow collaborative efforts to address research needs relating to the built environment.

1.0 RESEARCH IN PRACTICE: BUILDING TECHNOLOGY LABORATORY (TECH LAB)

Tech Lab was initiated in 2008 as a research entity within Perkins+Will to enhance project designs through dedicated research. Tech Lab's research agenda focuses on advanced building technologies, materials, sustainability, high-performance buildings, renewable energy sources and computational design. Tech Lab monitors developments in building systems, materials, and information technology; reviews and analyzes emerging technologies that can have a direct impact on the course of architectural design, and investigates building systems and technologies that can significantly improve the value, quality and performance of architectural projects.

Examples of Tech Lab's research projects are:

- Performance and life cycle cost analysis for building integrated photovoltaics

- Performance of double skin walls
- Renewable energy systems optimization
- Advanced thermal comfort modeling
- Parametric modeling and design
- Thermal analysis of exterior wall assemblies
- High-performance building envelopes
- Selection on renewable energy sources.

Primary research methods include simulations and computational modeling, which are used to investigate different design scenarios and strategies. Typical research process involves: 1) determination of research objectives and questions based on the needs of specific architectural/design projects; 2) identification of appropriate research methods; 3) identification of the timeline, schedule and research procedures; 4) execution of the study; and 5) dissemination and implementation of research results. Besides implementation of research results on architectural and design projects, sharing and dissemination of findings with the larger architectural and design community is a key aspect of Tech Lab's objectives. Publications of research data and methods, analysis processes and results benefits the entire industry, therefore, research studies and results are shared through Tech Lab Annual Reports, shown in Figure 1.

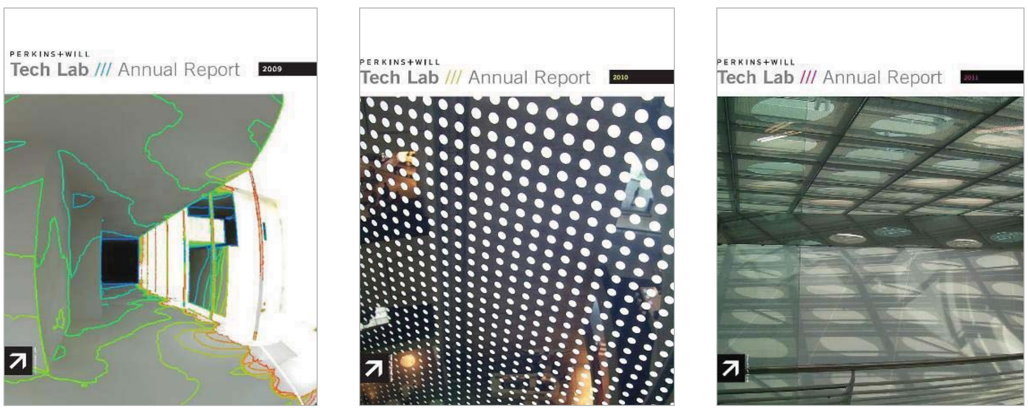

Figure 1: Dissemination of research results through Tech Lab Annual Reports. Source: (Aksamija 2010, Aksamija 2011, Aksamija 2012)

For example, Tech Lab Annual Report 2009 includes studies such as building envelope performance analysis and daylight optimization, life-cycle cost analysis of building-integrated photovoltaic system, building envelope studies and daylight analysis, relationships between thermal comfort and outdoor design elements, study of facade options and building integrated photovoltaics, and a feasibility study for stand-alone self-powered exterior signage lighting system (Aksamija, 2010). Tech Lab Annual Report 2010 includes facade energy studies, photovoltaic system energy performance and cost analysis studies, curtain wall heat transfer analysis, and exterior wall thermal transfer study (Aksamija, 2011). Tech Lab Annual Report 2011 includes studies relating to high-performance building facade, dew point analysis of a typical exterior wall assembly, hygrothermal analysis of exterior walls, and facade energy performance and daylight analysis studies (Aksamija, 2012). These reports also include selected white papers that are written on building technology topics, as well as published research articles and research reports.

The next section reviews a specific case to illustrate research processes and methods in more detail.

2.0. CASE STUDY: FAÇADE ENERGY PERFORMANCE AND DAYLIGHT ANALYSIS

2.1. Façade Design and Energy Performance

The purpose of the study was to investigate high-performance curtain wall facade design options for a commercial building, located in Boston. The study considered different facade orientations of the building, and different design strategies for improving energy performance and occupants' comfort.

Energy modeling using EnergyPlus software was performed to investigate different design options for each relative orientation, and these following design scenarios:

- **East orientation (Facade type 1, which encloses a two-story atrium)**:
  - Base case: Fully glazed curtain wall with low-e air insulated glazing
  - Option 1: Fully glazed curtain wall with low-e fritted air insulated glazing (frit pattern covering 50 percent of the vision area)
  - Option 2: Fully glazed curtain wall with low-e fritted air insulated glazing (frit pattern covering 50 percent of the vision area), and 1.5 ft deep exterior shading elements (vertical fins) spaced 2.5 ft apart
- **East orientation (Facade type 2, enclosing one-story interior space)**:
  - Base case: Curtain wall with low-e air insulated glazing unit and 2.5 ft high spandrel with approximate thermal resistance of 17 h-ft^2-F/Btu (window-to-wall ratio 70 percent)
  - Option 1: Similar to base case, with added 1.5 ft exterior vertical fins spaced 2.5 ft apart
  - Option 2: Similar to base case, with frit pattern covering 50 percent of the vision area
- **South orientation**:
  - Base case: Curtain wall with low-e air insulated glazing unit (window-to-wall ratio 95 percent), seen in Figure 2
  - Option 1: Curtain wall with low-e air insulated glazing unit and 2.5 ft high spandrel with approximate thermal resistance of 17 h-ft^2-F/Btu (window-to-wall ratio 85 percent)
  - Option 2: Curtain wall with low-e air insulated glazing unit, horizontal overhang (3 ft deep) and an interior light-shelf, and horizontal shading elements (0.5 ft wide fins spaced 1 ft apart below the overhang, and 2 ft above the overhang), as seen in Figure 2
- **West orientation**:
  - Base case: Curtain wall with low-e air insulated glazing unit (window-to-wall ratio 95 percent)
  - Option 1: Curtain wall with low-e air insulated glazing unit and 1.5 ft deep vertical fins spaced 2.5 ft apart
  - Option 2: Curtain wall with low-e air insulated glazing unit, horizontal overhang (3 ft deep) and an interior light-shelf (also 3 ft deep), and horizontal shading elements (0.5 ft wide fins spaced 1 ft apart below the overhang, and 2 ft above the overhang), identical to south facade option 2.

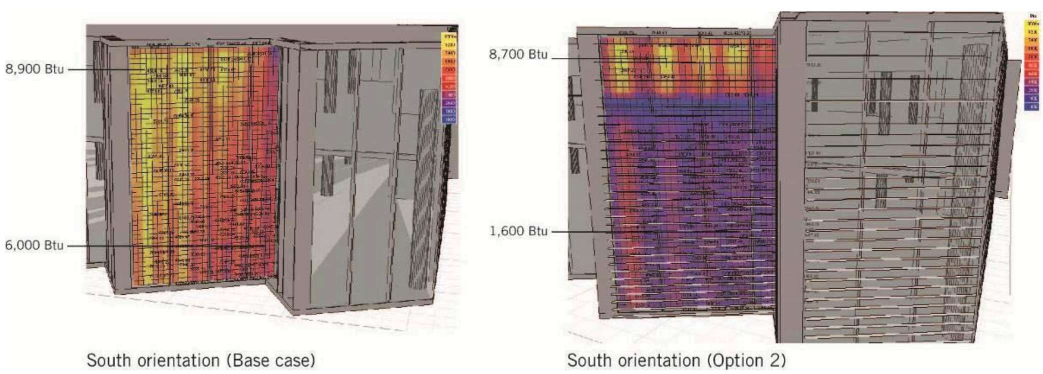

Figure 2: Comparison of solar radiation for south-oriented façade (Base case and Option 1). Source: (Aksamija 2012)

Properties of the glazing units are listed in Table 1, and all three scenarios considered thermally broken aluminum mullions.

Table 1: Properties of the glazing units.

Glass properties	Base case	Options 1 and 2 (fritted glass)
U-value (Btu/h-ft^2-F)	0.29	0.29
SHGC	0.38	0.26
Visual transmittance	0.70	0.48

Annual energy consumption, thermal comfort and daylight levels were investigated for all options. Figure 3 shows summary results for energy consumption for all building orientations and design options, while Figure 4 shows comparison of average annual daylight levels in interior spaces. The results indicated that Options 2 would be the best design scenarios for all four orientations for improving energy performance.

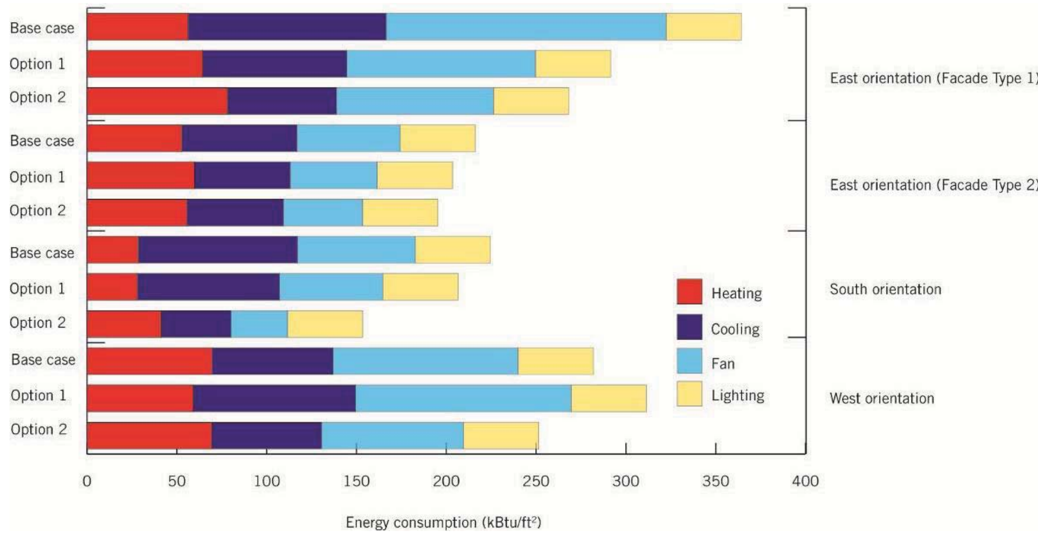

Figure 3: Comparison of energy consumption for all design scenarios. Source: (Aksamija 2012)

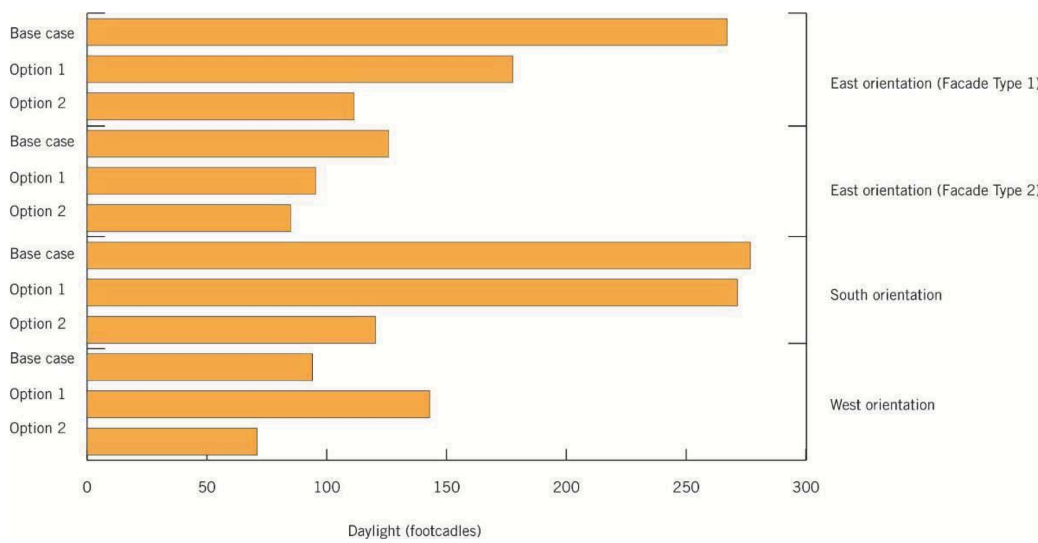

Figure 4: Comparison of daylight levels for all design scenarios. Source: (Aksamija 2012)

2.2. Daylight Analysis

Daylight simulations using Radiance software were performed to investigate availability of natural light reaching the interior space. Since it was found that the best-performing design scenarios for the south and west orientations include horizontal overhang, horizontal shading elements and a light-shelf for reducing energy consumption, these design options have been used to study availability of natural light. They were compared to two other design options:

- Base case: flat south-west facade
- Option 1: serrated south-west facade without any shading elements or light-shelves
- Option 2: serrated south-west facade with a 3 ft deep horizontal overhang, horizontal shading elements (0.5 ft wide fins spaced 1 ft apart below the overhang, and 2 ft above the overhang) and 3 ft deep interior light-shelf.

Daylight analysis was performed for September 21 at noon, with sunny sky conditions. Since this facade adjoins two-story interior space, the purpose of the analysis was to compare daylight levels on both levels. Specifically, light redirecting mechanisms for the office space located on the second floor were investigated, since this space is located approximately 20 ft from the facade, and is separated from the atrium by a glass partition wall. These different options are shown in Figure 5, as well as the daylight simulation results.

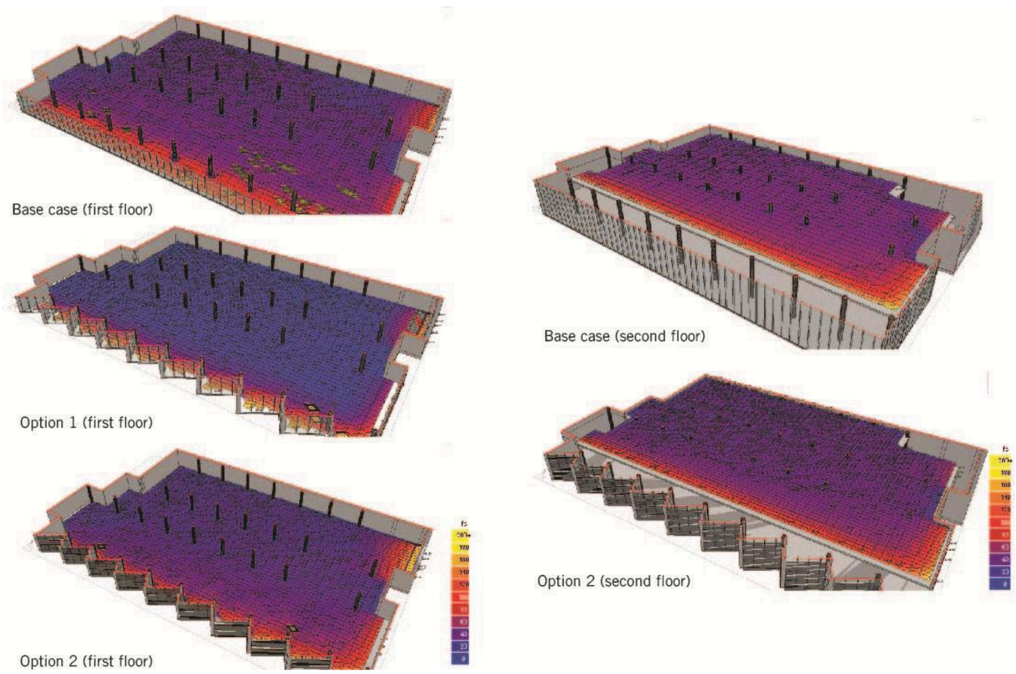

Figure 5: Design options and daylight levels. Source: (Aksamija 2012)

Generally, highest daylight levels for the first floor would be present for the base case scenario; however, this option is the worst from energy performance perspective. Comparison between options 2 and 3 shows that option 3 would provide more daylight, since the shading elements and a light-shelf would redirect light within the interior space. For the second floor, daylight levels are comparable for both options, although the actual values are higher for the base case scenario. Since option 2 is the best performing design scenario in terms of energy performance, the addition of light-shelves would balance the effects of shading elements on the availability of natural light. Tables 2 and 3 show detailed results of the daylight analysis.

Table 2: Daylight analysis results (first floor, September 21 at noon).

Distance from curtain wall	**3 feet**	**6 feet**	**9 feet**	**12 feet**	**15 feet**	**18 feet**	**21 feet**	**24 feet**	**27 feet**	**30 feet**
Daylight levels Base case (footcandles)	170	164	149	136	121	90	85	78	73	70
Daylight levels Option 1 (footcandles)	170	160	133	118	101	80	57	38	30	20
Daylight levels Option 2 (footcandles)	180	173	147	132	118	96	72	55	49	45

Table 3: Daylight analysis results (second floor, September 21 at noon)

Distance from curtain wall	**24 feet**	**27 feet**	**30 feet**	**33 feet**	**36 feet**	**39 feet**	**42 feet**	**45 feet**	**48 feet**	**51 feet**
Daylight levels Base case (footcandles)	150	142	120	103	76	63	58	54	52	48
Daylight levels Option 1 (footcandles)	131	102	80	70	58	52	46	44	42	40

This case study illustrates how research process can be beneficial for design decision-making. Having these results and quantifiable data allowed the design team to make informed decisions regarding the facade treatment for this specific project, as well as daylight harvesting strategies. At the same time, documenting results and sharing research processes, objectives and results is beneficial for the design community at large since these results can also be applied to other similar projects or design problems. Besides project-specific research, there is also a need for broader research spectrum that addresses all of the different aspects relating to the design of built environments, which may not necessarily relate to only a specific project. These types of research projects are often long-term, and may require substantial involvement from different disciplines, collaboration and investments.

3.0. NEED FOR COLLABORATIVE RESEARCH IN PRACTICE: AREA RESEARCH

In November of 2011, Perkins+Will launched a new nonprofit organization, AREA Research, for the purpose of advancing design through dedicated research. The objective for this organization is to become a platform that connects the design professions, academia, and research institutions, supporting innovative research that results in a higher-quality built environment, and by extension, the lives of the inhabitants of those environments. The mission is to align the long-range research capabilities of academic, and research institutions with the practical, project-based knowledge of the design professions.

The name AREA translates this mission into four actions that include advancing knowledge about the built environment and its design through the pursuit of collaborative research funded by a diverse range of third party sources. Further, the aim is to research innovative solutions that lead to technically sound, ecologically rich, healthy and livable buildings and communities, expand the research networks by partnering with industry leaders and research collaborators to undertake research pursuits and apply outcomes of the research to real world projects, demonstrating practical and tangible applications of the results.

Two primary conditions drove the formation of this company. First is the growing need for research institutes and other organizations to team with professional partners that represent the potential practical application of their research. Second is the need of design professions for a venue to investigate issues that are not project-specific, but longer duration efforts. Founded to address both demands, the true potential of AREA Research lies in its ability to bridge basic and applied research.

As a venue for partnerships, this organization will become a conduit for bringing the information garnered in the research process to the broader design professions, as well as others who might benefit from this valuable information as well as pushing data from professional sources back to the research community. Over time, it will translate both basic research into applications, and raw data into manageable knowledge. By facilitating the functional use of basic research, AREA Research will expand the impact of research on the built environment.

In terms of functional capacity, AREA Research is an independent 501(c)(3) nonprofit organization operating parallel to Perkins+Will. As a nonprofit organization, AREA Research allows Perkins+Will to engage in basic research, and further, partner with research institutions on any number of research projects. AREA Research is simply the next stage in developing Perkins+Will's current research efforts. The organization's initial focus is on HEALTH, SUSTAINABILITY, ENERGY, TECHNOLOGY, and CITIES, with the goal of expanding these research channels in the future (Figure 6). Further, AREA Research is a support mechanism for the pursuit of research partnerships and funding. By being flexible and offering various models for structuring projects, AREA Research is organized to take advantage of opportunities as they arise.

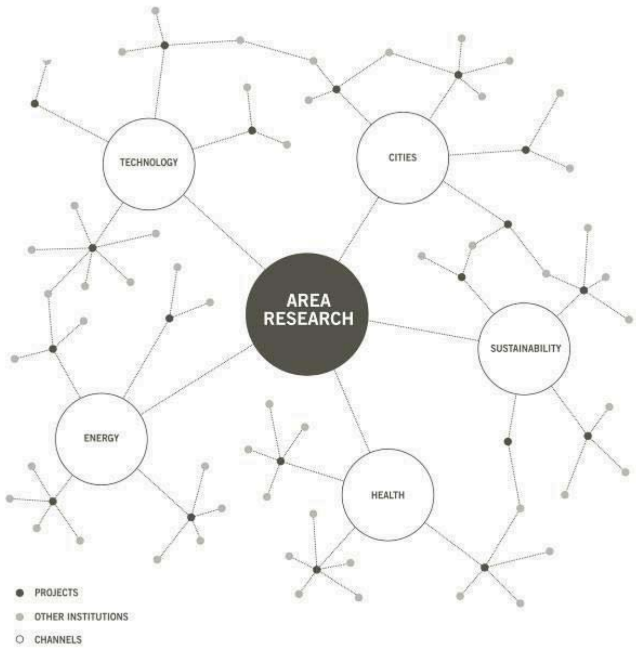

Figure 6: AREA Research and its channels.

Projects can be structured within AREA Research in a number of ways, but ultimately there are three fundamental models, as seen in Figure 7:

1. Externally funded projects in which AREA Research is a supporting member of a larger team, typically with a research institution as the lead. In this scenario, AREA Research would be providing specific services for the lead institution.
2. Externally funded projects with AREA Research as the lead. These projects may or may not have associated partners. If there are associated partners, AREA Research acts as the principal participant, and all funding runs through AREA Research.
3. Small, unfunded or internally funded projects.

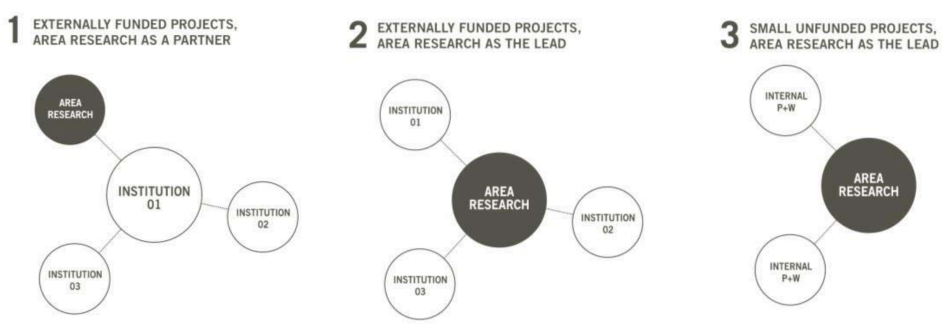

Figure 7: Methods for organizing research projects.

These partnership arrangements are meant to allow AREA Research to facilitate stronger relationships between basic research and applied research, combining the value of sustained research with project-specific data and expertise. To do this, the organization provides research services and partnership support to research institutions, corporations, foundations, and other entities engaged in basic research.

AREA Research is guided by a multi-disciplinary committee of Perkins+Will leadership, each with specific expertise tied to the research channels. As the governing body for AREA Research, the Committee includes channel directors and coordinators from each of the respective channels who provide leadership and direct operations across channels.

CONCLUSION

This paper examined the current and future trends in architectural and design research, reviewing activities of a practice-based research laboratory, as well as formation of a new non-profit research organization aimed to allow collaborative research between academic institutions and design practice. We discussed Tech Lab's activities as an example of research coming from practice, and we illustrated with a specific case study how research questions, methods and results are implemented on architectural projects. We also discussed the need to grow collaborative efforts between practice, academic and research institutions to progress knowledge, and we presented the objectives and focus of a non-profit research organization that was specifically formed to address that need. These collaborative efforts are aimed to increase visibility, as well as application of research relating to the built environment.

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Four Gates to Castle Neos: A Native Framework for Architectural Inquiry

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ABSTRACT: Various dimensions of architectural investigation are inherently hindered by the lack of a native framework. Consequently, what counts as disciplinary advancement in architecture has seldom risen to the towers of novel truth-value or the ramparts of reliability as in other disciplines. Architectural knowledge as a whole seems to be mired in a treacherous moat of crocodiles where sharp teeth are often what matters most. This paper proposes a new framework wherein four separate gates of investigation lead to the citadel of new wisdom, Castle Neos. Those gates are named Research, Design, Forensics, and Education. Each mode of investigation constitutes a worthy activity that opens a gate to significant architectural contributions. Each mode is also articulated by its own methods, strategies, settings, and tactics; as well as its own measures of truth value, novelty, and generalizability. The inclusive term "inquiry" is used here to both distinguish and integrate the equal bases of the four investigations. Formulation of that proposed framework for architecture constitutes a descriptive and normative theory because it explains the unique nature of architectural inquiry and offers a coherent means for incorporating it into current disciplinary knowledge.

One pair of castle gates opens to the north and to the south: Design and Research. The short but broad connecting street between them crosses at Analysis Lane and Synthesis Court, but along the way, Philosophers Row and Method Way vary as to your right and left according to your gate of arrival. Another primary road connects the West Forensic Gateway to the East Education Portal. Spread across the four quadrants of the castle, the intersecting alleys and by-ways abound with a variety of productive investigations.

KEYWORDS: Inquiry, research, design, forensics, education

INTRODUCTION

> We will have standing when we publish the body of knowledge upon which we base our practice (Donald Watson 2008, in Bachman 2009, 1).

This paper proposes a theoretical framework unifying four modes of scholarly and professional investigation undertaken in disciplinary pursuit of architecture: design, research, forensics, and education. The overarching construct beneath which those investigations are subsumed are discussed here under the inclusive umbrella of "inquiry." The use of this term should recognize its inspirational origin in the 1980 first edition of John Zeisel's book, Inquiry by Design. Reformulation under the master rubric of "inquiry" is intended as a landscape in which the four operations can be effectively distinguished, navigated, and critiqued… and therefore more productively employed. A corresponding clarification of architecture as a field of coherent disciplinary knowledge should result.

1.0 THE PROBLEM

Architecture's historical transition into the conventions of academic and professional accreditation involves the grudging adoption of research models from science and technology. Figures 1a (the normal academic standard) & 1b (proposed architectural model) illustrate this mismatch in terms of four investigative activities and the resulting four quadrants of supporting criteria. The conventional scientific method as depicted in Fig. 1a has not been entirely adequate for architectural investigations; nor have the corollary models of inquiry from philosophy and art. Those exterior models are catapulted stones that breach the fortress wall sometimes, but never enter through the muster of recognized gates. Architecture is of course neither science, nor philosophy, nor art; so a systemic framework for architectural inquiry must necessarily hold the roots of a different set of investigations.

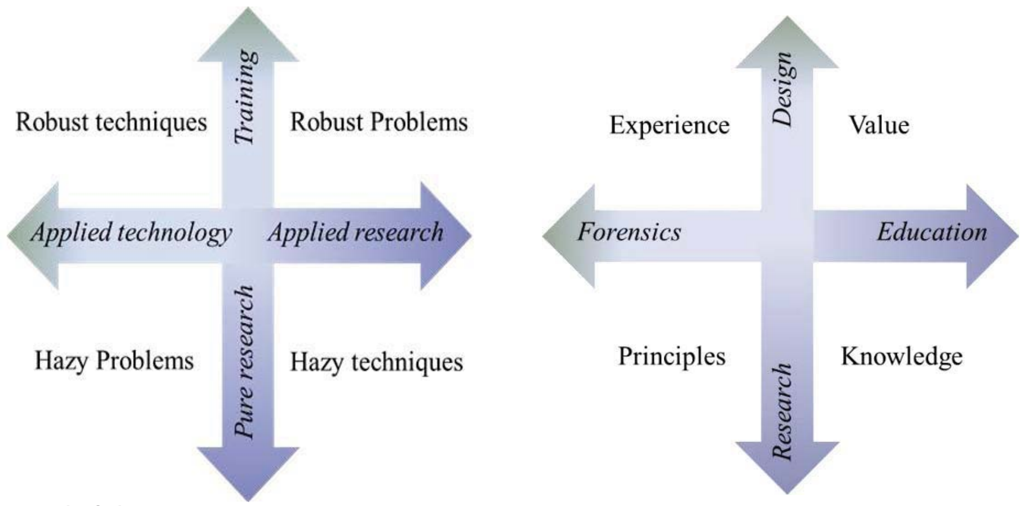

Figure 1a & 1b: Conventional framework of inquiry in other disciplines and the four quadrants of architectural inquiry. (Source: Author)

Commonalities with conventional analysis-synthesis modes exist of course. Figure 2a portrays the spiral of hermeneutic inquiry as befits our information age of indeterminate problems and dynamic complexity. Many texts on disciplinary knowledge and architectural research make fine connective transpositions (e.g., Snyder, Duffy, Zeisel, Groat & Wang…). Similarly, Figure 2b symbolizes our increasingly vivid and critical reflection on design, design method, and design issues (e.g., Protzen 2010, Plowright forthcoming for 2014). It remains however, that these are essentially translations; they begin with systemic modes of inquiry from outside architecture and use classical research methods as the dominant paradigm.

Thus, in postindustrial society where the basis of value is increasingly bound up in knowledge production, the epistemology of architectural knowledge remains shrouded in design mystique and an indiscriminate cloud of borrowed or imposed methodology. Architectural research, design, project specific searches for information, and the scholarship of teaching and learning in architecture are all marginalized by this weak disciplinary framework. They compete for validity rather than reinforcing one another. Such present quandary leaves the literature of architecture in a jumble and its discourse mired in a weakened framework of argument. So the impetus for new theory on architectural inquiry is manyfold: Society wonders what the architect really holds as unique knowledge and how the profession nurtures and grows that body of

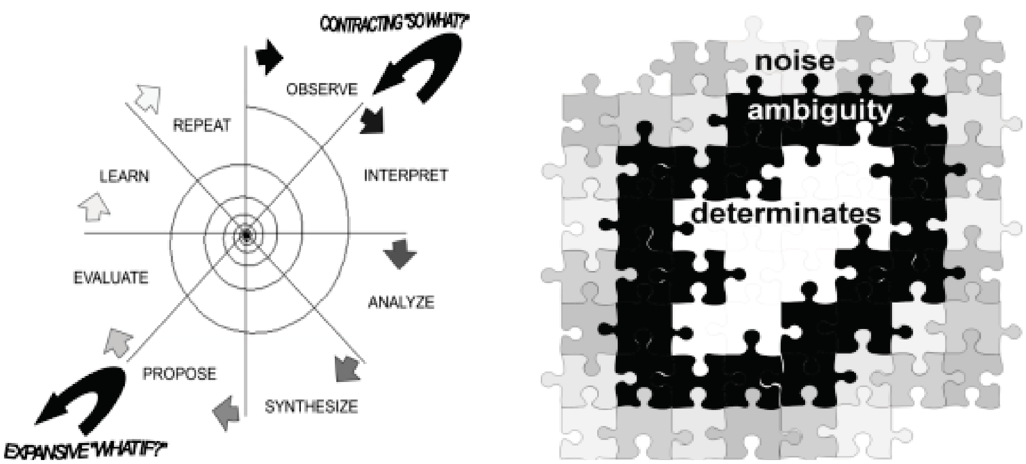

Figure 2a. & 2b: Hermeneutic abduction (Source: Bachman 2012) and Problem space in design (Source: Bachman 2012)

knowledge. The academy must vet creative validity from mere exploration. And, in the end, the profession must struggle to rigorously advance its own disciplinary knowledge base:

> The question of what constitutes research, what constitutes design and if it is even possible to consider design research as a form of knowledge are still questions much debated. In academia we primarily value research that brings new knowledge to the discipline and in professional programs in particular, we seek knowledge that has applicability (Erdman 2011, 2).

In practical terms, the lack of a unifying framework for architectural inquiry has three primary impacts across the full realm of architectural pursuits. First, practitioners struggle to earn value for design investigation and project planning that should certainly be performed to optimize our built environment. Such investigative practices are constrained by normative client expectations for the application of best practice; in part because clients don't view their projects as a basis for experiment, and in part because they do not see the architect as an experimental scientist. The current success of some firms who work to cultivate research based practice only reinforces the need to operationalize what the terms all mean as we go forward.

Secondly, our currently diffuse framework of inquiry has hindered the place of architecture in the academy. Built works designed by faculty members must be set in the context of scholarship and disciplinary contribution, not just as "creative works." Similarly, literature produced by faculty should be vetted on rigorous methodological grounds rather than well-reasoned argument alone. Lesser work in the more exploratory vein of investigation should be culled out for further development. Finally, the scholarship of teaching and learning (SOTL) in architectural education should be a vital basis for developing, validating, and sharing our best practices on teaching and learning.

The third set of practical limitations inherent in the current state of architectural inquiry is the ambiguous state of our fourth castle gate: forensic/strategic investigation. On one hand, digging for project information is not inquiry; it is just digging… and the results are mostly stenography (Leedy 1974). On the other hand, the strategic design component of architectural programming, systems selection, and problem-space definition should be elevated to the same status as design investigation (Bachman 2012). Differences between mere digging for information on one hand, and the structural wisdom of project management on the other deserve clarification. How we embody human intelligence in the built environment is, after all, of much more significance than most modes of product selection and pencil drawer counting. It is also important to note that the gray area between mere digging and clinical strategic forensics has a parallel to classic research in that any investigation that provides new generalizable frameworks for thinking can counted as inquiry, just as any similarly grounded literature review can. Forensics and clinical/strategic design activity are inquiry if, and only if, they pass this test.

2.0 METHODS

Four Gates employs logical argument to problematize existing thought on the root epistemology of architecture as a discipline. Naming and categorization are primary tactics. This is a meta-study in its mode of research-about-research, but does not invoke a comprehensive and comparative study of previous works. The core proposition is that a discipline-specific framework for architectural inquiry can advance structural understanding of architecture's various modes of investigation.

Towards such understanding, the *Four Gates* theory disambiguates architectural research from equally meritorious investigations concerning design, forensics, and education. At the same time, the *Four Gates* explains how these activities make a coherent whole that is unique and native to architecture.

3.0 ARCHITECTURAL INQUIRY AS A CONSTRUCT

Figures 3a lays out Castle Neos as the architect's domain of inquiry with its four gates of investigation. The connection of Design to Research is explained here as the Avenue of Essential Transformations, while the connection from Forensics to Education follows the Corridor of Connective Configurations. The four quadrants formed between the gates simply depict the intersecting neighborhood action. Figure 3b correspondingly illustrates how the architect's four modes of investigation can all fit together in a coherent set of disciplinary activities that comprise the activity of Inquiry.

Starting with the overarching construct, inquiry is the entire set of activities by which we *nurture and grow the wisdom of architecture*; it includes all four relevant modes of investigation. Practice, on the other hand, is how architects complete their contract with society through meritorious service in the *application of that wisdom*. In exchange for a monopoly on the title of architect then, the dual obligations of inquiry and practice are how the discipline is executed, perpetuated, and reproduced generation after generation. This distinction

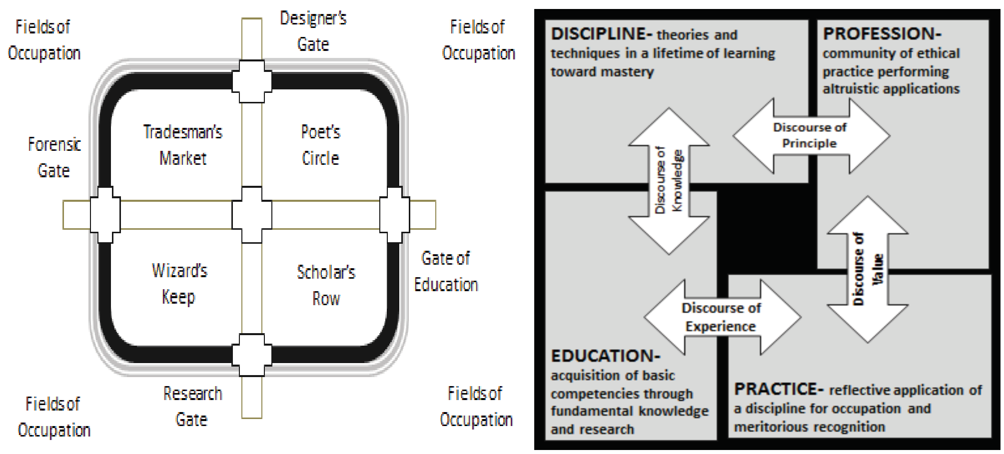

Figure 3a & 3b: Castle Neos and the four gates of inquiry in the context of four realms of the profession. (Source: Author)

separates inquiry from practice: The castle is an interior component of architecture and practice lies externally in the fields of occupation beyond. The walls of Castle Neos spread thick, the moat runs wide, and the spires soar high. This is an accurate illustration, because architectural inquiry concerns a large and difficult body of knowledge, a set of theories and principles, and a lifetime of learning (Fig. 3b)… and all these disciplinary efforts occur peripheral to the occupation of the architect in practice. To push the analogy a bit further, the public interacts with architecture in the fields of practice but, as in any profession, the disciplinary activities of inquiry operate behind the scenes, up the hill, behind the scrim of castle walls.

4.0 THE FOUR MODES OF INQUIRY AS CASTLE GATES

Disambiguating the four modes of investigation clarifies Castle Neos as the disciplinary stronghold of the profession, and how the castle is separate from the fields of occupation. Like the Romantic poets' depiction of the epicurean versus popular viewpoints on art, and like William Hubbard's (1986) comparison of architectural correctness to the shroud of expertise that surrounds the making of fair laws; Castle Neos is a mountaintop citadel where only the initiated can find their way around… more like a forbidden monastery than a popular museum.

To put this castle in order, we must map out the means of entry at each gate. Passage is dependent on the traction of truth value and on the specific methods, strategies, and tactics of each investigation. What passes at one gate is no better or sacred than what passes at another, but the processes, artifacts, and criteria for admission are different. When credentials are allowed too much ambiguity, then the integrity of the entire domain is threatened. Inside the walls, all inquiry is equal and all investigators are equally ennobled, but recognition and standing within the castle must be based on appropriate claims, not on who heralds the loudest trumpets with the fanfare of arrival.

4.1 Essential Transformations: Design and Research Investigations

The grand portals of research and design are ennobled for different reasons of course, but, in the ambitious quest to attain the high standards each mode of investigation represents, practitioners often make mistaken claims about what is research, what is design, and most confusingly, when are they the same thing. This error promotes a conceptual overlap between two very different forms of inquiry.

What design and research investigations share can be termed *essential transformations*. This characteristic pairs design and research in a way that usefully separates them from the *connective configurations* of forensics and education. Dealing first with essential transformations then, we recognize that both design and research are bound to the fundamental analysis-proposition-synthesis mode of human cognition: They both begin with a problematized challenge and work toward the creation of new wisdom that is validated, unique, and generalizable to other situations. They both add to what Gropius called, "the accumulated wisdom of architecture" as an operational test of their truth value. They are both defined by propositional wisdoms and ennobled by the quest for essential transformation.

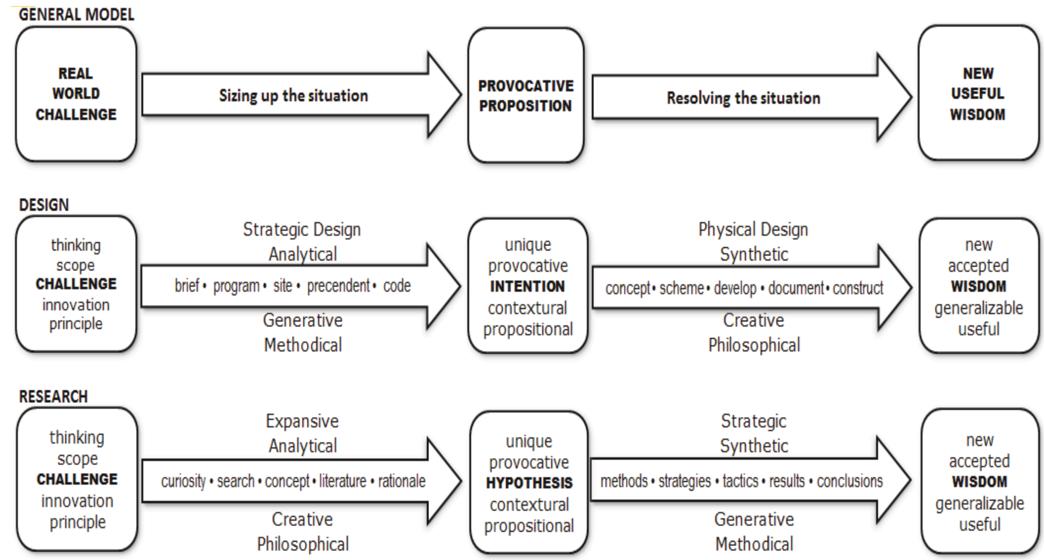

Figure 4. Research and Design in the frameworks of analysis-synthesis. Source: Author (2010)

From that general model however, the analytical and synthetic stages of research and design are crisscrossed and the two investigations become segregated. That is to say, design analysis is methodical, generative, definitional, and strategic. These analytical activities are embedded in clinical tasks of programming, planning, site, code, and other attempts to understand the challenge. In research however, the analysis stage is creative, expansive, and philosophical in its literature review and search for the research question. Correspondingly, in the synthetic post-propositional phases, research turns to methodical data acquisition, organization, and inference; while design synthesis is in its creative, expansive, philosophical mode.

Figure 4 reflects Figures 3a and 3b as a framework for design and research inquiry and shows how design and research are separate modes of investigation. To generalize, in research everything before the propositional question is philosophical and everything after the question is method. In design this is reversed, everything before the propositional idea is methodical, and everything after it is philosophical.
On operational principle then, the common grounds of analysis-synthesis are insufficient for any assertion about design-as-research, or research-as-design. It is probably more correct to say that the creative/methodical crisscross indicates complementary gates to the castle rather than similar ones. Design and research may both lead to new wisdom and essential transformations, but they are not the same mode of inquiry and must thus be regarded as radically independent investigations. Despite their shared rational framework and their mutual employment of generative-methodical and creative-philosophical tactics, design is not research; and research is not design.
In the *Four Gates* model then, we can define the Path of Essential Transformation connecting two gates:

- *Research, the South Gate*—Research investigation focuses on the development and testing of new architectural understanding and the progression of wisdom. Research exists to grow and nurture the large and difficult body of knowledge by which architects serve society. Theory building, case study methods, historical interpretation, and logical argument are primary components of architectural research.
- *Design, the North Gate*—Design Inquiry is fundamentally concerned with connections between the real and the ideal, between the intelligent and the sublime, and between understanding and appreciation. Both the strategic and the physical aspects of architecture are incorporated, but design itself is essentially bound up in the ability to connect the two spheres (Bachman 2012).

4.2 Connective Configurations: Forensic and Educational Investigations

The second pair of gates to Castle Neos is formed by the portals of forensic/clinical investigation and that of educational development. They are connected by the Corridor of Connective Configurations, an avenue where the essential transformations of design and research give way to work within existing knowledge. Through these gates, the architect's generative, unique and useful investigations are concerned with connective sense-making more than with transformation. The work may be just as creative and significant as with the design-research avenue, but its underlying purpose is directed differently.

Clinical forensics is the least understood mode of architectural investigation, while education is the least valued. Both however are part of a systemic whole and without them as equal fonts of architectural inquiry, the organic complexity of the entire apparatus withers and dies.

Forensics can also be reconsidered as one full half of design because forensic investigation is the *real* aspect that is tantamount to the *ideal* aspect. The root operation of design is to bridge between the two, attaining a constructed and high performing *realization of idealized* aspirations. Design itself is neither the ideal nor the real bridgehead across the moat, it is the act of spanning. The criteria of truth value in forensic investigation as to the *real* is usually taken at the episodic clinical level, but the better work in this quadrant enables novelty both by discovery and by invention. The other vital point is that forensic investigation is how we embody human intelligence in the built environment, so it is clearly one of the four *necessary but not sufficient* components of architectural inquiry.

Educational investigation is a sadly neglected and undervalued aspect of disciplinary knowledge in architecture. There are few empirical studies of the matter in publication. Presently, not one architectural journal focuses narrowly on educational outcomes in a dedicated way. In fact, despite architecture's claim to critical insight and creative approaches, little has changed in architectural education since the formalization of the subject at the Académie Royale d'Architecture in 1671, back when castles really were the paradigm of architecture. So what should be a highly experimental and vigorously innovative discourse on teaching and learning has proven instead to be extremely conservative. By this standard, the studio dominated teaching culture at most architecture schools for example, now lags far behind the intervening centuries of change in history, society, and technology. Furthermore, there is little concerted scholarly effort to connect contemporary architectural education with the best practices of contemporary teaching and learning. Present evolutions in accountability in higher education, evidence driven accreditation, and outcome specific curriculum design may exert some pressures on this situation, but this is regulated change, not systemic and native evolution.

The best opportunity to address deficiencies in educational investigation is to regard it as a wide-open opportunity into the Scholarship of Teaching and Learning (SOTL) in architecture. The SOTL movement was initiated in 1998 by the Carnegie Academy as a necessary public forum on continuous improvement, wherein instructional settings are regarded as laboratories for teaching and learning and the data produced in those laboratories lead to evidence-based improvements in best practice (Carnegie Academy, 1999). If architectural education as we know it deserves introspection, then this is a valid means of investigation. If on the other hand, the current instruction is perfect beyond refinement; then that too certainly merits validation by publication.

Education and Forensic investigations are paired at opposite ends of the Corridor of Connective Configurations because they both involve sense-making in a cybernetic context of steering through existing knowledge. Education is an autopoietic function where the discipline and the profession of architecture reproduces itself and should progressively evolve from generation to generation. In clinical forensics, connective configuration is a teleological function entailing the search for the unique essence of a situation and a match to the corresponding human intelligence that animates it. In both cases, investigations advancing the discipline are essential to a comprehensive map of architectural inquiry.

- *Forensics, the West Gate*—Forensic investigation is the strategic activity that supports project based selections and decisions. As such, forensics includes programming, planning, and other phases of a specific architectural project. Investigations in this area span from episodic project information to generalizable strategic wisdom. Disciplinary value is only attained at the strategic end of that continuum where human intelligence has been methodically embodied in the built environment. The clinical dimension of forensics acknowledges the use of disciplinary knowledge bases such as precedent studies and evidence-based design in the application of one-case-built-on-many-cases. Evolution of forensic investigation in knowledge society validates the necessity of rigor beyond intuitive approaches. This is inquiry.
- *Education, the East Gate*—Educational development is the lifetime of teaching and learning required to maintain and advance one's disciplinary knowledge in architecture. Investigation of teaching and learning towards that development (SOTL) includes well-defined learning objectives and incorporates best practice techniques for achieving them. The studio-centric model is a worthy foundation of instruction, and is well situated to advance the cause of problem based active learning strategies. As in clinical forensics however, the studio's generally intuitive and conventional approaches to teaching and learning in architecture are no longer sufficient. The time

Table 1. The four gates of architectural inquiry and their defining characteristics

	DESIGN	RESEARCH	FORENSICS	EDUCATION
SCOPE	Physical	Positive, post-positive, and emancipatory	Strategic, clinical (one case built on many cases)	Lifetime of teaching and learning
METHODS	Bridging the real and the ideal, abductive hermeneutics	Expanding wisdom and eroding existing paradigms	Information literacy	The scholarship of teaching and learning (SOTL)
SETTINGS	The built environment	Scholarly literature	Project specific	Principles, theories, practices, ethics
TACTICS	Precedent based, contextual, intentional, and opportunistic	Naturalistic, qualitative, and quantitative	Cybernetics, complex systems	History/Theory/ Criticism, studio, technology, and core topics
TRUTH VALUE	Essential transformations	Essential transformations	Connective configurations	Connective configurations
NOVELTY	Transformative, appropriate, and intentional	Contingent truth, new wisdom	Discovery and invention	Autopoiesis, reproduction of the profession
GENERALIZABLE	Critique and discourse	Reliability, validity, conformability, transferability, triangulation	Embodied human intelligence	Advancement of best practices

has come to recognize work that enriches our educational practices, and to lay these efforts out as an independent branch of architectural inquiry.

CONCLUSION

Four Gates theory describes existing states of architectural epistemology as a historically misaligned overlay of disciplinary architectural onto the traditional scientific method. This overlay was once deemed as essential to the entry of architecture into the academy and also vital to its professional status. Four Gates also explains how the construct of Inquiry serves as a better framework for the architect's various and variegated modes of investigation. Furthermore, this new framework provides a level of disentanglement that both distinguishes architectural research, design, forensics, and education as different pursuits, and combines them as an interwoven coherent whole (Table 1).

The descriptive and explanatory elements of the *Four Gates* theory also lead to a predictive component wherein the postindustrial context of knowledge society is liberating. In that evolution, architecture is freed from expectations imposed by industrial age norms of academic and professional status. In its new native framework of architectural inquiry, the hopeful prediction is that the *Four Gates* will open onto a more coherent map of the disciplinary neighborhoods within the castle wall and to a more productive future out in the fields of occupation.

To acknowledge some limitations, the framework presented here is largely concerned with distinguishing the four modes of investigation; but little attention is given to their ongoing nexus at the crossroads. The shared means of validation across all four investigations is not addressed beyond the normal tests of peer review, discourse, critique, and the proof of time. In that sense, this is admittedly a somewhat simplified perspective on a truly complex topic. Further work is required to depict the dynamic networks that weave architectural inquiry into a well-understood set of professional activities. As Figure 3b depicts, there are many connecting discourses which we must understand as well as we do the individual modes of investigation.

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as the support that sustains me. I have only myself to recognize for any shortcomings that remain, and trust that our community of scholars will skillfully vet out the next steps to be taken.

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Memory, Social Interaction, and Communicability in Extraordinary Experiences of Architecture

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ABSTRACT: Using nearly 2,900 entries from a previously documented survey on "Extraordinary Architectural Experiences" (or EAEs), this paper reports in how memory, socialization, and communication affect and, in turn, are affected by the highest aesthetic reception of architecture. More specifically, nine ('comparative mnemonic impact', 'fresh recollection', 'intensity', 'profoundity', 'vividness', 'transformation', 'body reactions', and 'weeping'), six ('social company', 'sharing', 'non-talking', 'introspection/silence', 'comparative mnemonic impact', and 'fresh recollection'), and three ('verbal', 'visual', and 'multimedia' language) categorical variables were gauged to determine the mnemonic, social, and communicability dimensions of EAEs respectively. The data was examined using three subsequent levels of statistical analysis. The results empirically demonstrate that (1) a committed aesthetic engagement of the built environment offers great opportunities for a deep and lasting existential experience; (2) EAEs cause a fundamental change in people's cognitive or affective understanding of architecture; (3) while EAEs are inevitably rooted in first-person phenomenology (i.e., not socially active events), they possess a strong a-posteriori social nature; and (4) EAEs resist communication to such an extent as to be considered ineffable. These are findings with practical and theoretical consequences for anyone interested in studying, teaching, or practicing architecture.

KEYWORDS: aesthetics, phenomenology, ineffable, socialization, survey

INTRODUCTION

As we argued in a previous ARCC article (Bermudez 2011b), the aesthetic experience of architecture remains one of the few areas in our discipline unable to address the expectations of scientific scrutiny. The reason for this situation at first appears well founded: we are talking of events unfolding 'behind' the seemingly impenetrable subjective box of embodied consciousness. Research efforts trying to address this situation have not been very successful. For instance, the investigations on the semiotics and phenomenology of the built environment during the 1980s and 1990s targeted this knowledge gap using 'meaning' as its main focus of inquiry. While valuable, these studies were directed toward our ordinary cognitive, symbolic or behavioural engagements of buildings and left untouched the most significant experiences of architecture. The fact that there is very little published information describing or even acknowledging the highest aesthetic reception of architecture is a case in point (Bermudez 2009b, Britton 2011). When scholars have tried to address this matter phenomenologically (Jones 2000, Perez-Gomez 2006), its qualitative nature returned the investigators to pre-modern methods of reasoning, hermeneutics or poetic narrative, thus failing to respond to contemporary demands for scientific inquiry.

This situation prompted Bermudez to start a research program utilizing the scientific method to study Extraordinary Architectural Experiences (or EAEs). EAEs were chosen because of their exceptional nature that (a) amplifies the experiential effects of buildings, making them easier to study than under normal aesthetic circumstances, (b) guarantees recall accuracy and thus facilitates data gathering and reliability, (c) has lasting consequences in the lives of both the public (Hiss 1990, Jones 2000) and professionals (Ivy 2006), and (d) are usually tied to well known places and/or perceptual features that simplify later objective analysis. The investigation originated 6 years ago with an online survey on EAEs done in Spanish and English over the course of one year (April 2007-April 2008). The poll defined Extraordinary Architectural Experience as:

> an encounter with a building or place *that fundamentally alters one's normal state of being*. By 'fundamental alteration' it is meant a powerful and lasting shift in one's physical, perceptual, emotional, intellectual, and/or spiritual appreciation of architecture. In contrast, an ordinary experience of architecture, however interesting or engaging, does not cause a significant impact in one's life.

Specifically, the survey asked respondents to recall their EAE and queried them about the phenomenological qualities of that event. The poll produced the largest empirical database available on the subject: 2,872 individual testimonies (1,890 in English and 982 in Spanish) gauged through 27 interrelated variables that chart their experiential structure, process, and features. In addition, the database includes detailed population data and over 250 pages of text describing the experiences from 3 open-ended entries. We will not expand on the rationale, details, and decisions shaping the survey nor the responding population characteristics. This information along with a wide range of findings are available elsewhere (Bermudez & Ro 2012, and Bermudez 2011a, 2011b, 2011c, 2010, 2009a, 2008).

In this article, we present new results addressing the following aspects of EAEs:

- The mnemonic impact of extraordinary aesthetic experiences of buildings measured in (1) vividness and recollection by themselves and in comparison to other strong life experiences as well as (2) the average years passed since reported experience.
- The social dimension of the experience: does it matter whether or not one is alone, with a friend or strangers in order to have access to these unique phenomenologies? And if so, how? Do we share our EAEs with others or, giving their highly affective and private nature, keep them to ourselves?
- The communicability potential for sharing such experience with others (via images, words, or multimedia).

The analysis will include comparisons between responses given by the English and Spanish populations. Please note that statistics of the English poll will be formatted in **bold** whereas the Spanish numbers will be in *italics.*

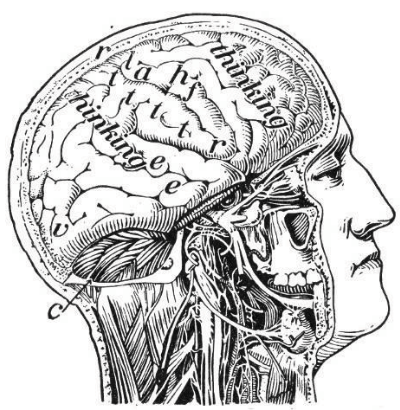

Figure 1: Extraordinary experiences of architecture have a powerful effect on memory and embed themselves in our subjective box of embodied consciousness. Source: (Illustration from A. Davison, *The Human Body and Health Revised* [1908], p.226, *CC-BY-SA-2.0,* http://creativecommons.org/licenses/by/2.0)

1.0. METHODOLOGY

Following Bermudez 2011b, we applied three consecutive statistical analyses to the survey data. The first level is univariate descriptive statistics consisting of the general responses to a survey question and was produced using the mathematical engine of *StudentVoice* —the online survey provider that encoded the questionnaire and then collected and organized the data (www.studentvoice.com). The second level of analysis incorporates bivariate descriptive statistics. *Pearson's Chi-Square* tests are performed between the responses to different survey variables (i.e., questions) and employed to determine if there existed correlations between them. Following standard statistical practices a *probability p-value* equal or below 5% (0.05) was recognized as reliable significance.[1] Lastly, and when necessary, a third level of bivariate analysis considered the established correlations by 'segmenting' the survey data into cross-tabulation or contingency tables with *StudentVoice* statistical software. This latter study allowed the comparison of, for example, how those responding "yes" or "no" to a particular question answered a second question, thus illuminating their correspondence at a higher level of statistical resolution.

2.0. MEMORY

Three survey questions were designed to address the mnemonic dimension of EAEs. The first of these is question 22 which requested survey participants to determine *how vivid and memorable their EAE was in comparison with other very strong life experiences*, and provided five choices: *Well Above, Just Above, Similar, Just Below,* or *Well Below.* **46.7%,** *32.4%* of the respondents reported EAEs to be '*Above'* other powerful existential moments, followed closely by the ranking '*Similar*' (**44.7%**, *44.5%*). The fact that a large majority in both groups (**91.4%**, *76.9%*) judged EAEs to be similar or above other powerful events in one's existence underlines the importance of aesthetics, particularly architectural aesthetics, in the lives of the people surveyed.[2]

Question 28 prompted people to determine *how fresh/vivid the recollection of their EAE was* and offered three choices: *Strong (feels like yesterday), Moderate,* or *Vague.* A clear majority (**63.5%**, *63.7%*) answered 'Strong' with only a minuscule minority selecting 'Vague' (**3%,** *2.2%*) thus, at least partially, explaining the high rating of EAEs in relation to other powerful life experiences (question 22) and the longevity of the impression in people's memories (question 3 below).

Last, question 3 among other things,[3] asked individuals to define *the length of time that had passed since the actual occurrence of the experience*. Considering the 10 most common places cited by the respondents (which account for **21%** and *24.6%* of the total number of survey entries) the average recollection was at least **13** and *11* years old with the oldest experience going back to **1950** and *1958* (with many from the 1960s and 1970s). Memories that last over a decade (and some much longer) without losing much of their freshness (see answers to question 28) is a significant finding and only possible if a person's inner psychological core has been touched —something that would also account for the responses to question 22 (Figure 1).

When we take into account that **71.3%,** *78.8%* of survey participants had 10 or less EAEs in their entire lives (with over 50% in either poll reporting 5 or less),[4] we realize the uniqueness, power and rarity of these experiences and why they are ranked so high (i.e., as in responses to question 22— see above), remembered so well, and for such a long period of time. Moreover, the strength in mnemonic freshness, impact, and longevity of EAEs is all the more impressive when we consider that **45%**, *44.6%* of those who were surveyed clocked the entire duration of their EAE at 'under 30 minutes' (nearly the same percentages of those estimating it at 'over 30 minutes').[5] The brevity of the experience underlines the tremendous emotional and perceptual force of the event. Not surprisingly, respondents describe their EAE as being '*emotional*' (**70.3%**, *76.7%*), '*intense*' (**80%**, *88.3%*), '*profound*' (**89.2%**, *91.7%*), '*vivid*' (**85.3%**, *84.5%), 'spontaneous'* (**78.5%**, *91%*), and causing '*strong body reactions',* such as goose bumps, heart pounding, shivers (**56.3%**, *43.4%*), and '*weeping' *(**17.9%**, *28.7%*). The compounded effect of all these characteristics and effects of the lived EAE could account for **81.4%**, *79.4%* of people reporting some kind of transformation in their cognitive or affective understanding of architecture,[6] something remarkable given the high educational level (i.e., college and above) and expertise (i.e., architecture) of a majority of survey participants (Bermudez 2010, 2008).

We conducted Pearson's Chi-Square analysis to test correlations among all of the phenomenological dimensions of EAEs related to memory (represented as 'Comparative Mnemonic Impact' [question 22] and 'Fresh Recollection' [question 28]). Table 1 presents the results of this analysis and shows a strong dependency in 11 out of 16 cases. The remaining 5 are in such borderline or split statistical conditions as to generally validate their overall interdependency (except in three sub-cases). This suggests, for example, that the more '*Comparative Mnemonic Impact'* an EAE has, the more '*Fresh Recollection'* it possesses (and vice versa). Similarly, the more 'intense', 'profound' or 'spontaneous' the EAE, the clearer its recollection and higher its ranking in comparison to other strong life events (and vice versa). Picking just one example so we can go in further detail, EAEs deemed (well and just) 'above other very strong life experiences' were more '*Emotional'* (**+21%**, *+10%*), '*intense'* (**+28%**, *+13%*), '*profound'* (**+14%**, *+7%*), '*vivid'* (**+14%**, *+8%*), '*spontaneous'* (**+12%**, *+6%*), more likely to cause a *change in one's understanding of architecture* (**+5%**, *+8%*), *'fresher recollection'* (**+43%***, +23%*!), and involve more '*weeping*' (**+16%**, +14%) and '*body reactions'* (*+17%*) than EAEs judged (well or just) 'below other very strong life experiences'.

While these statistical findings are hardly surprising in light of common sense and what philosophers and psychologists have long argued (e.g., Johnson 2007, Merleau-Ponty 1962), it is important to empirically demonstrate the essential role that emotion and embodiment play in establishing and keeping architectural memory (for more on this see Bermudez 2011b). While the correlations between Memory and 'Transformation' is borderline (with 'Fresh Recollection') or only half there (with 'Comparative Impact'), there is enough empirical circumstantial evidence in the rest of the survey findings, to make a claim that a committed aesthetic engagement of the built environment offers great opportunities for profound and lasting existential experience. This is something particularly significant for those interested in studying, teaching, or practicing architecture.

Table 1: Correlation matrix summary of Chi-square test results analyzing the dependency or independency between 9 variables. The existence of a correlation is established by a probability p-value <0.05 while no correlation by a p-value >0.05. Underlined numbers indicate 'borderline' p-values (0.07>p<0.05) that are likely to point at a dependency between the variables. N varies depending on the question/variable. Black cells show at least one of the p-values to be above 0.05 (and beyond borderline condition), that is, prove no significant correspondence between the variables. As in the rest of the paper, bold numbers stand for English survey statistics whereas italics for Spanish data. Source: (Authors 2013)

	Comparative Mnemonic Impact	Fresh Recollection	Weeping (Q9)	Body Reactions (Q10)	Transformation (Q27)	Intensity (Q14)	Profoundity (Q15)	Vividness (Q16)	Spontaneity (Q17)
Comparative Mnemonic Impact (Q22)		**0.000** *0.000*	**0.001** *0.008*	**0.000** *0.000*	**0.581** *0.020*	**0.000** *0.028*	**0.000** *0.016*	**0.000** *0.633*	**0.000** *0.000*
Fresh Recollection (Q28)	**0.000** *0.000*		**0.002** *0.070*	**0.000** *0.176*	**0.070** *0.074*	**0.000** *0.000*	**0.000** *0.004*	**0.000** *0.000*	**0.000** *0.029*

3.0. SOCIAL DIMENSION

As social beings, we humans have the natural tendency to share what happens to us the individually with others. Any thorough study of EAEs, therefore, demands to consider its societal dimension. Following are the three questions specifically designed to address this matter, which, in relation to response to other survey questions (as we will see) helps us cast empirical light on the issue at hand.

- *Question 6: When you had this experience, were you: (with one friend, with many friends, alone, with strangers, don't recall.)*
- *Question 26: Have you shared your EAE with others? (Yes, No, Don't recall)*
- *Question 29: If you wish, and in less than 500 words, tell us of your EAE as close as possible to how you remember it.*

The social dimension of EAEs is clearly behind **70.9%**, *73.8%* of people who acknowledge visiting the inspiring places with others (either one friend, several friends or strangers) although a good quarter of the respondents (**27.1%**, *25.3%*) reported being alone. Of course, this answer also has to do with the fact that buildings generally function as socio-cultural environments and are of a scale that welcomes large numbers of people, even if such places end up being tourist destinations (Figure 2). Yet while the responses would seem to suggest some social type of aesthetic experience, the reported phenomenology of EAEs is far from it. In effect, when we analyze what survey participants describe as happening during their EAE, we find that a good majority (**61.9%,** *56.8%*) indicate that their experience was strong enough to cause them to *refrain from talking* (a convincing indicator of lack of social engagement).[7] Similarly, **87.1%**, *87.1%* of those surveyed recognized that their EAE made them '*introspective and silent*'. [8] A Chi-Square test between these two variables (talking and introspective/silent) shows a p-value of **0.000**, *0.000* that confirms their significant correlation and suggests that EAEs cause individuals to cease being social even when they may have been with others. In other words, despite the inevitable social expectations of verbal and non-verbal communication that being with others demands, the event was sufficiently strong enough to shift the person's attention to subjective, first-person, or internally felt experiences. Thus, the EAE was not principally lived nor shared socially even though, later on, people may have felt the necessity to share it with others.

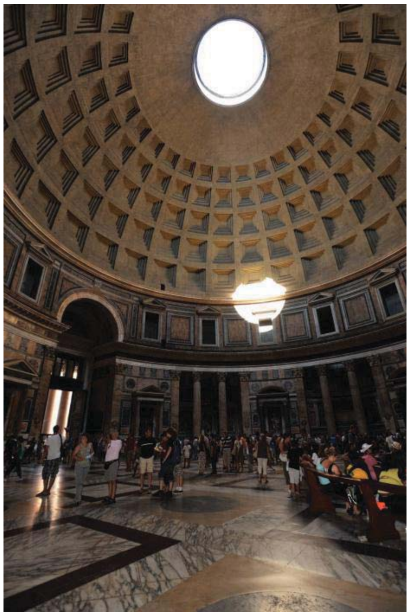

Figure 2: The Roman Pantheon, one of the top cited buildings from the survey, is one example where the social dimensions of EAEs came into play (see Bermudez & Ro 2012). Source: (Emilio Labrador, *CC-BY-SA-2.0,* http://creativecommons.org/licenses/by/2.0)

Cross checking responses between '*social company*' (question 6) and *how vivid and memorable the EAE was in comparison with other very strong life experiences* (question 22), we found no statistical evidence that the '*comparative mnemonic impact*' of an EAE in someone's life was affected by the social dimension of experience. In other words, whether one was alone or with others had no relevancy as to the power of the experience; however, we did find that the type of experience was different. EAEs were **29.2%**, *27.5%* less talkative and (consequently) almost **7%**, *9%* more introspective and silent for those who were alone than for those who were with one or more friends.[9] There are obvious reasons for this finding, such as being alone results in not having someone to talk to about the experience while it takes place; nevertheless, the net result is that less talking and more introspection/silence probably deepens the quality of the experience. We also found that those who had their EAE alone had more (+**8%**, *+11%*) '*fresh recollection*' than those who were with one or more friends.

Responses to question 26 overwhelmingly (**85.2%)**[10] portray people sharing their EAE with someone else after it had happened. The large testimonial percentage clearly indicates the need people had to communicate their experience to others and the importance of the event which made it worth sharing (supported by answers to question 22).[11] It is here where EAEs find their true social dimension as opposed to when they are happening. Several Chi-Square tests support all these interpretations (See Table 2).

Table 2: Summary of Chi-square test results analyzing the dependency or independency between 6 variables related to the social dimensions of EAEs. Source: (Authors 2013). The code used to shade the table cells is the same as in Table 1.

	Social Company (Q6)	Sharing (Q26)	Non-Talking (Q8)	Introspection-Silence (Q11)	Comparative Mnemoic Impact (Q22)	Fresh Recollection (Q28)
Social Company (Q6)		0.254	0.000 *0.000*	0.000 *0.006*	0.221 *0.074*	0.000 *0.000*
Sharing (Q26)	0.254		0.000	0.318	0.137	0.000

If there is still any doubt about how important it is for people to share their experience with others, poll participants casted an affirmative vote by going well beyond the minimal demands of the survey and typing their story when responding to open-ended question 29. A good **46.7%**, *40%* of respondents decided to give even more of their time (often writing stories well beyond the 500 word limit requested) to share their exceptional aesthetic moment with others! And we could go further. After all, how else can we see the completion of the survey but as an attempt to share one's EAE with the world?[12] Such an effort shows the compelling need people have to communicate their significant lived experiences with others, even when most individuals understand at some level the difficulty behind conveying it (see 'Communicability' section below). As Nehamas (2007) and many other philosophers argue, the very desire and effort to make others see the beauty we have experienced and, if possible, convince them that it is so are the hallmarks of a true aesthetic experience.

4.0. COMMUNICABILITY

Since there is no way to engage in the social dimension of EAEs without a common intersubjective language that enable the interaction between individuals, it is important now to complete our study by looking at what we term, for lack of a better word, 'communicability'. Three survey questions probed people's perceived ability to communicate their EAEs.

- *Question 23: Could your extraordinary experience of architecture be fully communicated through Words? (Yes, No, Don't know)*
- *Question 24: Could your extraordinary experience of architecture be fully communicated through Images? (Yes, No, Don't know)*
- *Question 25: Could your extraordinary experience of architecture be fully communicated through Multimedia [e.g., video, sound, immersive 3D]? (Yes, No, Don't know)*

(Un)fortunately, the word 'fully' was missing in the Spanish version of these questions. Its absence greatly affected the answers and accounts for the large differences between Spanish and English responses. While we could all probably agree that something (however limited) about one's EAE may always be communicated, it would be much harder to concur with one's ability to 'fully' or 'completely' transmit such an experience. Hence, on the one hand English speakers agreed that words, images, and multimedia were *incapable* to 'fully' communicate the lived experience (**56.8%, 57.0%** and **51.9%** respectively).[13] On the other hand, Spanish speakers reported that words, images, and multimedia were *capable* to communicate (something about) the lived experience (*73.8%, 65.6%*, and *55.6%).*[14] Pearson's Chi-square tests between questions 23, 24 and 25 found a p-value of **0.000** and *0.000* across the board, thus demonstrating a significant relationship between how respondents answered one question to how they answered the others. It is noticeable that respondents in general had more confidence in using words (**33.2%**, *73.8%*) rather than either images (**32.4%**, *65.6%*) or multimedia (**26.9%**, *55.6%*) to share their experience.

These three questions empirically tested the 'ineffability' claim so often made regarding extraordinary aesthetic events. We are talking of what Le Corbusier (1948) called the experience of 'ineffable space', meaning the indescribable, inexpressible, or incommunicable nature of profound experiences of architecture. Rudolf Otto (1970) presented a similar condition when discussing the phenomenology of the 'numinous.' According to Otto, when we encounter the Holy Other through beauty (and this is the ultimate reach of aesthetics for him), such an experience resists and transcends all ability of human communication and/or language. Looking at the responses of the three questions, it is clear that a good **2/3rds** of the English speaking respondents (if we include the 'Don't Know' group, which seems a legitimate move) agree with Le Corbusier and Otto whereas 'only' *1/3rd* of the Spanish speakers do, but then again their responses seem to be even more poignantly in support of such ineffability considering the context in which they were answered.

Such realization did not keep survey participants from trying to communicate their experience, especially those that enjoyed EAEs the most. For example, survey participants that ranked their EAE to be *'above other strong life experiences'* were nearly **7**, *2* times more likely to share their stories in Question 29 than those who ranked them 'below'. Quite simply, as we argued above, we are compelled to share with others our most important experiences even when such effort may end up falling short.

CONCLUSION

We conclude summarizing the results of our empirical study of the mnemonic, social and communicability dimensions of EAEs. Regarding memory, we found that a committed aesthetic approach to architecture offers a real chance to produce a profound and lasting impact on one's life. Survey participants made clear that EAEs are second to none when compared to other powerful events in one's existence. They also reported that EAEs caused them to change their cognitive or affective understanding of architecture. These are findings with practical and theoretical consequences for anyone interested in studying, teaching, or practicing architecture. In addition, the high level of mnemonic recall discovered is important to claim that the testimonies, indeed the survey results, are trustable, valid and thus relevant. Poor recollection would have been the kiss of death to any argument that EAEs are at all extraordinary. Exceptional things get recorded in our memory, whereas ordinary events succumb to oblivion.

We found that the social dimension of EAEs plays an essential role after and not during the event. While an extraordinary experience takes place, the aesthetic phenomenology is unavoidably first-person bound. However, immediately afterward, when we find the need to share the experience with ourselves (in order to explain or rationalize what has happened to us) and definitely with others, we frame a largely non-verbal, multidimensional, and non-intellectual phenomenology (Bermudez 2008, 2009a, 2011c) into the straight jackets of a language (through words, images and so on). There is little doubt that much is lost in translation, hence the long-held argument on the ineffability of EAEs — something for which we acquired a good empirical proof in our study of communicability. Here we remember our own findings on the powerful role that embodiment and emotion play in EAEs (Bermudez 2011b) and how such nature points at the ultimate impossibility to literally convey the full 'thickness' of an extraordinary aesthetic moment through any language or media. This radical physical, emotional, subjective quality of EAEs also explains their remarkable mnemonic longevity, power, and attraction.

ACKNOWLEDGEMENTS

We want to thank the thousands of individuals worldwide who gave their time to participate in the survey. Not only is each selfless act helping advance the state-of-the-art of our knowledge but, more importantly, is also a living proof of the true and staying power and relevancy of architecture in our lives.

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ENDNOTES

[1] The Pearson's Chi-Square test for independence considers how likely a result is due to chance. In our case, this statistical test looks at whether responses for one question are independent of the responses for another. That they are independent (i.e., no relationship exists) is the null hypothesis. A Chi-Square probability value (*p-value*) of less than or equal to "0.05" is justification for rejecting the null hypothesis that the two variables are unrelated. In other words, a p-value of "0.05" means that there is a five percent (.05) chance of being wrong — or that there is a 95% chance that there is a true correlation between the two variables being compared. In general, anything below "0.01" (i.e., 1%) is considered to be an excellent result (i.e., 99% confidence). For more on this, see Agresti & Finlay (1997, 223-228).

[2] We did find a large difference between English and Spanish speaking populations when comparing their lower assessment of EAEs. Whereas a small minority of the English speaking respondents (**8.5%**) considered EAEs '*Below*' other strong life experiences, over a fifth of Spanish speakers (*23.2%)* ranked them in this manner. We could hypothesize that this might be due to how Latin cultures place more importance on socially driven events in a person's life as compared to the more individualistic attitudes of English speaking cultures.

[3] Question 3 stated *"Please name the building or place that elicited your extraordinary experience and, if possible, the year you had it and how far you lived from the location."* For a list of the 10 most cited places see Bermudez 2009a, Bermudez 2010. For findings about distance refer to Bermudez 2011a

[4] These statistics cover responses to Question 2: *"How many extraordinary experiences of architecture have you ever had? (1, 2-5, 6-10, over 10)."*

[5] Question 20 asked *"How long did your EAE last in its totality? (Under 5 minutes, 5-15 minutes, 16-30 minutes, Over 30 minutes, Don't Recall*)),"

[6] These are the results of answering survey question 27: *"Did this experience change your understanding/appreciation of architecture? (Yes, No, Don't know/Not sure).*"

[7] This finding comes from answers to *question 8: As it was happening, did your extraordinary experience of architecture make you talk? (Yes, No, Don't recall)*

[8] Question 11 asked survey participants if, *"as it was happening, their EAE made them introspective /silent"* and offered three possible answers: *"Yes, No, Don't recall"*

[9] To be precise, the **7%**, *9%* statistics refers to being with many friends. The difference shoots to *+15%* when we compared it to experiences taking place with only one friend.

[10] This question was missing (due to an error) in the Spanish Survey.

[11] Of course, there is the potential that those reporting more sharing possess a more 'social' type of personality. In our case, they tended to be slightly more female (**+4%**), educated (**+11%** with graduate school or above), and with less background in architecture (**–6%**).

[12] There are other possible interpretations, such as the need to validate one's experience.

[13] There was also a relatively high level of "Don't know" responses: **9.9%**, **10.6%** and **21.4%** respectively; the latter indicates a lack of understanding of what multimedia could do.

[14] In comparison to the English, there was a very low level of "Don't know" responses: *0.8%*, *1.1%* and *2.5%*.

Spatial Configuration and Social Life for People Experiencing Dementia

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ABSTRACT: In this paper, we will focus on the important, facilitating role architectural design plays in social interaction within long-term care facilities. Social interaction is considered an essential therapeutic intervention for people with Dementia of Alzheimer's Type (DAT). Here we apply space syntax as an objective measure of environmental characteristics and whose body of knowledge shows that the physical environment affects social interaction, in turns affecting individual well-being. Two key characteristics related to social interaction are proximity and visibility and yet studies involving these concepts in Long-term Care Facilities (LTCF) are almost absent. This research hypothesizes that proximity and environmental visibility in social spaces—dining rooms and living rooms—found within LTCF-DATs may affect social interactions among residents.

Almost 150 rounds of behavioral observations utilizing a field observation protocol including a behavior-mapping technique were collected in the social spaces of three local LTCFs with different spatial configurations. By using the visibility and proximity metrics of space syntax, the locations of occurrence of various social activities in relation to the furniture layout on architectural floor plans has been identified. The observed data of the dementia residents that particularly related to the social activity, visibility and proximity metrics of space syntax were then analyzed.

The results of this study show that the residents of the facilities were engaged in very low to low level of social interactions in locations with better visibility and accessibility. However, for very high-level of social interactions, they preferred locations with less visibility and accessibility. This is an important, nuanced finding as it suggests that architectural configuration factors impact the type of conversations likely to occur in certain locations. A more enriched and differentiated spatial layout of social spaces in care facilities could generate positive consequences for social interactions, positive affect and overall well-being.

KEYWORDS: long-term care, social interaction, space syntax, elderly

INTRODUCTION

The relationship between the physical environment and the prevalence of social interaction has been a core topic of inquiry within environmental gerontology (Cioffi et al. 2007; Davis et al. 2009; Kang 2012; Kovach et al. 1997; Lawton et al. 1984; Lawton & Simon 1968), where, social interaction is considered an essential therapeutic intervention for people experiencing dementia of the Alzheimer's type (DAT). Lawton (1980: 14) suggested quite eloquently "a small improvement in environmental quality could make all the difference in the world to a person with major limitations on his competence." A growing body of literature shows that the physical environment affects social interaction, in turn affecting individual, group, organizational outcomes and even quality of life (Burton 2012; Calkins 2009; Ulrich et al. 2008). Although for the past fifty years it has been accepted that the physical setting plays a salient role in the quality of life for persons with dementia, we have not found any literature that objectively and quantitatively measured such environmental settings.

Space syntax is an analytical tool that can objectively measure the spatial layout of physical settings. According to space syntax literature, spatial layout generated by spatial configuration plays an important role in the communication patterns, space use and movement (Penn et al. 1997). Spatial interconnectedness is another factor affecting observed levels of interaction (Grajewski 1992) that can be measured by visibility, accessibility, openness and connectivity. Therefore, the aim of this paper is to understand the impact of spatial configuration on social life for people experiencing dementia and as an analytical technique we used space syntax. In order to accomplish the research aim, our hypotheses are that spatial configurations characterized as having greater visibility and proximity should promote greater occurrence of low-level social interaction, but that high-level social interaction, often viewed as the most therapeutic, will most likely occur in locations with less visibility. This paper seeks to explore these hypotheses in relation to dining rooms and living rooms within long-term care facilities for people experiencing dementia of the Alzheimer Type (LTCF-DAT). However a comprehensive model to understand the relationship between social interaction and spatial configurations is still missing in the research literature and therefore we begin with such a model.

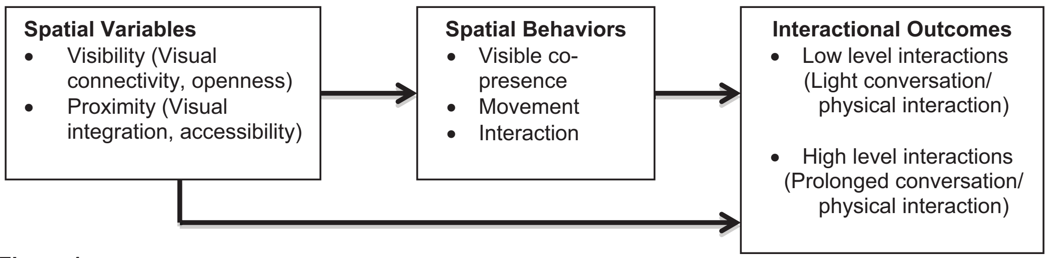

Figure 1: Spatial behaviour-interaction model.

The spatial behavior-interaction model (Figure 1) can describe the relationships among spatial configuration, spatial behavior and social life for people within a setting. Visibility and proximity are two spatial variables that can influence spatial configuration. In this model 'visibility' represents visual connectivity or openness and 'proximity' represents visual integration or accessibility. Here visual integration and visual connectivity are analogue of axial integration and connectivity. Among spatial behaviors, visible co-presence (defined as the number of people visible from a path of observation), movement (defined as the number of people moving along a path of observation) and interaction (defined as the number of people engaged in any reciprocal exchanges in a space) are different variables that can influence the interactional outcome.

In this model it is assumed that spatial variables may have direct or indirect effects on social interaction. For example, an easily accessible and visible social area in LTCF may have direct positive effects on social interaction that could facilitate low level or high level interactions; a highly connected layout of LTCF may have indirect positive effects on social interaction by facilitating movement or by increasing visible copresence and so on. The model also shows that the relationship between space and social interaction are important because any increase in interactions may be influenced by the spatial configuration or behavior.

1.0 METHODOLOGY

This study used a three stage, multi-method research design including behavior-mapping and spatial analysis. In the first stage, to investigate the relationship between social interaction and the environmental variables of proximity and visibility in dining rooms and living rooms in LTCF-DATs, fieldwork was conducted by using behavior-mapping technique. The protocol of behavior mapping technique was suggested by the Bradford Dementia Group (1997), which provides detailed operationalized observational ratings of the activities that residents are engaged in, recorded every 5 minutes over a period of 6 hours. This particular behavior mapping instrument focuses on social interaction and has been utilized in numerous previous studies (Diaz Moore & Verhoef 1999; Van Haitsma et al. 2005).

In the second stage, the visibility and accessibility of all three LTCF layouts were analyzed using the techniques of the visibility graph analysis (VGA) of space syntax. The `Depthmap' software was used for this purpose. Space syntax is a set of descriptive techniques for representing, quantifying and modeling spatial configuration in buildings and settlements. To assess proximity and visibility to and from dining rooms and living rooms in LTCF-DATs, this study used the tools and techniques of space syntax, which researchers around the world employ to study and measure quantitatively the consistent effects of the configuration of space on behaviors at various scales of the physical environment (Hillier 1996; Hillier & Hanson 1984; Peponis & Wineman 2002). The innovation and advantage of space syntax over other analytical method is that, it could objectively suggest design recommendations based on existing architectural design layout that would help to improve the physical environment of LTCF and also the quality of life of people with DATs. Space syntax has several numerical measures for describing the configurational attributes of a spatial layout. One of the most commonly used spatial units in space syntax is the axial map, which is a measure of physical proximity. An axial map of a layout is comprised of the fewest number of axial lines needed to go to every space in a layout.

Among a number of spatial measures, the most important is 'integration', which is the relative depth or hollowness of any spatial system seen from any particular point within it. The integration value of axial lines is one metric of proximity and has proven a particularly good predictor of movement. Integration is therefore about syntactic not about metric accessibility (Hillier & Hanson 1984). Integration is an indicator of how easily one can reach a specific line of the axial map. More specifically the higher the integration value of a line, the lower the number of axial lines needed to reach that line (Baran et al. 2008). In several studies of buildings and cities, integration is often correlated significantly with movement patterns at the level of 0.7 or above.

Space syntax studies also measure visibility as a correlate of spatial behaviors. Visibility can be measured using either visual field analysis or Visibility Graph Analysis (VGA) (Rashid et al. 2006; Turner et al. 2001). Visual field analysis provides the relational patterns of the visual fields drawn from all the spatial units of a setting (Haq & Luo 2012; Rashid et al. 2006; Rashid et al. 2009). In contrast, VGA involves the creation of a graph of mutually visible locations in a spatial system. Consequently, a location in a spatial system is characterized based on how visually connected the location is both locally and globally (Holscher & Brosamle 2012; Turner et al. 2001). These spatial characteristics of a setting are important to understand spatial behaviors in general and social interaction in particular. Increased proximity and visibility are associated with higher levels of interaction within a space (Cai & Zimring 2012; Rashid et al. 2009). It has also been demonstrated that more frequent face-to-face interactions between individuals may occur when they are visually or physically proximate (Rashid et al. 2006). The utilization of space syntax within environment gerontology enabled us to draw upon well-validated and operationalized measures of proximity and visibility and apply them to concepts that have otherwise eluded measure and description.

In the last stage of the study, we analyzed the relationships between the spatial and observational/behavioral data using statistical techniques. We performed descriptive and correlational analysis in order to find out where these behaviors occurred in relation to visibility and proximity.

1.1 Data collection and analysis

The spatial data using space syntax was gathered by computer analysis of digitally formatted architectural plans of LTCF-DATs, and they included different global, relational and local measures of proximity and visibility. The observational data of activities occurring in dining and living rooms was recorded with a well-utilized behavior mapping instrument/technique by research team observers who participated in training to enhance inter-rater reliability (Van Haitsma et al. 2005).

Observations occurred over 2 days in each facility for a total of twelve hours of observations per facility (Chenoweth et al. 2009). The social interaction data resulting from the behavior mapping was then aggregated to the facility level of analysis in terms of both amount and level of social interaction. This data was associated with the spatial metrics of the respective dining and living rooms provided by space syntax. Plans were analyzed using space syntax techniques for their configurational properties of proximity and visibility.

For simplicity of data analysis with this relatively small sample, social interaction data was aggregated for each designated space. In order to examine the relationship between proximity and visibility of each space with the social interaction data, Pearson correlations was calculated for both types of spaces (dining room and living room). This resulted in 2 Pearson correlation coefficients for each type of space, a value representing the relationship between social interactions and proximity and a second value representing the relationship between social interactions and visibility.

1.2 Case Studies

This research included three long-term care facilities in Lawrence, Kansas as case study to establish the hypothesis, one of which (Neuvant House) was designed recently. Although previous literature identified the effects of proximity and environmental visibility in several workplace studies using space syntax theories and techniques (Rashid et al. 2006; Rashid et al. 2009), studies involving proximity and visibility in LTCF-DATs are almost absent. Therefore, a pilot study was conducted at three local long-term care facilities with different spatial configurations and floor layouts to develop and validate the techniques of behavioral observations discussed in the methodological section, and to see if the results of data analysis would support our hypothesis.

Our first case study, Neuvant House (Figure 2), has a small rectangular plan with an internal courtyard around which residential units and social spaces are organized. The social space of Neuvant House is formed with an open plan kitchen, dining area, family living and activity space. The second case study, Windsor of Lawrence (Figure 3), is a mid-sized facility with an internal courtyard, but here the residential units and activity spaces are organized around a circular circulation spine. Besides the main activity space, the dining room and courtyard also act as an activity space for the residents. Our third case study, Pioneer Ridge (Figure 4), is a large amalgamation of neighborhoods of up to 26 residents each, organized around a central core which has a large dining space through which access may be gained to a centralized courtyard.

Due to the limited accessibility this courtyard is not used by the residents and caregivers. Although there is designated activity space for the residents, most of the time the large dining area served as a primary social area and activity space for this facility.

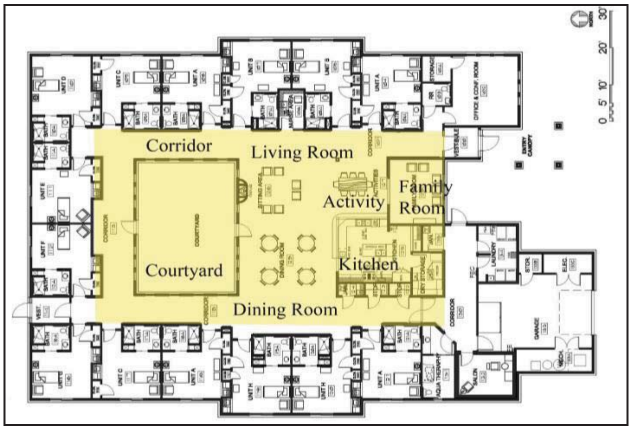

Figure 2: Floor plan and layout of social space in Neuvant House

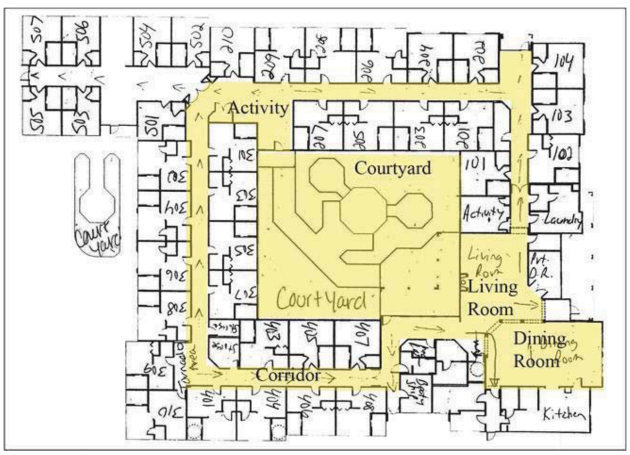

Figure 3: Floor plan and layout of social space in Windsor of Lawrence

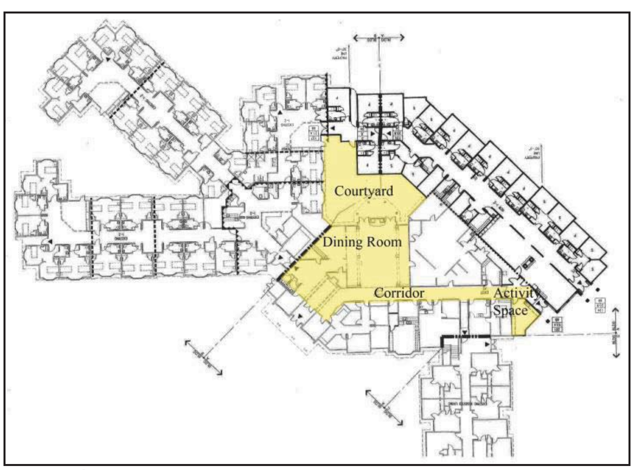

Figure 4: Floor plan and layout of social space in Pioneer Ridge

2.0 RESULTS

2.1 Descriptive Analyses of the Observation Data

The behavior-mapping instrument allows for recording observed social interactions at four levels of intensity: no contact, incidental social contact, low-level interaction and high-level interaction. Only light level conversations with minimal physical interactions were noted as low-level interaction. On the other hand, prolonged conversations or those involving physical touching, were identified as high-level social interaction. The majority of observed interactions in three LTCFs occur in dining room and family spaces.

For Neuvant House, the corridor also acts as an important interaction space. The open plan kitchen, dining room and family living area are mostly used as social space for this LTCF. On the other hand for Windsor of Lawrence, dining room, living room and courtyard are heavily used by the residents for social interactions. For Pioneer Ridge, the mostly used social space is the dining room, which is also used as an activity space. Table 1, represents the visibility and accessibility data of three LTCFs from space syntax analysis. According to the analyses, these three LTCFs were laid out to increase social interactions and from previous literature we know that more frequent interactions between individuals may occur when they are visually and physically proximate (Rashid et al. 2006). Therefore from the following tables, Neuvant House has the most connected (2428.66) and visually integrated (10.174) social space and Pioneer Ridge has the least connected (628) and visually integrated (6.983) social space for social interactions.

Table 1: Mean spatial data of three LTCFs from Space Syntax Analysis

	Neuvant House	Windsor of Lawrence	Pioneer Ridge
Mean Connectivity	2428.66 (89-5788)	2063 (101-5952)	628 (4-1653)
Mean Visual Integration	10.174 (3.479-19.564)	8.363 (3.038-15.209)	6.983 (2.597-12.389)
Visual Mean Depth	2.215 (1.548-4.085)	2.507 (1.749-4.752)	2.476 (1.772-4.682)
Visual Node Count	10216	16241	4537

2.2 Visibility Graph Analyses of three LTCF Layouts

Visibility Graph Analysis (VGA) measures visibility of any spatial system both locally and globally and involves the creation of a graph of mutually visible locations. After collecting the observation data of each resident in relation to the individual piece of furniture through behavior-mapping instrument, the visibility (isovist areas) and proximity (integration) metrics of space syntax were then applied to the location of each individual piece of furniture. Most of the time social activities were taking place near the furniture or while the residents were using the furniture. We then performed descriptive and correlational analysis in order to find out where these behaviors occurred in relation to visibility and proximity.

In general, a LTCF requiring more interactions would have its social spaces more easily accessible. We used the mean connectivity and visual integration value of three different LTCFs to determine the accessibility of these spaces. According to space syntax study, in general, public spaces are located along more integrated lines, whereas private spaces are located along less integrated lines. This makes sense because visibility graph of a layout with lower integration values are physically and visually less accessible. From Table 1, we could see that mean connectivity (2428.66) and visual integration (10.174) of Neuvant House is comparatively higher than Windsor of Lawrence and Pioneer Ridge. Therefore, according to our hypothesis, the large integrated social space of Neuvant house with better visibility and proximity is considered to promote low-level of social interactions. On the other hand, the lower mean connectivity and visual integration of Pioneer Ridge with less visibility and proximity is considered to promote high-level of social interactions.

3.0 FINDINGS

The findings of the descriptive and visibility graph analysis show that the residents were engaged in low-level social interactions in locations with better proximity and visibility (Figures 5&6). However, for very high-level social interactions, they preferred locations with less visibility and proximity (Figures 7&8). The correlational analysis, which show significant negative correlations between high-level interactions and proximity (integration) and visibility (isovist area), further supports this observation (e.g., Pearson correlation of -.565 ($p<.01$) and -.538 ($p<.01$) respectively). These findings also support the previous literature (Rashid et al. 2006; Rashid et al. 2009) indicating that for high-level interactions in workplaces people tend to avoid more visible and accessible locations. From the findings of this study, it is evident that to promote high-level social interaction between residents and care givers, less visibility and proximity is considered as preferred spatial configurations for LTCFs.

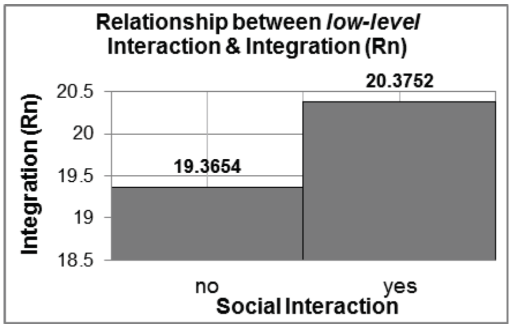

Figure 5: Mean integration values of locations where very low-level social interactions occurred vs. where they did not occur.

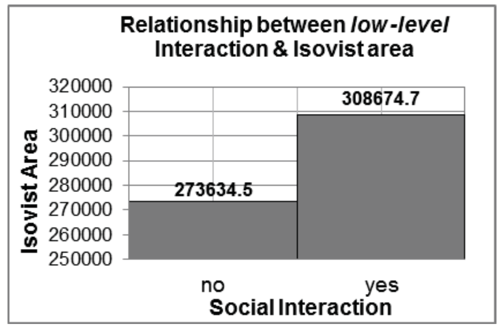

Figure 6: Mean isovist areas of locations where very low-level social interactions occurred vs. where they did not occur.

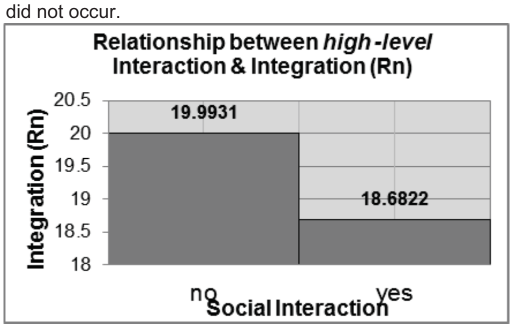

Figure 7: The mean integration value of locations where high-level social interactions occurred vs. the mean integration value of locations where they did not occur.

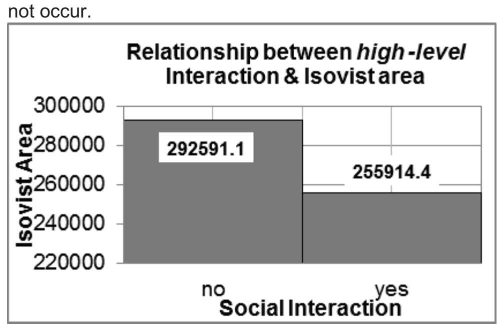

Figure 8: The mean isovist area of locations where high-level social interactions occurred vs. the mean isovist area of locations where they did not occur.

DISCUSSION

In this paper we have reported a study in which we used space-syntax theories and methods to address questions of how patterns of spatial layout affect movement, visible copresence, and interactions. Space syntax is interesting because it allows us to describe the generic properties of three different spatial layouts in a rigorous way. Although it was difficult to perform a comparative study of widely different LTCFs, space syntax eliminates the problem, because its methods of description using visibility graph can be used to study any physical setting without ambiguity.

It is also necessary to note here that there is a significant lack of studies involving movement, visible copresence, social interaction, and layout attributes. Until now, there has been no consistent technique for observing these behaviors. As a result, researchers have been unable to investigate the relationships among these behaviors and layout attributes in different settings, especially in LTCFs. In this regard, we have presented a methodological innovation. We showed how these behaviors can be consistently and simultaneously observed by using behavioral observations.

Social interaction is repeatedly considered as an essential therapeutic intervention for people experiencing dementia of the Alzheimer's type (DAT) to improve their quality of life. We believe that these findings will have a measurable impact on the future design of long-term care settings. According to the findings, people were engaged in fewer interactions in spaces, and were less visible from spaces with higher visibility, integration and connectivity values. Residents avoided interacting with others and being seen with others from such spaces, which are more visible and accessible. From the previous literature, proximity and visibility are considered as a significant design criteria that could objectively define the shape and design of care communities in the future. Therefore, a finer grained and systematic analysis of visibility and proximity metrics of space syntax is intrinsically important for future robust analysis in LTCFs, to encourage and expedite social interaction in individuals with dementia.

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The Question Concerning Design

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ABSTRACT: The American Heritage Dictionary defines design as both a verb and a noun with the general meaning that someone makes and/or executes plans or the actual plans. However, many disciplines claim to design as a part of their productivity and result of their labor. The problem comes when these disciplines and professions work collaboratively. Their individual understandings of the term “design” can lead to much confusion and misunderstandings amongst team members. Since so much design is interdisciplinary and collaborative, this is becoming more and more of issue. I am currently working in an environment with architects, engineers and scientists who are coming together to “design” a project but we are coming at this from very different understandings of the term.

This paper will attempt to unpack the meaning and practice of design for the disciplines of architecture, engineering and science. I will employ the comparative method to examine the way that architects, engineers and scientists use this word to describe what they do in order to discover the similarities and differences of usage. The paper will begin with a look at the etymology of the word,” design,” and then will provide an overview of the literature and practices available on the topic of design for each discipline. The intent is to find a common ground between the disciplines or at least provide a lexicon for the disciplines when working together.

KEYWORDS: design, architecture, engineering, science, terminology

INTRODUCTION

Martin Heidegger wrote an article/presentation in 1953 titled, “The Question Concerning Technology.” The piece was developed over several years as Heidegger grappled with the essence of technology as the destiny of the West in the 20th century. In this article he situates “technology” as that which has always existed and that which is primary to one’s understanding of oneself and humankind. His argument extends our understanding of technology and gives our drive to control nature a primacy akin to religion and politics. However, in the 21st century, post-Industrialization world, we have begun to seek other ways of understanding our capacity for creation. In that light, the term “design” continues to gain credibility as disciplines not normally associated with design try to understand how they might reconsider themselves. For example, business schools are now trying to employ “design thinking” as are others.

No philosopher or cultural critic has yet come forward with a transformative essay on the nature of design as a part of our human essence, yet the term is so prevalent as to demand defining and some comparative analysis. In what follows, I am making an attempt to look at the word design from its linguistic roots and then to reveal how three major disciplines use the term.

1.0 THE PROBLEM OF TERMINOLOGY

The word design means to make a plan or a scheme for the construction of an object but can also be used as a noun to describe the constructed object itself. The word is derived from the Latin roots of *de-* meaning to move away from something and *signare* meaning to mark or inscribe; put together – to mark out. The meaning of design always meant more than merely a plan, but rather describes something more thoughtful and intellectual, an exercise beyond rote planning. The key aspect of this is the making of the plan, not just the result of a plan itself or the object that results. Both of these distinct products, a process and an object, are just results of design. In the enlightening essay, “The Etymology of Design: Pre-Socratic Perspective,” Kostas Terzdis takes on the challenge of exploring the term “design.” Terzdis argues that our notions about design have become more conflated with planning but that the true nature of design is more about discovery and innovation.

Yet, in contemporary usage the term design has taken on metaphorical extensions that are used to describe a variety of activities and processes within different disciplines. In the past couple of years I have been part of an initiative that brings together scientists, engineers and architects to study and speculate about the coastal environment.[1] These collaborations are often hampered by our initial lack of understanding about each other's fields, beginning with our language. Generally, we are finding that it can take up to four months to start to feel comfortable with each other's terminology and language. The process of doing the actual research work we intend to engage in would be greatly facilitated by expediting the language barriers.

Two of the key thought leaders in the field of design thinking are Herbert A. Simon and Donald A. Schon. While their work was primarily conducted in the 1960's and 70's, their iconic texts, *The Sciences of the Artificial* (1969) and *The Reflective Practitioner* (1982), respectively, continue to provide the defining context for design thinking in the sciences, engineering and architectural disciplines. Simon's book, which is currently in it's 3rd edition, offers a clear look at the underlying difference between science and professions, such as engineering and architecture. He argues that scientists operate through the lens of the natural world, versus the professions, which work through constructed, or artificial, world. This is illustrated in the following passage:

> Historically and traditionally it has been the task of the science disciplines to teach about natural things: how they are and how they work. It has been the task of engineering schools to teach about artificial things: how to make artifacts that have desired properties and how to design.
>
> Engineers are not the only professional designers. Everyone designs who devises a course of action aimed at changing existing conditions into preferred ones. The intellectual activity that produces material artifacts is no different fundamentally from the one that devises a new sales plan for a company or a social welfare policy for a state.

Schon's book follows in some parts, on the thinking of Simon, but delves more deeply into the nature and manner in which professionals think and act.

The question of design, and our understanding of it, has been studied by many different groups including the Design Research Society (UK) which publishes the journal Design Studies: The International Journal for Design Research in Engineering, Architecture, Products and Systems. In its own words, the journal aims to:

> *Design Studies* is the only journal to approach the understanding of design processes from comparisons across all domains of application, including engineering and product design, architectural and urban design, computer artefacts and systems design. It therefore provides a unique forum for the analysis, development and discussion of fundamental aspects of design activity, from cognition and methodology to values and philosophy. The journal publishes new research and scholarship concerned with the process of designing, and in principles, procedures and techniques relevant to the practice and pedagogy of design.
>
> As design increases in complexity and in its social, cultural and economic importance, it is vital for researchers, educators and practising designers to stay abreast of the latest research and new ideas in this rapidly growing field; with its interdisciplinary coverage, *Design Studies* meets these needs with maximum effect.

In trying to compare the thinking of architects, engineers and scientists, I created the diagram in Figure 1 to explain the differences between the fields in term of perspective, design process, design goals and applicability. The results show that the fields have varying degrees of creativity, experimentation and expectations in their use of the term design.
The authors Kees Dorst and Judith Dijkhuis wrote a very helpful article in *Design Studies* titled "Comparing paradigm for describing design activity." In this article, they posit that there are fundamentally two paradigms for describing design activity: the rational and the reflection-in-action. I will be applying this terminology to the disciplines outlined below.

2.0. METHODS

My inquiry into the use of the term "design" began as a generalized issue within a collaborative practice. I have employed the comparative method when looking at the use of the term "design" across three disciplines. Although I am an architect, I have attempted to learn about the other disciplines in order to understand and illuminate our differences and likenesses. I will also be using illustrative examples from each of the disciplines to demonstrate the thinking behind each. It is interesting to note some of the similarities and differences in modes and choices of topic in the representational aspects of each discipline. The role of the diagram is not a key component of this argument but could be expanded, as could the role of the model and notions of what is meant by the term "research."

Design thinking professionals	ARCHITECTS	ENGINEERS	SCIENTISTS
Perspective on design	process oriented	product oriented	process oriented
Design process	creative	prescriptive	creative/prescriptive
Design goals	firmness, commodity, delight	optimization	hypothesis
Applicability	product	problem-solving	knowledge

Figure 1: Diagram showing the comparative values and approaches to design, by design thinking professionals. Source: (Author 2012)

3.0. ARCHITECTURE AND DESIGN

Architects generally think of design as a process but are also are accustomed to referring to a project as "the design," meaning the end result of their work. For an architect, designing is a creative process that can take different forms including a data and information driven form, or a more intuitive form (reflection-in-action). Generally speaking, architectural projects have many complex variables that have to be considered, from the clients wishes, to the technical limitations of site, structures and materials. Through the design process, an architect can only be responsive to some of the variables at any given moment. In arriving at the final project design, Schon describes the architect's process of design as one of continuous "talking back" and response, or a conversation with the situation. Because of the complexity of an architectural project (and perhaps loose disciplinary boundaries), the architect's use of the term "design" is inherently more holistic in referring to the entire project rather that a component or a system.

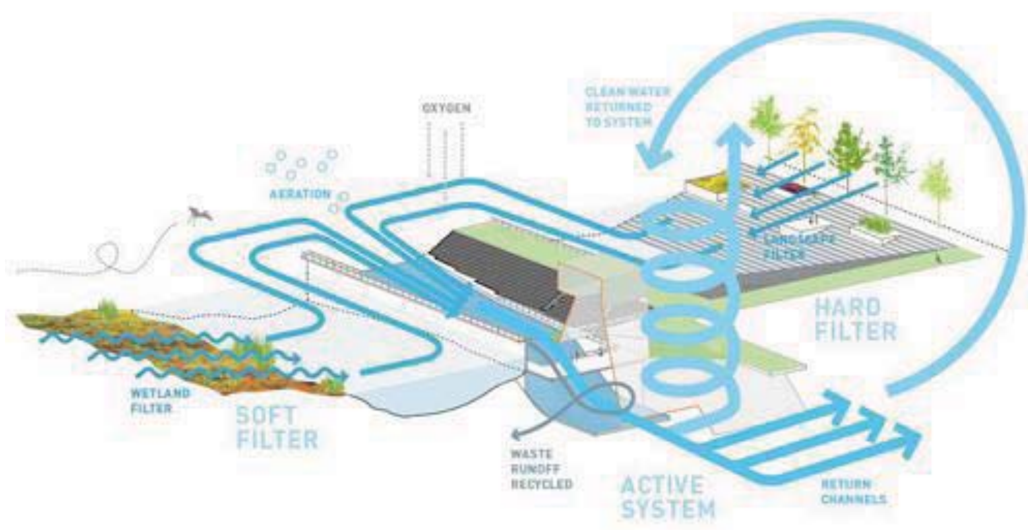

Figure 2: Example of architecture design drawing. Source: (Stan Allen Architect)

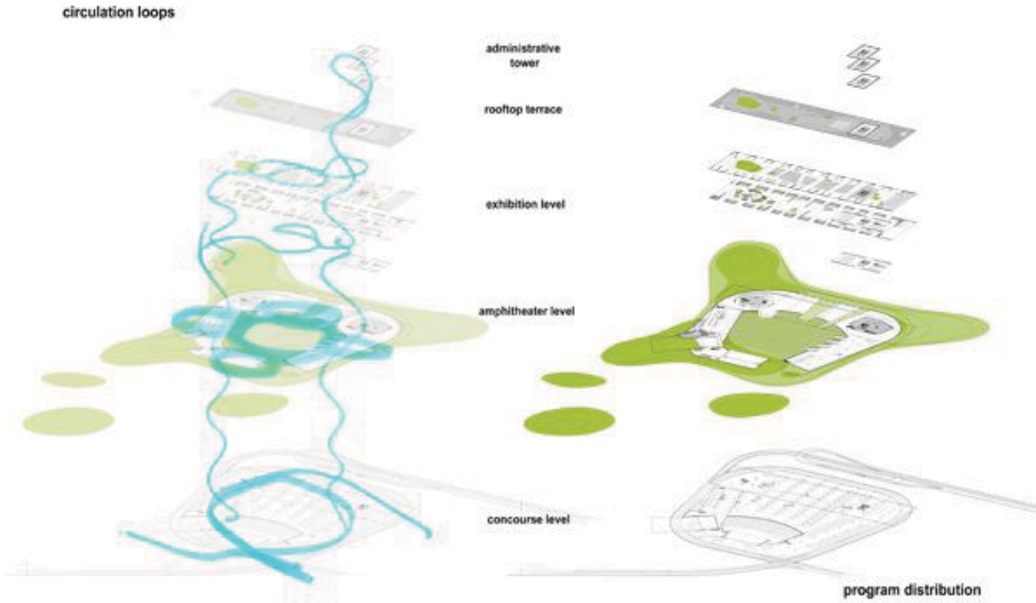

Figure 3: Example of architecture design drawing. Source: (Stan Allen Architect)

4.0. ENGINEERING AND DESIGN

For engineers, design generally refers to a specific performance goal and therefore to an object which results. The ultimate aim of design for an engineer is a product, whether it be a bridge, car, spillway or building. As evidenced in the figures below, for engineers, design is clearly attached to, and perhaps derived from, data and discreet information about an object or condition. There is an entire subset of the discipline of engineering called Engineering Design. Engineers would generally come under the rationalist design paradigm. The primary term that engineers use in describing the goal of a given design problem is "optimization." This term gives every design an almost moralistic imperative to be optimal…which could mean faster, cheaper, stronger…or any combination of these terms. So the goals of design for engineers can be seen as quite different that those of architects and the use of the term "design" is then also quite different.

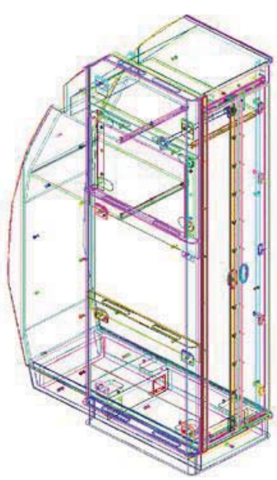

Figure 4: Example of engineering design drawing. Source: (Aero expert)

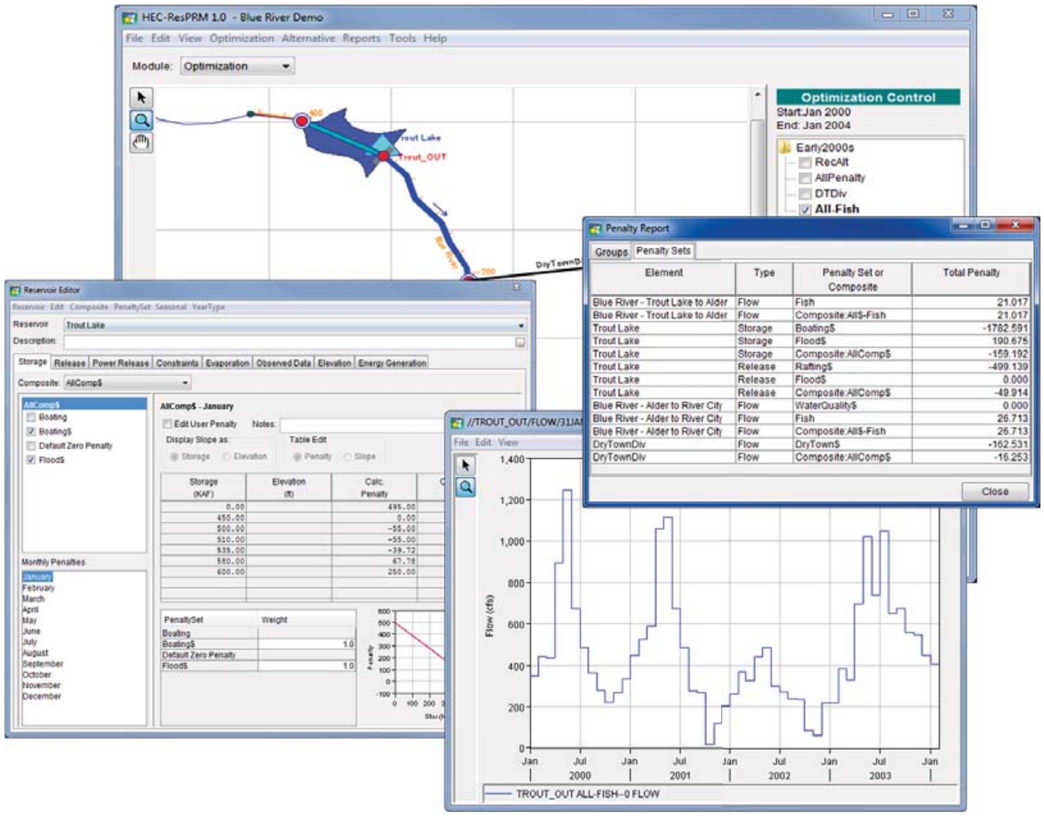

Figure 5: Example of engineering design process with data and applicable information. Source: (US Army Corps of Engineers)

5.0. SCIENCE AND DESIGN

For scientists, design refers to the way in which they develop their experiments and follow through on their hypotheses. For most scientists, the design is as important as the execution, for without a properly designed experiment, the entire endeavor is flawed and therefore invalid. For scientists, design is generally understood through diagrams that show relational values or sequencing. The design rarely refers to an actual object or physical manifestation. Therefore, the goal of design for scientists is not at all based on the final product, but on the process of experimentation, which is used to derive empirical data/knowledge about the natural world.

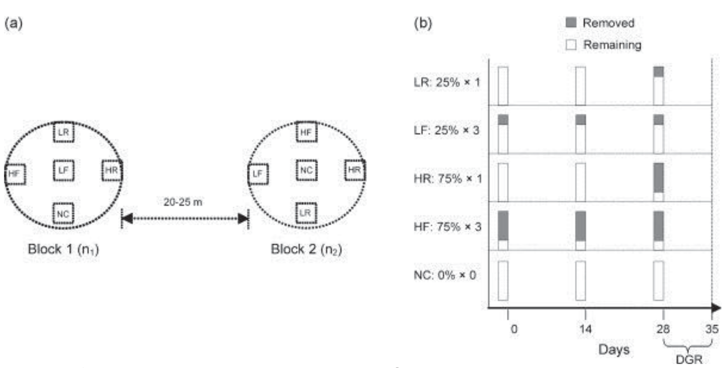

Figure 6: Diagram outlining the design of an experiment by botanists. Source: (Eklöf, et al)

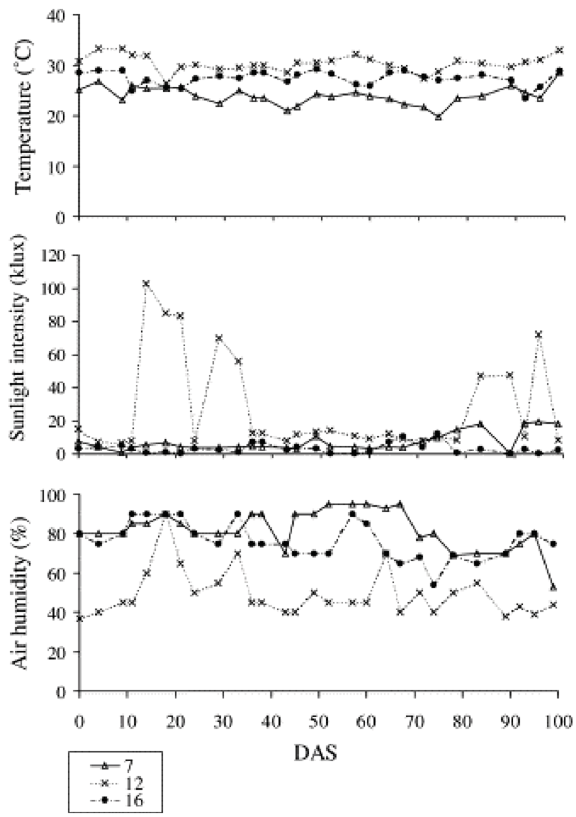

Figure 7: Part of article section called “Experimental procedure and design.” Source: (Rodiyati, et al)

CONCLUSION

In popular parlance, the term “design” is somewhat interchangeable with art, and has some implied relationship to a focus on intuition as process rather than on an intentional and rigorous search for knowledge. However, as an activity, design manifests itself in many aspects of non-artistic fields such as engineering, business, law and medicine. The most productive framing for design comes from H. Simon who says, “Everyone who designs devises courses of action aimed at changing existing situations into preferred ones.”

However, it is still clear that the disciplines themselves have further refined and defined their own disciplinary approaches to design that is can be difficult to find the common principles of design. It is difficult to expect members of different disciplines to change their typically used terminology and language in order to achieve a common understanding. However, it is crucial to a good working environment for all members of a team to be aware of the differences and relations of terminology, particularly when all members use the same term but with different inferences and applications. There are certainly other terms that could be examined using a comparative method to facilitate understanding such as “research,” and “model.”

What has been revealed through this study is that design is critical to each of the case study disciplines. Iconic thinkers in the field of design knowledge agree that design is a primary activity, in fact, so primary that design thinking is found in many professional disciplines as well as the science. Design was selected as a key term because of its current focus as a primary human activity and because of its central role in our own work. While Heidegger posited technology as central to the human endeavor in “The Question Concerning Technology,” one could question whether design, rather than technology, is a more primary endeavor and one that expands our conception of how and why we seek to continually improve our relationship to our environment.

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ENDNOTES

[1] The LSU Coastal Sustainability Studio is an initiative aiming to bring together multi-disciplinary teams in the study of Louisiana coastal issues. For more information see http://css.lsu.edu.

Spatial Correlates of Patients' Travel Experience & Satisfaction in Hospital Outpatient Department

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ABSTRACT: Designing a physical environment that is safe, accessible and easy to use can significantly improve patients' satisfaction and the quality of healthcare experience. Literature shows that difficulties in wayfinding cause delay in patients' movement, together with loss of time, decreased safety, and increase environmental stress. However, less is known concerning how wayfinding difficulties affect patients' satisfaction and travel experience. In this research it is assumed that an easily accessible and visible spatial layout may have direct or indirect positive effects on patients' movement, travel time, and way finding; and, as a result, it may have positive effects on patients' travel experience and satisfaction. The data was collected through systematic behavioral observation, patient survey, and floor layout analysis that included the measurement of actual route distance, travel distance, and spatial network distance using space syntax techniques. Findings of the study include the following: 1) patients' satisfaction depends on age, number of visits, frequency of visits, signage system, overall layout, and design quality; 2) patients' travel behavior is positively affected by route attributes; 3) overall patients' satisfaction does not seem to have any relation with the patients' travel behaviors and syntactic attributes of the layout; and 4) male and female patients' satisfaction and travel behavior show different association with syntactic properties of the layout. It is hoped that the study will contribute to an improvement of the design of the spatial layout of the outpatient department so that patients may receive their services in the least amount of time without becoming lost or missing an appointment due to wayfinding problems; and an increase in patients' satisfaction and travel experience.

KEYWORDS: Patients' Travel Experience, Patients' Satisfaction, Space Syntax, Spatial layout, Wayfinding.

INTRODUCTION

Patient satisfaction is a useful measure in assessing patient's experience in health care. This multidimensional concept focuses on the technical and interpersonal aspects of care, accessibility, and the outcome of the health intervention (Sitzia & Wood 1997). The purposes of measuring patient satisfaction are to understand patient experiences of health care, to promote co-operation with treatment, to identify problems in health care, and to make evaluation of health care (Fitzpatrick1984). Traditionally, the design of hospital was more focused on arranging a functional layout for the delivery of service rather than meeting the expectation of the user. Compared with the traditional concepts, the current design is more focused on creating an environment that meets and exceeds patients' needs for safety, security, support, competence, and physical and psychological comfort (Fottler, Ford, Roberts, Ford, & Spears Jr 2000).

Patient experience in the healthcare environment is an important factor in overall patient satisfaction and care outcomes. In hospital, patients get their first impression of the healthcare experience from the environment. This interaction with the environment can influence a patient's experience and satisfaction level even before he or she receives any services. Spatial design, ambient condition, and signage system are the three environmental components that patients usually perceive when they first enter in the hospital settings (Fottler, etal. 2000). Due to complex spatial layout patients sometimes experience long travel distance that may adversely affect their satisfaction level. Literature shows that difficulties in wayfinding cause delay in patient movement through the buildings along with loss of time, decrease in safety, and increase in environmental stress (Carpman, Grant, & Simmons 1993). In this case, designing efficient spatial layout and signage system may have a significant beneficial effect on patients' perception of care received (Urlich,etal. 2004, Harris,etal. 2002).However, less effort has been made to understand patients' satisfaction and travel experience in relation to wayfinding in outpatient department. Therefore, the purpose of this research study is to find out if an easily accessible and visible spatial layout, signage system of the environment, and quality of design have an direct or indirect positive effects on patient's movement, travel time, and wayfinding, and whether, as a result of these positive effects patients' travel experience and satisfaction improve.

1.0.

1.0. BUILT ENVIRONMENT AND PATIENTSATISFACTION

In the outpatient context, the environment in which the service is experienced can significantly improve patients' satisfaction and the perceived quality of care (Becker & Douglass 2008; Becker, Sweeney, & Parsons 2008; Fottler et al. 2000; Harris, McBride, Ross, & Curtis 2002). Sitzia and Wood (1997) propose that accessibility, waiting times, waiting environment, attitude of staff, and patient information are critical components of patients' satisfaction. Backer's (2008) study show that patients' perception of overall quality of care and experience depend on the physical attractiveness of the waiting room environment. Besides this, different features of healthcare settings such as clarity of signs and directions, orderly facilities and equipment, pleasantness of atmosphere are important determinants of patient satisfaction (Ware etal. 1983). To understand how spatial design of the outpatient departments could support patient satisfaction, it is important to understand the journeys that patients make through the department. In an inefficient layout, the long distances and complicated routes from the hospital entrance to the department can give the patient a poor travel experience. Literature shows that the plan and layout of the hospital might impact the ease of wayfinding and the speed of travel to various locations (Carpman, Grant, & Simmons 1993). Therefore, it is important to facilitate the movement of patients and visitors through design within the outpatient departments to ensure less walking time to locate their destination.

The signage systems that aid patients in finding their way have greater influence on patients' travel experience and satisfaction. In an unfamiliar environment, when patients engage in the wayfinding process, their satisfaction level depends on what they expect to find in that environment. In this case, poor signage systems can make them frustrated and can increase anxiety, confusion and dissatisfaction with hospital experience (Carpman et al. 1993). In addition, interior design features like floor finish, color, artwork and the layout of furniture effect patients' physical comfort and, therefore, can influence their experience (Arneill & Devlin 2002; Becker & Douglass 2008; Harris et al. 2002).

2.0. SPATIAL LAYOUT AND PATIENT'S TRAVEL EXPERIENCE

Designing a spatial layout is an important factor for patients' wayfinding and travel experience. Research shows that people depend more on spatial layout and the other architectural features than on signage in wayfinding situations (Carpman et al.1993; Weisman 1981). A simple and regular spatial system can make the building easy to understand in wayfinding situations and can improve the experience of movement through the environment (O'Neill 1991; Weisman 1981). In wayfinding situations patients also feel more comfortable when they make more frequent visits to the hospital (Gärling, Lindberg, and Mäntylä 1983; O'Neill 1992)

The travel experience of the hospital building is affected by the way in which spaces are connected, the changes of direction imposed by the circulation system, the creation of room sequences, the distribution of branching points, the availability of alternative routes, and the relations of visibility between and across spaces (Peponis and Zimring 1996). Therefore, the number of changes in direction needed to access the reception area from main entrance; the distance between the treatment rooms and the main entrance; and the number of treatment rooms that visitors and patients will pass when travelling between these areas, all need to be considered during hospital design (Khan 2011). All this suggests that physical accessibility of the spatial layout is an important factor for improving patients' travel experience and satisfaction. In addition, visual accessibility appears to be crucial in influencing the way in which people experience the spaces (Turner, Doxa, O'sullivan, & Penn 2001) and in facilitating one's spatial orientation and wayfinding (Gärling, Böök, & Lindberg 1986). Higher visual accesses in the spatial layout give patients a greater sense of spatial orientation in wayfinding situations (Montello 2007).

3.0. RESEARCH METHOD

The study examined the relationship between spatial structure and patients' travel experience and satisfaction in several outpatient departments. Multi-method data collection was used in this study, including systematic behavioral observation, patient survey, and the floor layout analysis.

3.1 Systematic Observation & Patient Survey

All patients who entered the reception area of the outpatient department were invited to participate in the study. Informed consent of the patients was taken by the principal investigator before a systematic observation was done of patients' behavior in wayfinding situations. Observation was conducted with synchronized watch and data collection sheets. Each patient was tracked form the entry (reception area) to the destination (clinical unit). The travel time needed to complete each trip was recorded on data collection sheets. When the patient reached his or her destination and was waiting for medical service, he or she was asked to fill out a survey concerning his or her travel experience and satisfaction. In addition, individual patient route and travel behavior such as the number of decision making stops, the number of times the patient needed to look around to find the way, and the number of times the patient needed to ask for directions on the movement route were also recorded on the observation sheet. Observations occurred over a 2-week period. In the study, 60 patients were observed in 80 hours of data collection.

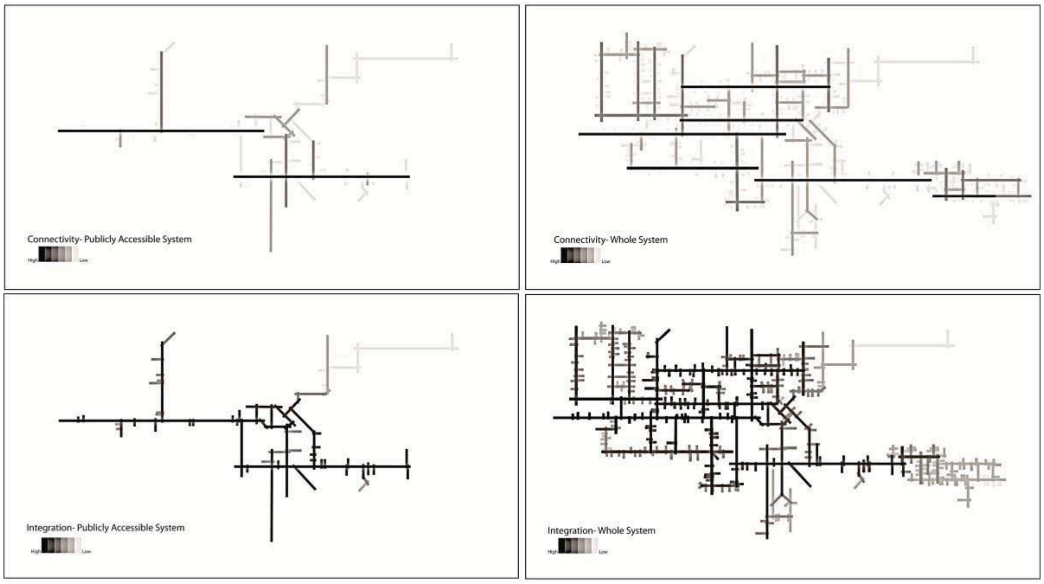

Figure 1: Axial map analysis of the whole system and the publicly accessible system

3.2. Floor Plan Analysis

The primary source of physical design data was the floor plan drawings of the outpatient department. The study focused on four departments (i.e. Pain management, Laboratory, Radiology and Surgery) that are all on the entry level of the building. The accessibility and inter-connection of the layout were analyzed using the construct of space syntax theories and method. Research has shown that space syntax variables can predict deliberate use of space in wayfinding situations (Peponis, Zimring, & Choi 1990; Zimring et.al.1998; Haq 1999;). For analysis, an axial map was produced for the *whole spatial system* of the study floor and the *publicly accessible route* of the floor (Figure 2). The "*whole spatial system"* refers to all circulation spaces on the study floor that were used by patients, staff nurses and doctors and the "*publicly accessible route*" refers to all spaces that patients could use.

The *axial map*, which represents a set of minimum number of longest sight line that covers every circulation space in the layout, was created for the study floor. "*Depth map 9*", a space syntax software program, was used to assess the relational pattern of the axial lines in the axial map (Figure 1). In this study, only *connectivity* and *integration* measures of space syntax were used. *Connectivity* is measured by counting the number of lines or spaces that are directly connected to another line or space. It provides the degree of choice on the line. A higher connectivity value represents more choice of movement on that line. *Integration* measures the relative position of any space or axial line with respect to all the space and lines in building layout. A higher integration value represents the space that is easily accessible.

4.0. ANALYSIS

The research evaluates the overall satisfaction with the hospital experience, and explores differences in patients' satisfaction across four departments. All data are analyzed in SPSS 20. In this analysis, patient satisfaction is measure in relation to patient demographic characteristic, spatial attributes, and spatial configuration

4.1 Patient Characteristics and Satisfaction

Patient demographic characteristics are an important determinant in studying patient satisfaction (Cleary & McNeil 1988). In this study, the aged patients (+60age) show higher satisfaction whereas the middle age groups (36-65) are less satisfied with signage system, overall layout, and design quality (figure 1). The findings are consistent with prior research that shows aged people are always more satisfied than younger and middle age (Rahmqvist, 2001; Schoenfelder, Klewer, & Kugler, 2011).

Literature shows that gender difference has an impact on patient satisfaction (Rahmqvist, 2001; Schoenfelder, Klewer, & Kugler, 2011; Sitzia & Wood, 1997). The findings show that in wayfinding situations, female patients are less satisfied than male patients in relation to spatial layout, signage system, and overall design quality (Figure1). Various research (Lawton, Charleston, & Zieles, 1996; Lawton & Kallai, 2002)reported that females are more stressed and anxious in wayfinding situations than males. In wayfinding situations, more stress can be a reason for less satisfaction among female patients.

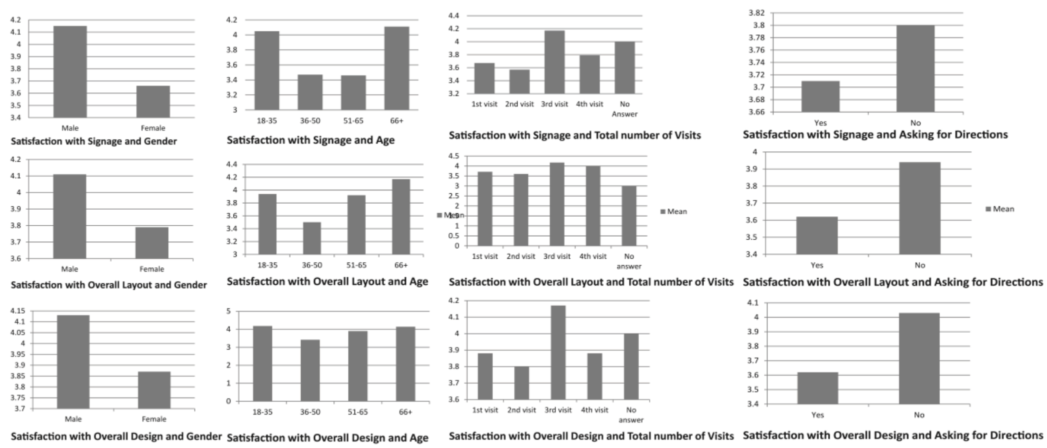

Figure 2: Patients' personal characteristics and satisfaction

In wayfinding situations, the study showed that patient who asked for volunteer help are less satisfied with the signage system, overall layout, and quality of design. It is possible that patients who were not confident in finding their way ask for volunteer and show dissatisfaction in order to locate their destination.

The study also showed that patient satisfaction depends on the number of visits and the frequency of visits (Figure2). Patients who visited this hospital for the third time (about 10%-13% of all observed patients) are more satisfied with the signage, overall layout, and design than patients on their first, second, and fourth visits. This finding supports that familiarity with the environment reduces the stress level of patients in wayfinding situation and at the same time increases their satisfaction level. This study showed that patients who visited this hospital fourth time were less satisfied than the third time visit patients. It is possible that due to long time gap between third visit and fourth visit patients who visited this hospital fourth time were less satisfied in this study.

Table 1: Spatial attributes of Patient route

		Pain Management& Endoscopy	Laboratory			Radiology and Surgery		
		Route1	Route 1	Route 2	Route 3	Route 1	Route 2	Route 3
No of directional change		1	4	4	5	5	5	6
Distance from entry		116.42 (ft.)	246.00(ft.)	240.75(ft.)	279.67(ft.)	359.5(ft.)	354.25(ft.)	383.33(ft.)
Signage on	wall	4	4	7	7	8	10	13
	floor	1	1	4	4	1	2	4
	roof	7	7	8	8	14	12	14
Landmark		You are here map	You are here map	You are here map	You are here map	You are here map	You are here map	You are here map
		Atrium	Atrium	Atrium	Atrium	Atrium	Atrium	Atrium
				Shop and setting	Shop and setting		Shop and setting	Shop and setting
					Elevator lobby1			Elevator lobby1
								Elevator lobby 2

This research only observed the main entrance that leads the visitor to the main atrium place. Within the three departments (Pain and Endoscopy, Laboratory, and Radiology & Surgery), only seven patient routes were studied. Table 1 shows the total length of the route, the number of directional changes, the number of directional signage, and the type and the number of landmark. The 'You are here' map, food court atrium, gift shop, and lift lobby are the landmarks in the setting. The map was placed in the central position of the atrium facing the entry. Therefore, it was visually and physically accessible to the patients. Information desk is physically and visually accessible from the entry. The findings show that the increases in the number directional change in the route also increase the number of signage and the length of travel route (Table 1).

4.2 Spatial Attributes and Patient Satisfaction

The correlation analysis between spatial attributes and patients' satisfaction with overall signage system, overall layout, and quality of design showed no significant relationship in this study. These denote that the number of signage was not related to patients' travel experience and satisfaction in wayfinding situations. However, the number of signage is highly correlated with patients' travel behavior (Table 2). The increase in the number of signage also increase patients travel time, travel distance, number of stops, number of looking around, number of asking for direction.

Table 2: Correlation between Spatial attributes, Patients' travel behavior and Satisfaction

	Satisfied with overall signage system	Satisfied with amount of time taken to reach services	Satisfied with overall layout	Satisfied with overall quality of design	Travel time	Travel distance	Number of stops	Number of Looking Around	Number of Asking for directions
Number of wall signage	-0.048	-0.072	-0.003	0.095	0.634**	0.855**	0.433**	0.678**	0.468**
Number of floor signage	0.185	-0.038	0.23	0.11	0.414**	0.511**	0.403**	0.486**	0.337**
Number of Ceiling Signage	-0.194	-0.139	-0.173	-0.033	0.521**	0.651**	0.254	0.500**	0.344**
Number of Landmark	0.097	-0.07	0.197	0.078	0.502**	0.657**	0.457**	0.620**	0.481**

** Correlation is significant at the 0.01 level (2-tailed)
***. Correlation is significant at the 0.05 level (2-tailed)**

Table 3: Syntactic measure of Patient's travel route

	Correlation (R^2)		Mean Syntactic Measure	Pain Management & Endoscopy	Laboratory			Radiology and Surgery		
				Route1	Route 2	Route 3	Route 4	Route5	Route6	Route7
Whole System	Rn - CV	0.108	Integration	1.81	2.03	1.88	1.84	1.95	1.87	1.89
			Connectivity	24.00	24.00	19.14	23.11	25.00	19.14	22.36
Publicly accessible system	Rn - CV	0.211	Integration	1.42	1.36	1.31	1.27	1.29	1.26	1.23
			Connectivity	9.50	7.20	6.57	5.67	7.33	6.75	5.90

4.3 Spatial Configuration and Patient Satisfaction

The axial map analysis of space syntax was done for both the publicly accessible system the whole spatial system. The analysis of the observed patient travel routes in the whole spatial system show the highest global integration value (Rn=2.03) for the Route 2 which take patient from the reception area to the laboratory (Table 3). The axial map analysis of the publicly accessible system shows that the connectivity value and global integration were highest for the Route 1 which takes patient from reception to pain and endoscopy department. The axial map analysis of the floor plan reveal poor correlation between global integration and connectivity (Rn-Cn) for the whole system ($R2=0.108$, $p<0.5$) and the publicly accessible system ($R2=0.211$, $p<0.5$). Hillier, Hanson, & Peponis (1987) define this correlation as the degree of intelligibility of a layout that helps to predict the spatial structure of a whole system. The findings denote that the spatial structure of the outpatient department is not intelligible to structure knowledge in wayfinding situation.

Table 4: Male patients' travel behavior, syntactic route attribute and satisfaction

Male Patient	Whole System				Publicly Accessible System			
	Department route		Patient route		Department route		Patient route	
	Integration	Connectivity	Integration	Connectivity	Integration	Connectivity	Integration	Connectivity
Travel Time	-0.053	-0.009	0.097	0.148	-0.309	-0.455	-0.249	-0.478
Travel distance	0.004	-0.404	0.473	-0.201	-0.846**	-0.614*	-0.437	-0.712**
Num_ stop	-0.444	-0.421	-0.109	-0.361	-0.704**	-0.452	-0.552	-0.656*
Num_ Looking around	-0.184	-0.469	0.227	-0.289	-0.611*	-0.476	-0.527	-0.546
Num_ Ask for direction	-0.228	-0.4	0.054	-0.489	-0.54	-0.117	-0.394	-0.36
Satisfied with overall signage system	-0.149	0.049	-0.174	0.261	0.186	0.24	0.075	0.454
Satisfied with amount of time taken to reach service	0.409	0.085	0.325	0.16	0.181	-0.049	0.27	0.118
Satisfied with overall layout	-0.05	-0.174	0.012	-0.092	-0.03	-0.081	-0.01	-0.013
Satisfied with overall quality of design	0.266	0.306	-0.094	-0.033	0.742*	0.806*	0.729*	0.801*

The correlation analysis show that satisfaction for all patients does not show any relation to patient travel behavior and syntactic attributes of the layout. However, male and female patients' satisfaction and travel behavior individually show a different correlation with syntactic properties of the layout. The study shows that for male patients, higher integration and connectivity value of the publicly accessible route will decrease travel distance, number of stops, and at the same time increase male patient's satisfaction about overall design (Table 4). The findings indicate that if male patients choose the publicly accessible route which is highly accessible and have higher degree of choice, they may be more satisfied in finding their destination. On the other hand, when female patient's choose route with higher integration and connectivity value, the route decrease the female patient's travel time, travel distance, number of travel behavior, and at the same time they are not satisfied with the overall layout and design (Table 5). Moreover, female patients are not also satisfied when their travel route has higher mean integration value.

Table 5: Female patients' travel behavior, syntactic route attribute and satisfaction

Female Patient	Whole System				Publicly Accessible System			
	Department route		Patient route		Department route		Patient route	
	Integration	Connectivity	Integration	Connectivity	Integration	Connectivity	Integration	Connectivity
Travel Time	0.087	-0.261	0.411**	-0.115	-0.761**	-0.471**	-0.749**	-0.526**
Travel distance	0.282	-0.385**	0.654**	-0.126	-0.910**	-0.699**	-0.870**	-0.709**
Num_ stop	-0.075	-0.213	0.089	-0.248	-0.407**	-0.324*	-0.450**	-0.412**
Num_ Looking around	-0.006	-0.255	0.277	-0.151	-0.712**	-0.528**	-0.762**	-0.599**
Num_ Ask for direction	-0.097	-0.137	0.038	-0.179	-0.360*	-0.256	-0.435**	-0.377*
Satisfied with overall signage system	-0.144	-0.111	-0.108	-0.11	0.014	-0.097	-0.009	-0.094
Satisfied with amount of time taken to reach service	-0.431**	-0.179	-0.334*	-0.181	0.203	0.192	0.213	0.224
Satisfied with overall layout	-0.377*	-0.105	-0.295	-0.132	0.042	0.054	-0.016	0.027
Satisfied with overall quality of design	-0.143	-0.274	0.054	-0.204	-0.275	-0.295	-0.278	-0.316

CONCLUSION

The aim of this study was to understand patients' travel experience and their satisfaction in relation to wayfinding in outpatient departments. The study focused on the satisfaction and travel experience of the patients' from reception to three outpatient departments - Pain and Endoscopy, Laboratory and Radiology and Surgery. The study showed that spatial layout, signage system, and the design quality of the environment were important factor for improving the patient's travel experience and satisfaction in wayfinding situation. The study also showed that personal characteristics of individual patient played an important role in determining satisfaction level. The numbers of signage system on the route have an effect on patient travel behavior. In wayfinding situations patients' personal characteristics like age, gender, and familiarity of the environment have an effect on patients' satisfaction levels. Integration and connectivity of publicly accessible route have the ability to predict male and female satisfaction separately. At the same time female patients are always less satisfied with the spatial layout, signage system, and overall quality of outpatient department in wayfinding situation than are male patients. Therefore, the findings of this research help us understand about how layout affects the satisfaction level of patients in hospital building. The limited number of sample size, observation departments and simple hospital layout is the limitation of this study. In addition to large sample size and more observation departments, the study needs to focus on complex hospital layout. Further studies measuring patients' stress level would be needed for understanding the causes of dissatisfaction among female patients in relation to spatial layout.

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The Dynamic Double Façade: An Integrated Approach to High Performance Building Envelopes

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ABSTRACT: The LivingLight house, an entrant in the 2011 Department of Energy Solar Decathlon, incorporates an innovative dynamic double façade system. This paper details key features of the façade system including aesthetic integration of technical components, natural and electric illumination, design of shading devices, and use of the façade cavity to harness solar-thermal energy.

KEYWORDS: Smart Façade, Double Façade, PV Technology, Automated Building Control Systems.

INTRODUCTION

This paper details key features of the integrated façade system developed for the LivingLight house. The house, one of twenty entries in the 2011 Department of Energy Solar Decathlon, resulted from a collaborative effort between students and faculty of Architecture, Mechanical Engineering, Electrical engineering, Graphic Design, Landscape Architecture, Interior Design, and Business. In addition to meeting the contest criteria of achieving a zero-net energy balance through the use of solar-electric power, the LivingLight house proposes an innovative double façade system to passively harness solar-thermal energy. Although integrated into a small house for the competition, the façade system lends itself well to commercial and residential applications in both retrofit and new construction. The façade resolves the multiple aims of its diverse design team and proposes a new aesthetic expression for an emerging building technology.

Concept

Through a series of multidisciplinary charette sessions early in the project, the team developed a set of six principles to focus design decisions (Figure1):

Figure 1 six key design principles

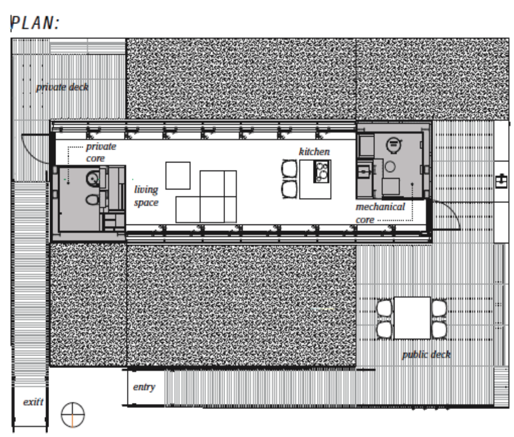

Figure 2 Floor Plan Living Light House

Two dense cores pushed to the perimeter of the space leave the living area free, opening it up to exterior views and maximizing daylighting capabilities (Figure2). These two cores organize the daily routines of life.

The public core contains most kitchen appliances and is near the mixed-use island accommodating dining and food preparation. The millwork of the public core can be entirely closed to hide its function while the island extends to accommodate from two to eight people. The opposite core contains the more private elements of the bed and bath. The adjacent entertainment center acts as a footboard and defines the space of the bed when in use and folds out to become a desk when the pull-down bed is stored. The proportions of the home are strictly limited by our transportation method, which dictates the maximum dimensions in height, length, and width. These tight restrictions however allow us to create a single, airtight volume.

The design of the LivingLight house owes equally to the precedents of the Cantilever Barn of Southern Appalachia and Mies van der Rohe's Farnsworth house. The simple formal and climatic strategies of vernacular architecture inspired the use of passive energy systems while the elegance of the modern glass box lead to the development of an energy efficient transparent façade (Figure 3).

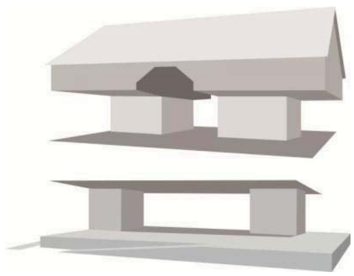

Figure 3 Shown on top, a diagram of the Cantilever barn and on the bottom, the LivingLight house
The Illustration shows the transformative approach of using the vernacular forms of the Cantilever Barn as a strategy to organize space in the LivingLight house. Support spaces are arranged as two dense cubes of program framing the open living space in between.

The Living Light house makes extensive use of glass for transparency, daylighting, and spatial connection to the surrounding environment. A dynamic double façade system, made up of interior high-performance insulated glazed units and a single-pane exterior, is implemented along the majority of the north and south facades.
These facades become the stage upon which the building comes to life. Sandwiched within the façade cavity is a motorized horizontal blind system that blocks sunlight and heat before it reaches the conditioned space. The blind system is programmed to provide proper lighting and shading throughout the year as well as provide privacy when desired. The cavity within the system is integral to the mechanical system of the home as a means to thermally buffer incoming fresh air and to moderate heat gain and loss.

1.0 Aesthetics and Experience

In the LivingLight house the ubiquitous glass façade is re-imagined as a transparent wrapper that simultaneously resolves dissimilar interior and exterior design criteria. From the exterior the outer layer of the façade appears taught, flat, and monolithic. Depending on time of day its appearance varies from reflective to transparent, becoming a glowing lantern at night.

Figure 4 Exterior view of the south Facade of the LivingLight house from the public deck. The glazing appears dark and reflective, contributing to the reading of the glass house as monolithic and private. Cylindrical photovoltaic modules extend over the glazing to provide shade.

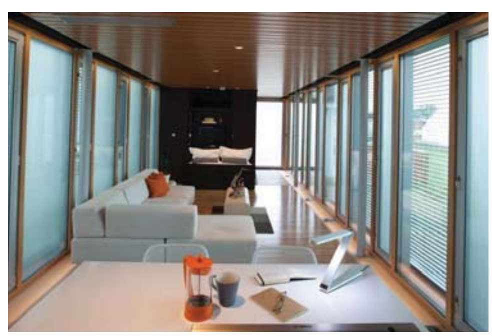

Figure 5 Interior view of the open, loft-like, living space. Alternating translucent and transparent glass panels help provide privacy to the public front and more extensive views to the private back. The large expanse of glass also allows the house to be naturally lit during the daytime.

By contrast, the interior layer of the façade has expressed oak-clad mullions defining a rhythm of transparent, translucent, and operable glazed panels. The wood mullions lend warmth and scale to the residential interior and harmonize with the other wood surfaces. From the earliest stages of design, the intent has been to incorporate technological systems at an aesthetic level. Lighting, ventilation, and shading are all given an integrated architectural expression in the façade. Given the constraints of a relatively small area and high-energy efficiency, the LivingLight house celebrates the luxuries of transparency, natural illumination, and abundant space.

2.0 Solar Photovoltaic System, Mechanical Systems, Home Automation System

The integrated roof-top array not only supplies two times the amount of energy to power the home, but it also shades the home's south facade. The 10.9-kW array employs a cylindrical module, so that direct, reflected, and diffused sunlight is captured across a 360° photovoltaic (PV) surface while maintaining a low profile (Figure 6).

The home is optimized to be controlled by a home automation system while providing the user with vital information about the house so they are able to make educated decisions about their energy usage. Lighting and operation of blinds located in the air space of the double facade are also controlled through the automation system (Figure7).

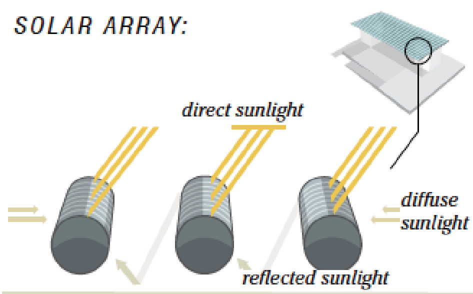

Figure 6 Diagram - Sylindra PV system

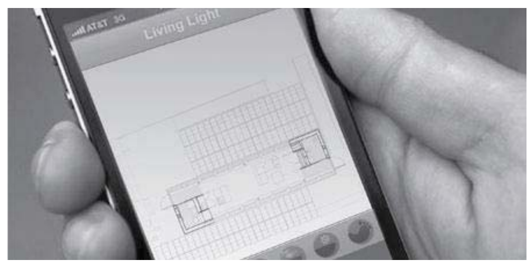

Figure 7 Home Automation System Interface

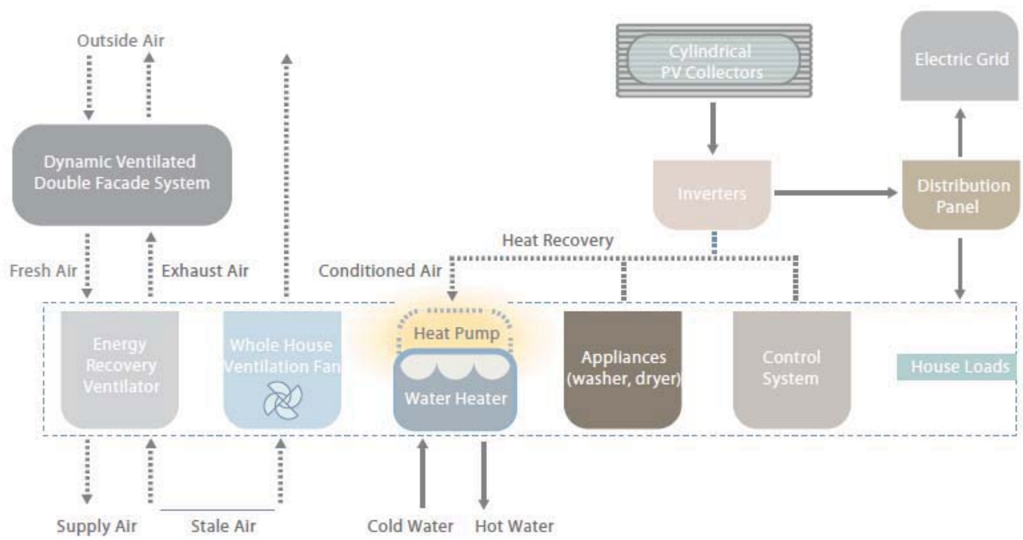

Figure 7 The mechanical room centralizes all of the mechanical, electrical, and plumbing systems.

3.0 Illumination

Control of both of natural and artificial light is incorporated into the facades. Daylight is controlled through motorized 2" Somfy blinds mounted between the inner and outer layers of both long facades. These blinds may be adjusted directly by the occupant through the mobile touch pad interface, programmed to follow a schedule, or set to maintain a preset illumination level. The blinds are divided into five-foot units on the module of the exterior layer of the façade and can be controlled simultaneously or in groups. In order that both natural and artificial light come from the outside walls, electric light sources are built into a strip at the floor and ceiling just inside the inner façade.

Figure 8 The lighting can be easily adjusted to pre-set 'moods' from the home automation system. The dinner party mood is illustrated in the interior view to the left. The LED lighting strips help create a unique and memorable ambiance.

Figure 9 LED lights arranged in strips embedded in the floor vary in color and intensity. All light coves and luminaires change colors from a "warm" 2700 k to neutral 4000 k and daylight 5400 k. This allows different lighting actions in different areas, taking care of physiological and psychological needs. For example: Bedroom lighting is activated when the alarm clock sounds.

The ceiling strip lights are high efficiency linear fluorescents with step dimming to provide general, ambient illumination. The floor lights are three-color strip LED fixtures mounted beneath textured and tempered glass panes. The floor mounted LEDs are capable of producing warm white or a full spectrum of colors and can be controlled independently or in groups. The blinds and lighting are linked to the central home automation system. The full functionality of all systems is available to the occupant directly through the mobile touch pad interface or pre-programmed 'moods' may be selected. For instance, setting the *dinner party* 'mood' sets the blinds to open, turns on the LED spot over the dinner table, selects dim warm white floor illumination and edge-lights the canopy over the front door (Figure 8/9). Selecting the *bedtime* 'mood' closes the blinds, turns on a dim night-light in the bathroom, and awakens the occupant at the pre-set time with gently increasing sunrise hues in the floor lights.

Construction

Although novel in approach and form, the double façade system is assembled from standard components. The LivingLight team worked closely with manufacturers to make the best use of their existing product lines. The aluminum framing systems for the inner and outer layers of the façade were selected to optimize performance and economy for their particular functions. The outer layer is framed with Kawneer TriFab VG 451 components with concealed vertical mullions.

Figure 10 Section through the south façade from BIM model Figure 6 Façade elevation

In keeping with the function of the outer layer as air barrier and heat reflector, its framing system is not thermally broken and its 9/16” laminated glass from AGC has low-e hard-coating facing the interior of the façade cavity. In contrast, the inner layer is the primary insulating system. It makes use of thermally broken Kawneer 7500 series curtain wall components and 2” insulated glazed units from Serious Materials. The IGUs are made up of two panes of ¼” tempered glass sourced from AGC with two additional internal films and are filled with argon gas for an R-value of 11 (Figure 10).

The primary reason that storefront and curtainwall systems were chosen for this project was their relative ease of customization. These systems allow for facades to be tuned to exact energy efficiency, privacy, and operability requirements. The inner layer of the LivingLight façade incorporates operable thermally broken ISOWEB casement windows, translucent and transparent insulated glazed units, and white oak veneered mullion caps. Additionally, aluminum framing systems lend themselves to retrofit applications and greater ease of maintenance. In the LivingLight house, the layers of the façade are structurally independent of one another with the outer layer being exterior glazed and the inner layer being interior glazed. This allows for the replacement of damaged glass from either side and opens up exciting possibilities for adding a second façade layer to existing buildings with minimal impact on structure or tenants.

4.0 The Dynamic Double Façade

The Living Light house makes extensive use of glass for transparency, daylighting, and spatial connection to the surrounding environment. A dynamic double façade system, made up of suspended film, highly insulated (R-11) interior glass and single-pane exterior glass, is implemented along the majority of the north and south facades of the home. Alternating translucent and transparent panes allow for views of the landscape while maintaining a sense of privacy for the occupant.

The north and south facades become the stage upon which the building comes to life. Sandwiched between the two panes of glass is a motorized horizontal blind system which blocks solar radiation, or sunlight, before it reaches the conditioned space. The blind system is programmed to provide proper lighting and shading throughout the year. It also provides more privacy when desired. The cavity within the system is also integral to the mechanical system of the home.
Development of the energy efficiency measures of the double façade required research into four key areas:

- Heat gain in the facade cavity
- Location and type of blinds
- Design of shading overhang
- Integration with ventilation and HVAC

The double façade was designed based on data from both predictive modeling and a constructed prototype. Based on ISO standard 15099, students and faculty developed a code to model heat transfer coefficient and solar heat gain coefficient in the façade. In addition, the WINDOW program (version 6.3.19) created by Lawrence Berkeley National Lab (LBNL) was used to benchmark the new code for SHGC. At normal incidence, WINDOWS predicts a SHGC of 0.70 as compared to the derived number of 0.697. Hence students developed a working code capable of predicting the radiation, convection and conduction occurring in multiple-pane windows (Figure 11).

Category	Modeling Tool(s)
Envelope/Heating and Cooling Loads	EnergyPlus
Double Glass Façade	Analytical Computer Code, COMSOL 4.0a, EnergyPlus
Photovoltaic Power Production	Solyndra Energy Yield Forecast Tool
Appliance and Misc. Electric Load Consumption	Excel
Roof Loads	STAR

Figure 11 Energy Modeling Software

A physical prototype was constructed with south-facing glazing configured in both single and double facades. Both were monitored with thermocouples to measure the temperature gradients between the inner and outer glass surfaces and the air temperature distribution inside the double façade air cavity. Thermocouples were also used to record the exterior and interior temperatures and pyranometers were used to measure the vertical and horizontal solar irradiance incident on the south facing façade. The data shows that for a summer day with strong solar irradiance, the air temperature in the façade air cavity will experience a 10°C temperature gain, under natural convection. In the winter the air cavity showed a 15°C temperature gain due to natural convection (Figure 12).

From this data it was determined that a strategy of exhausting the cavity in summer and admitting the warmed air in winter was feasible. Additionally, it was determined that the inner layer of the façade would need to be substantially insulated. The data suggests areas of future study in the areas of variable blind systems incorporating reflective ad low-emittance coatings.

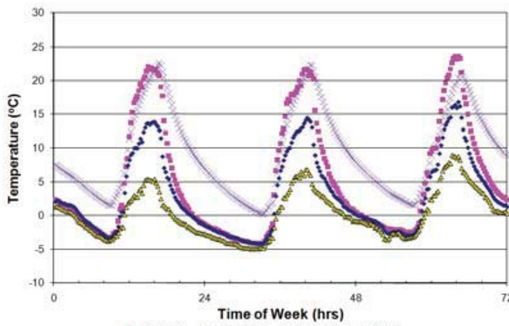

Figure 12 Winter façade cavity temperatures

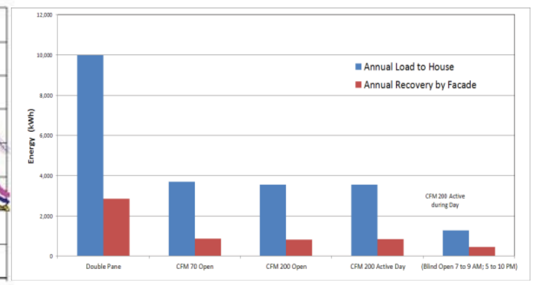

Figure 13 Optimal façade configurations and energy balance

A model of the LivingLight house was created with EnergyPlus software. The model was first run to simulate performance over a full year with a standard window of double pane glass as control and compared to multiple runs with the double façade in varying configurations of cavity airflow and blinds. The optimum configuration was achieved with the cavity ventilation at 200 cfm (set by the Energy Recovery Ventilator) during daylight hours only with the blinds open from 8 AM to 10 AM and 5 PM to 10 PM only. This scenario seems to track well with actual occupancy of the home and yields a 90% reduction in house load comparable to the control case (Figure 13). All models predict some condensation forming on the exterior façade in the early morning hours.

Simulations were created using EnergyPlus software to model the effect of thermal loading on the façade with blinds in the cavity, inside the conditioned space, and without blinds. Contributing interior loads were calculated based on the Building America (BA) Research Benchmark Definition. It is important to note that the software was unable to calculate the active airflow of the unique double façade therefore the model introduces some error by approximating performance with an unventilated cavity. Even so, the study proved that blinds exterior to the conditioned space reduced the cooling energy by 47.4%. Placing the blinds in the cavity allows for the best performance between summer and winter conditions (Figure 14). The heat radiated to the cavity by the black blinds can be scavenged in winter and exhausted to the exterior in summer.

Energy Plus Results	Max Heating Load (Btu/hr)	Total Heating Energy (kBtu)	Max Cooling Load (tons)	% Difference in Max Cooling Load	**Total Cooling Energy (ton-hrs)**	**% Difference in Cooling Energy**
No Shading	15,656	16,003	2.24	0	**3,231**	**0**
Interior Shading	16,662	17,399	2.39	+6.7%	**3,365**	**+3.8%**
Exterior Shading	15,419	16,185	1.26	-43.8%	**1,700**	**-47.4%**

Figure 14 Blinds analysis results

In addition to studying the blinds, the EnergyPlus model was used to predict the effect of horizontal shading on the south façade. The analysis was run with no overhang and again with an overhang of 50% transmittance. The model overhang was based on the LivingLight house's cylindrical CIGS-based photovoltaic panels with a horizontal projection optimized to block summer sun and allow lower angle winter sun. The benefit of the shading provided by the overhang is an additional 18% reduction in cooling energy (Figure 15). [1]

	Max Cooling Load (tons)	Total Cooling Energy (ton-hrs)
No Overhang	2.69	3,940
PV Overhang (50% transmittance)	2.24	3,231
Percent Difference (%)	16.7%	18%

Figure 15 Shading overhang analysis results

The Living Light house uses a dynamic envelope strategy utilizing an ERV (Energy Recovery Ventilator) and passive solar heating from the double glass façade. The home automation and control system allows easy control of the three ventilation schemes including heating, cooling, and whole house ventilation.

In the cooling mode, fresh air will be introduced to the space through the north façade and the relatively cool air will then exchange heat in the ERV with the stale air being exhausted through the south façade, thus cooling the cavity (Figure 11). In the heating mode, the air flows through the façade cavities will reverse (Figure 12). Solar irradiance will heat the south façade cavity so that fresh air pulled through it will increase in temperature. Stale air will be exhausted through the north façade, heating the cavity, which helps to buffer any additional heat losses. The heating and cooling modes of operation are depicted below.

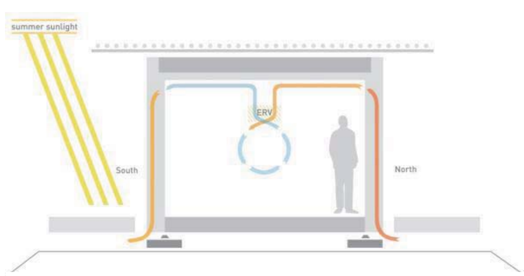

Figure 11 Summer cooling mode showing ventilation through the double façade.

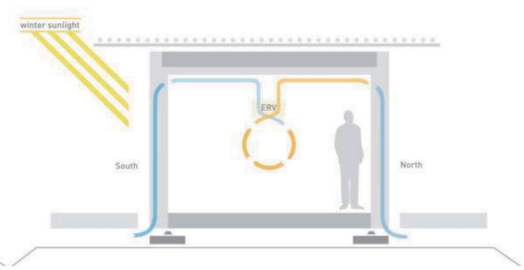

Figure 12 Winter heating mode showing ventilation through the double façade.

The whole house ventilation scheme takes advantage of favorable outdoor conditions during which temperatures are between 60 and 76 °F with relative humidity near 50%. This comprises 25% of the year in Southern Appalachia and is comparable to weather patterns in the competition city of Washington D.C. When these conditions arise, the automation system alerts the occupants that whole house ventilation is an energy saving strategy. Should the occupant wish to use this setting, they may select it and open the operable windows of the north façade to bring in the cooler fresh air while keeping the south windows shut to reduce heat gain. This setting will turn off the mini-splits and allow a small duct fan to ventilate the entire house. About 70 kWh of cooling energy, about 6%, can be saved using this mode.

This is an important feature of the Living Light house as it demonstrates the possible energy savings in buildings with inefficient cooling systems. It was expected that this system would save more energy but because of the efficiency of the mini-splits, the savings of this system were reduced. [2]

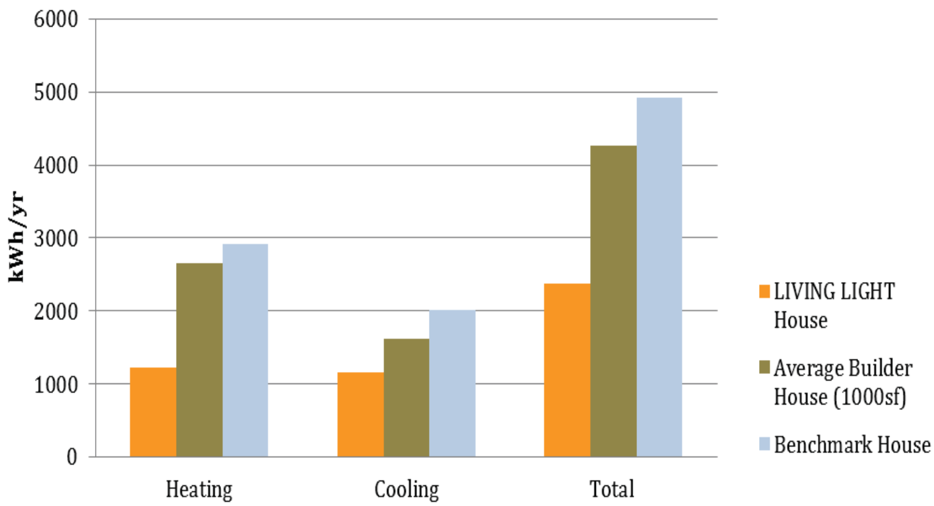

Figure 13 Heating and cooling comparison

The energy recovery ventilator (ERV) is used to ventilate while minimizing energy loss in the Living Light house. The ERV exchanges sensible and latent heat between fresh and stale (exhaust) air streams. When the outside temperature is relatively low, the ERV pre-heats and adds humidity to the incoming fresh air. In the summer months or when the temperature is relatively high outside, the ERV pre-cools and dehumidifies the incoming fresh air. The utilization of the ERV in the Living Light HVAC system helps to reduce heating and cooling costs normally associated with bringing in fresh, outdoor air (Figure 13).

5.0 Future research

The LivingLight house is currently touring cities in the region as an outreach, education, and engagement tool for sustainability and energy efficient building technologies. After the tour, the LivingLight team has plans to monitor the home's performance through an embedded sensor suite and weather station. With a year's data in hand, the home will serve as an experiment station for modifications to optimize its performance. A few intriguing lines of research already identified by the team include:

- Studies of the psychological benefits of natural daylighting, variable daylight spectrum LED lighting and biophilia (instinctive positive response to natural materials) in residential environments
- Further net reduction in energy required to heat and cool the home by increasing the airflow through the façade ventilation system
- Methods to eliminate early morning condensation on the outer façade including short periods of reversed ventilation cycle
- Development of new blind materials to variably augment either emissivity or insulation in the façade cavity

CONCLUSION

The value of the LivingLight project can be positively measured on three scales. First, as proof of concept for an innovative double façade system, the house has demonstrated a new technology that is functional, robust, aesthetically integral, and scalable. Second, as a pedagogical tool, the project has created a multidisciplinary platform for the collaboration of multiple departments and opportunities for students to gain hands-on experience with emerging building technologies.[3] Third, the LivingLight house proved to be a strong competitor in the 2011 Solar Decathlon. In addition to securing team standing with its first ever proposal, the house ranked first in Energy Balance, third in Engineering, fifth in Architecture, and eighth overall. [4]

Figure 14 Exterior

Figure 15 Visitors Touring the Living Light House

ENDNOTES

[1] Synopsis of post-competition Mechanical Engineering Final Report compiled by graduate students Steven Coley, Matthew Berwind, Isaac Bosley, and professors William S. Johnson and William S. Miller of the Department of Mechanical, Aerospace, and Biomedical Engineering. Report submitted to DOE and NREL October 24, 2011.

[2] Coley, S. 2012. Symposium Presentation, "University of Tennessee's Living Light House, the Design and Analysis of a Net Zero Energy Home for the 2011 Solar Decathlon," presented at the ASHRAE 2012 Annual Meeting, Chicago, Ill.

[3] E. Stach, J. Rose, A. Howard, "UT Zero Energy House - Sustainable Design-Build as a Teaching Tool", Purdue University, Ray W. Herrick Laboratories, 2010 Purdue Compressor Engineering, Refrigeration, Air Conditioning and High Performance Buildings Conference, 7/2010

[4] Solar Decathlon website, Official Scores and Standings, www.solardecathlon.gov.

How Space Augments the Social Structures of Innovation

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ABSTRACT: Research on the enabling factors of innovation has focused on either the social component of organizations or on the spatial dimensions involved in the innovation process. But few have examined the aggregate consequences of the link from spatial layout to social networks to innovation.
Preliminary results from this NSF sponsored research were presented at ARCC 2012. The research explores how spatial layout and social networks promote innovation among professionals working in different research-intensive organizations. The associations between innovation within these organizations and the organization's social and spatial structure are investigated. This paper presents results for one of our partner organizations, an international automobile manufacturer.
The study applies spatial analysis to map and characterize physical space and sociometric surveys to capture contacts among employees. For the automobile manufacturer, we were able to augment these tools with location tracking methods. Our use of the UWB location system, allowed us to assess contact networks in real time.
Social networks play important roles in structuring communication, collaboration, access to knowledge, and knowledge transformation. These processes are both antecedent to and part of the innovation process. Spatial layout structures patterns of circulation, proximity, awareness of others, and encounter in an organization. These interrelationships become fundamental to the development of social networks, especially those networks critical to the innovation process. We hypothesize that network positions and office locations influence workers' ability to prospect for new ideas and mobilize the resources and attention necessary to implement those ideas, both critical ingredients to innovation.
Results demonstrate the salience of both social and spatial dimensions in the processes of innovation. Our findings indicate that relationships between salutary network positions and beneficial locales themselves derive from institutional contexts that shape the priorities, opportunities, goals and practices of discovery. Thus, we suggest that innovation is a process that occurs at the intersection of social and physical space, and moves toward a socio-spatial science of design for innovation.

KEYWORDS: organization theory, innovation, spatial analysis, workspace design

INTRODUCTION

Research on the enabling factors of innovation has most often addressed either the social component of organizations or the spatial dimensions involved in the innovation process. This research bridges disparate disciplines, and their respective bodies of knowledge, to explore the social dimensions of innovation as they are embedded in a specific spatial milieu.

The research[1] focuses on three organizations: a non-profit life sciences institute dedicated to translational research on cancer, the research labs of a multinational software corporation, and the quality control group of an automobile manufacturer. The associations between innovation within these organizations and the organization's social and spatial structure are investigated. This paper presents results for one of our partner organizations, the automobile manufacturer.
A core premise of our research is that spatial layout structures patterns of circulation, proximity, awareness of others, and encounter in organizations. These interrelationships become fundamental to the development of social networks, especially those networks critical to the innovation process. It is therefore essential that we gain a fine-grained understanding of how different types of spatial layouts, such as the ones in our diverse set of organizational partners, influence the structure of formal and informal communication between organizational actors, and ultimately innovation outcomes.

Methods of space syntax are used to map and characterize physical space and sociometric surveys are administered to capture contacts among employees. For our partner organization, the automobile manufacturer, we were able to augment these tools with location tracking methods. It could be argued that sociometric surveys capture the 'perceived' social network. Social networks researchers have been very interested in assessing 'real' networks either as reliability checks on sociometric survey networks, or as stand-alone networks. Our use of the UWB location system, allowed us to assess networks in real time.
In this research, we hypothesize that network positions and office locations influence workers' ability to prospect for new ideas and mobilize the resources and attention necessary to implement those ideas, both critical ingredients to innovation. In particular, the spatial measures of proximity (*mean distance*) and movement choice (*metric choice*), and the social network measures of *betweenness* and *degree*, are examined to understand their influence on the processes of innovation.

1.0 BACKGROUND

1.1 Social network
Most networks-based analyses of social factors related to innovation have focused on the relationship between various aspects of an actor's network position and either performance (Burt, 1987), social capital (Burt, 1987, 2000), or innovation involvement (Ibarra, 1993). Innovation has been understood as being manifest in two stages: the invention or creation stage, and the adoption or diffusion stage.
Social networks are dichotomized as sparse (brokerage) or dense (closure) depending on the density of ties between actors. Brokerage networks are commonly perceived as providing actors with advantages in the generation of good ideas (Burt, 2004a; Obstfeld, 2005) while closure networks are seen as essential to the promotion of good ideas (Obstfeld, 2005). While most networks research has categorized brokerage and closure networks as polar opposites on a continuum, more recent research suggests that the two networks are discrete phenomena, and that both are critical for the successful generation of innovations (Burt, 2004b; Reagans and Zuckerman, 2001).
A fundamental assumption of our approach is that innovation is a process that is stimulated by new ideas (or new applications of existing ideas) but also depends upon a continuous process of communication to move an idea to implementation. We expect that these links will be manifest in the organization's social structure as we examine individual level innovation.

1.2 Spatial layout
Although we acknowledge that there are many forms of communication, this research focuses on face-to-face communication. Research suggests that there appear to be few substitutes for face-to-face interactions in knowledge intensive work. As physical distance increases, the likelihood of collaboration decreases (Olson and Olson, 2000). Olson et al. (2002) report that radical collocation doubled the productivity of software engineers by increasing the team's ability to monitor and learn from one another's work. Early studies exploring the link between space and work processes focused on the effects of linear or geometric distance on processes such as communication. Allen (1977) showed that the probability of communication between engineers dropped precipitously at the 30 meter mark. Allen's work was also seminal in suggesting that other physical aspects of the pathway between individuals, such as doorways and stairs (barriers) or turns in the corridor (topologic characteristics), extended perceived 'distance'.

The importance of proximity is not limited to one's local work group. As Allen indicates from his studies of engineers, the most powerful ideas were reported to develop not from communication within the workgroup, but through communication beyond the workgroup with others in the organization.

Innovation research has been rigorous in its treatment of the various aspects of the social dimension of innovation, but much less so the spatial dimension. The techniques for the analysis of spatial form or "space syntax analysis", developed by Bill Hillier and his colleagues at University College London (Hillier & Hanson, 1984), provided some researchers with rigorous methods of measuring both global and local spatial network characteristics and relationships between them (Peponis and Wineman, 2002). Principles of spatial organization affect the generation and distribution of movement patterns in space, space use, and the ways in which occupants encounter others in space (Penn et al., 1999).
In exploring how spatial layouts connect individuals across the organization, it becomes clear that particular layouts of offices and corridors may cluster movement locally or enhance global movement. Similarly layout patterns may concentrate movement along few pathways or distribute movement across multiple access routes. Such spatial patterns affect how individuals come into contact with others in the organization and create opportunities for the serendipitous encounters promoted by Peters and Waterman (1981). Recent studies have shown associations between spatial layout and innovation/productivity work outcomes (Peponis et al., 2007; Wineman et al., 2009).

Our efforts to explain individual level innovation in organizations thus emphasize two key points in the discovery process: the ability to access new ideas via conscious search or serendipity, *prospecting,* and the ability to enroll colleagues' support and attention in order to validate those ideas, or *mobilizing.* In very general terms, we expect people with greater access to more varied sources of knowledge and those who are better positioned to sway others to the cause of their ideas to be more successful innovators than colleagues with limited access to diverse perspectives or lesser claims on their co-workers' attention.

2.0 METHODOLOGY

For our study of the automobile manufacturer, we collected survey data on social network relations, applied spatial analysis approaches to understand spatial layout characteristics, and also gathered location tracking data. The relative contributions of these measures were then examined to predict our innovation outcome measures.

2.1 Sample selection

The automobile manufacturer study group worked in collaborative teams and consulted with other units within the international organization. The group was comprised of 24 professionals occupying one floor of a multi-floor office building on a larger campus of the organization's buildings. Managers are housed in closed perimeter offices, non-managers occupy partitioned offices.

2.2 Measures of innovation

Our approach to the development of innovation measures has been predicated on the premise that, rather than attempt to identify a measure or set of measures for all organizations, it would be more prudent to find innovation outcomes that are most pertinent to each organization. Using data from manager interviews, we have identified target innovation measures as follows.
Innovation for the automobile manufacturer focused on team projects. One distinguishing feature about this organization is that it is exceedingly difficult if not impossible to parse out a given individual's contribution to the organization's project(s), given that work and innovation are heavily structure around work groups or teams. Therefore, there were no ready-made innovation outcome measures that allowed us to assess individual innovativeness.

For the automobile manufacturing company (AM), organizational administrators provided us with a list of recent/ongoing innovative projects. Since we had a much smaller data set and many individuals participated in only one project, our innovation measure was a binary variable that represented participation or no participation in these creative projects.

2.3 Social network survey

All professional personnel in our study group were asked to complete a sociometric survey. This survey collected data on the nature of the relations between the professional colleagues in the group (unit) in our study. Network models reflect responses to the question: About how often do you have discussions with this person in order to get your work done?
The social network variables used in this study are *degree* (number of communication links) and *betweenness* (how often you are likely on the shortest path between others in the network). *Closeness* (social distance from others) was highly correlated with the other two variables, so we removed this variable from our analysis.

2.4 Spatial layout characteristics

The spatial variables used in this study to characterize spatial layout are *mean distance* (a measure of the mean metric distance between an individual's workstation and all other professional employees' workstations within the study unit) and *metric choice*. The variable *metric choice* represents the extent to which an individual's workstation is on or near spaces that are on the shortest path (based on metric distance) when moving from all professionals' workstations (within the study unit) to all others.

2.5 Location tracking

As mentioned above, we were able to collect movement tracking data at AM. Movement tracking entailed the use of a non-intrusive ultra-wideband (UWB) location system to track participants (on a volunteer basis) at the research project site. Tracking enabled us to accurately map patterns of spatial use and real-time social interactions.
UWB technology has accuracy advantages over rival systems when it comes to indoor tracking. The accuracy advantage is not insignificant as it allowed us to track people to within 12-24" locational accuracy.

The system allowed us to tag and categorize certain kinds of events, such as the 'interaction' event described below and have them stored in a separate database for our analysis. For example, we specified that each time certain tags (representing different actors) were within a certain distance of each other for a minimum period of time or longer, that this be tagged as an interaction event. Further, we could then categorize these events by the type of space where the interaction took place e.g. hallways and other circulation spaces, coffee/break rooms, workspaces, etc.
Each participant in the study wore a tag with a unique identifier during working hours for the study period. Tracking was conducted at AM over a nine week period September-November, 2009.
Social networks were then constructed based on our real-time communication data. On average a pair of respondents had 13 conversations during the nine week tracking period. This suggests a similar pattern to the sociometric responses of 'several times a week or more'. However, it is acknowledged that these two definitions may be capturing different numbers/kinds of interactions. Results for AM will be presented for data from both the sociometric survey and location tracking.

3.0 FINDINGS

An initial analysis was conducted to examine correlations between the social network constructed from sociometric data and that constructed from our location tracking data. The reported strength of a tie (sociometric survey) was strongly correlated with interaction frequency (location tracking) between dyadic contacts (r^2 = 0.455, p<0.001 n=435). However, the sociometric network diverged in its ability to capture the centrality of respondents as compared to the data derived through location tracking (Degree: β=-0.000, p=0.998, Closeness: β=0.222, p=0.239, Betweenness: β=-0.169, p=0.373, Eigenvector Centrality: β=0.174, p=0.357). The sociometric model built on the basis of location tracking provided stronger results than the model constructed from survey data. Therefore, for this analysis we will be summarizing results from the location tracking model (although results for both models are presented in Table 1).

Logistic regression was applied to examine the contributions of social network power (*betweenness)* and prominence (*degree)*, and relative spatial location, as measured by the variables *mean distance* and *metric choice*, to our outcome variable, innovation. Initially models included managers and non-manager professionals.

For this and other sites, variables became significant when managers were excluded from subsequent analysis. Managers are likely to have job-associated functions that bring them into contact with others across the organization, and are therefore less reliant on the effects of spatial layout. In addition to looking at only one job type, non-manager professionals, the control variable *distance to coffee bar* (CafeDist) was also included in our analysis.

Findings suggest individual contributions of spatial measures and social network measures to innovation outcomes (see Table 1).

Table 1: Logit regression analysis

	AM	**AM**
D.V.	Innovation Involvement	Innovation Involvement
Regression Model	Logit	Logit
Observations	23	23
Data Collection	Location Tracking	Sociometric Survey
Independent Var.	**B (p-value)**	**B (p-value)**
MetChoice	8.192 (0.018)*	2.944 (0.194)
MeanDist	10.721 (0.019)*	5.205 (0.083)+
Deg	-2.716 (0.065)+	1.322 (0.153)
Bet	5.540 (0.075)+	0.962 (0.661)
Controls	**CafeDist** -5.634 (0.038)*	**CafeDist** -3.620 (0.057)+

Notes: +p<0.1;*p<.05; **p<0.01; ***p<0.001

Spatial variables *metric choice* and *mean distance* were found to consistently contribute significant elements to the model for innovation. For AM whose production depends on innovative projects, individuals who have easy access to spaces that are likely to attract and channel movement (spaces that individuals from various locations in the building choose to move through or ‘high *metric choice* spaces’) have a higher likelihood of innovation (MetChoice: B=8.192, p=.018). Spatially, high movement spaces create opportunities for serendipitous encounters that support the activity of *prospecting* for new ideas.
The second spatial layout variable we explored was *mean distance* from an individual to all other professionals in the study unit. For AM, where the study unit was located on one floor of a multi-floor building, a person whose office location was more distant to all others (low access) would be more likely to be a participant in innovative projects (MeanDist: B=10.721, p=.019). It is suggested that in organizations, where being adjacent to high movement corridors is potentially valuable to innovation, the opposite is true for mean distance to others.

Results for the association between the social measures (*degree* and *betweenness*) and innovation were also significant. For the automobile manufacturer (AM), a higher number of conversation partners (degree) was associated with lower innovation (Deg: B=-2.716, p=.065). This relationship seems to follow a similar pattern to the spatial variable mean distance (as discussed above). For AM, high betweenness was associated with higher innovation (Bet: B=-5.540, p=.075).

Results suggest that for the spatial measures, organizations appear to depend upon either *metric choice* or *mean distance* to bring professionals into contact with others. For AM, innovation is higher for professionals whose offices locations are close to high use spaces with lower access to others.

CONCLUSIONS

First and foremost we have found that spatial variables matter to innovation. The spatial variable *metric choice* is a significant and positive influence on innovation for AM. The second spatial variable *mean distance* was also found to be a significant contributing factor for innovation. For AM, greater distance to others (low access) supported innovation.

In interpreting our results it is informative to refer to the recent work of Obstfeld (2005) who suggests that while much of the social network literature focuses on strategic network positions that allow an individual to prospect for new ideas (sparse networks and structural holes), these network locations are less supportive of activities such as the mobilization of resources that are necessary to bring an idea to fruition. Obstfeld’s research indicates that enhancing connections between individuals (higher density networks) enables the assembly of resources associated with innovation.

We propose that, through exposure to moving others, locations with high *metric choice* may provide the opportunities for serendipitous encounters among individuals who may come from disparate parts of an organization (prospect for new ideas); whereas low *mean distance* to others may provide the enhanced connections necessary to mobilize the resources and attention to move innovative ideas forward. These dual functions of spatial network relations can suggest insights into the interpretation of our research results.

AM is an organization focused on innovative *project* outcomes. These projects bring diverse professionals together to create new processes and products. Individuals are more successful if they are spatially situated to maximize opportunities to prospect for new ideas. Workspaces should be designed such that circulation and social spaces concentrate activity and enhance the likelihood that professionals from across the organization will encounter one another (high *metric choice*). We see a similar effect in the social network. More productive social locations are those on the shortest links between all other professionals (high *betweenness*).

Professionals benefit from spatial locations that are more separated from others (high *mean distance*). This may also be a function of the size of this work unit and their location on one floor of a single building. Professionals are likely to know everyone and therefore be less dependent on spatial support for promotion of innovative ideas. Similarly for the social network, individuals with fewer social ties (low *degree*) have higher innovation. Socially for AM, it is less important how many people you know, but how you are situated to access new ideas.

To summarize, results demonstrate the salience of both social and spatial dimensions in the processes of innovation. Thus, we suggest that innovation is a process that occurs at the intersection of social and physical space, and moves toward a socio-spatial science of design for innovation.

As foundational work, the limitations to this research are many. Future studies will benefit from larger sample sizes and exploring organizational contexts and innovative outcomes in more controlled settings. It would also be useful to extend the contact networks to reflect other modes of communication, such as email. Results from the further development of this work will provide guidance for institutions in creating environments and organizational contexts that enhance the processes of discovery.

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POSTER PROJECT ABSTRACTS

Making as Methodology: Digital Design + Build Studio on the Atlanta Beltline

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ABSTRACT: The gap between the description of a thing and the thing itself has been the subject of inquiry dating back to the Platonic construct of the Ideal. In today's construction industry, this gap could also be understood in terms of the relationship between the design representations of the architect and the material constructs of the builder during the actualization phase: the act of translation from drawing to building. The traditional process of interpreting design intent into constructible form has long been established through the system of shop drawings, submittals and specifications. This process of interpretation and translation is a contested space riddled with perceived limitations, miscommunications, and ambiguities. It also represents a vast territory for research in light of the computational tools and technologies such as Building Information Modeling (BIM) and Computer Numerically Controlled (CNC) equipment that have emerged both in practice and academia. These tools are transforming the Architecture, Engineering, and Construction (AEC) industry and are creating new opportunities to increase creativity, quality, and efficiency in the built environment via shared representational frameworks, process protocols, and material implementations.

This poster will serve as a case study for a recent digital design + build studio in the CENSORED which engaged with the issues described above. This vertical studio was composed of graduate and undergraduate students who worked with the Atlanta Beltline Inc (the agency responsible for the design and implementation of Atlanta's new 22-mile transit corridor) to design, engineer, construct and install three full-scale structures that were parametrically design, digitally fabricated, and built from low-grade wood; all by the students. The projects each created a threshold condition on the Beltline marking a point of transition from one section of the corridor to the next, as well as created a unique tectonic construct made from very humble sustainable construction materials that underwent a type of digital alchemy in the way in which they were configured, detailed, manufactured and assembled. The students were required to take a project from 'concept to construct' in the span of a single semester. Each team moved quickly through the traditional design phases of site analysis, programming, and concept design and into design development and construction drawings with detailed shop drawings and digital cut files for a 5-Axis CNC router. The structures where then digitally fabricated in the CENSORED and assembled and load tested on site before being inspected and approved by the Atlanta Beltline Inc officials. These structures were all designed to be safe, stable structures within a very demanding public environment and all three structures performed well.

In structuring the pedagogy with such a strong emphasis on real construction materials, structural requirements, design detailing, logistics and assembly the students gained an extraordinary amount of experience and understanding for the art of building. The studio platform required the students to consider the material logic and construction process as integral to the design process rather than as an afterthought left to the engineer or builder.

Place as Scaffolding: Temporary Visibility / Permanent Imprint

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ABSTRACT: Every part of the world can be identified by the design and construction methods, developed over decades by its inhabitants in order to suit their place of belonging. These methods, in a sense, are taken as 'local', or vernacular to that place, culture and community. However, one construction technique remains unvernacularized, a method common to all human design and building processes throughout the entire world: scaffolding. With its analysis, one can start to understand how the purity of a skeleton built as architectural armature may have defined places, however temporary or 'invisible' the structure was. Scaffolding has always been an internationalized vessel, which brings infinite architectural possibilities to many parts of the world and, acting much like an imprint, leaving traces of its presence behind.

However, unlike the vernacular, the contemporary international style of architecture is undefined, yet quickly progressing. As the vernacular method begs for local materials, the contemporary style of architecture seen internationally tends to trade details made through local construction for the practicality and affordability of pre-fabricated parts. The scaffolding method, as place-maker in architecture for its interaction with permanent buildings and the process of making, has an intricate role and a legacy attached to these changes. Inferring that one could define the vernacular as permanent and the international as temporary, this research proposes that, to bridge the gap between vernacular and international architecture, scaffolding can be analyzed as metaphor between permanent and temporary architecture.

The research proposes a framework defined by the characteristics of tectonics, boundaries, and transition – these notions then are developed within three major relationship groups: cultural, spatial and material. Case studies such as inherited environments, vernacular methods and structural concepts provide specific, tangible details and the framework compares objects, interprets similarities, and extrapolates an architectural response implied by the historical evidence.

The objects analyzed are photographs and graphic representations of the exemplified case studies, images which become vessels for the understanding of cultural influence in architectural technique, and the comparison of scaffolding to the ways in which design is structured. As objects of analysis, they enlighten aspects of cultural influence, colonial and civil impacts, geographic characteristics, and so on – all factors which are influence to the legacy of scaffold in the architecture that followed, and made visible by the way it is build, used or represented.

Just as vernacular architecture differs from international style, and temporary visibility speaks to permanent imprint, in seemingly opposition there is a correlation between them embedded in the method of scaffolding. Our design thinking as architects can also be compared to scaffold itself - how do we as designers construct our thoughts, what is our own form of ‘bracing’? And if there is one, should it be made visible? Parallel to the concept of ‘temporary architecture’, scaffolding begs the question of whether or not the real permanence of architecture is in the deconstructed, the thorn-down, the non-solid; this poster explores the idea that buildings are reflections from the scaffolding with which they were erected.

Assembling Appalachia

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ABSTRACT: Assembling Appalachia is a research project that considers the interplay between text and image as a form of the production of knowledge. This poster and associated text recognize and seek to expand on the potential for images to propose new structures and points of access for research practices, allowing images to be integral to research, and not strictly the result of research. While recognizing the autonomy of the image, this work follows the philosophical position that works of art are their own forms of cognition and truth, and furthermore, are producers of context.

The images link themselves to the sense of some country undiscovered, and to something formerly hidden. Without revealing everything, they also sponsor an expansive dialogue. The work of Assembling Appalachia locates affinities through the range of media that fill out the cultural landscape of Appalachia, and grounds the work in a series of images that will become the reference through which the region is explored, and contemplated.

This poster presents a single image, caption, location of image, and supporting text in order to weave together and construct the context of a research project in its early stages. The work presented considers the ways in which images and text may be co-involved in the development and articulation of research agendas. This particular project advocates for the involvement of images, especially in the early stages of research to be significant contributions to the shift in perception that ideally accompanies any work of research. The project is fundamentally about creating the access to underlying orders and the opening and shifting of perception afforded by images, the making of images, and the questions that arise in this dialogue.

At this stage, the images fall into three categories: order, preconception, and contingency. It is through the relationships and overlaps of text and image that the complexity of discoveries that are to be found in the

region begin to be suggested. For example, the interplay between the single word, order, next to the title, the primitive hut, next to the image, a nylon and aluminum framed tent covering the trace of some gathering, suggests a way of seeing and thinking about the place that is at once specific and open. The photographic manifestation of the work finds a reference through the existence of traces, outcomes, and projections of architecture's participation in this contextual production.

The work advocates for the potential of visual research to contribute to the more broad discourse on architecture and culture, not standing in as props, or literally increasing the visibility of research per se, but of acknowledging that the multiple ways in which the complex and emerging patterns of culture may be understood, are in part at least, accessed through visual literacy and the models and modes of thinking that resonate with the activity of research itself.

Affordable Housing with SIPs - A Design-Build Project in Historical Frenchtown, Tallahassee, FL

Olivier Chamel
Florida Agricultural & Mechanical University School of Architecture, Tallahassee, FL

ABSTRACT: The SIPs house design presented herein is a Design-Build project initiated by the School of Architecture of Florida A&M University to draw attention to energy-efficient solutions for low-income housing. The goal of this project is to demonstrate the merits of using Structural Insulated Panels along with simple and efficient design concepts in the cost sensitive market of affordable housing.

The design presented responds to the requirements of an existing vacant site located in the Frenchtown District, a historical and low-income neighborhood in Tallahassee, Florida. This design-build project is being developed in partnership with the City of Tallahassee and the Frenchtown Community Development Center, a not for profit group involved in building affordable housing projects. The Frenchtown CDC is providing an existing site ready to receive the first house prototype. The design-build component of this project presents an opportunity for students and faculty to share design ideas and also physically participate in the construction of a house. The design featured on the poster only presents the design component of the overall project. The construction phase has not started as of yet.

The three-bedroom house sits on a 0.1 acre lot and features 1200 sf of conditioned space along with a single car garage. The main space combining living, dining and kitchen forms the core of the house and opens to a south-facing porch while the garage and bedrooms create a buffer to the west and north. The wrap-around porch while a historical feature of the Frenchtown District also helps shade the west façade.

Space planning strategies include maximizing open living spaces, reducing hallways and bedroom sizes while allowing adequate storage space. Sustainable features include increased insulation values (R20 walls, R38 roof) which made possible the installation of a smaller high-efficiency heat pump system. The southern exposure of all living spaces allows daylight harvesting with views to the outside. Our approach with regards to materials focused on issues such as recycled content (fiber cement siding), low VOCs (paint, formaldehyde free SIPs panels) and simple construction detailing (sealed concrete slab on grade).

This project will help illustrate the competitiveness of SIPs with regards to hard costs while accepted studies have demonstrated significant long-term savings due to lower energy consumption.

In addition to its flexibility and speed of installation SIPs panels provide a high quality building envelope which increases energy efficiency, indoor air quality and acoustical comfort. It also supports a variety of cost efficient exterior finishes requiring limited maintenance. As a consequence and as our cost analysis will show, building affordable housing with SIPs presents unique advantages especially when it comes to meeting the challenges posed by increasingly stringent energy code requirements associated with publicly funded housing programs.

Standard Visualizations of Architectural Concepts in Support of Architectural Education

Mark J. Clayton
Texas A&M University Department of Architecture, College Station, TX

ABSTRACT: Although Building Information Modeling (BIM) is widely accepted as a powerful tool for architectural production, explorations indicate that it can also be used to aid conceptual design by producing standard diagrams, drawings, and expository views. Students often struggle with how to present their architectural ideas, constraining the time available to explore alternatives and develop more complex ideas. Naïve presentations can often intrude upon recognition and assessment of complex and sophisticated ideas. BIM can be used to focus upon architectural issues by "factoring out" graphic arts issues that often confound the evaluation and assessment of architectural design quality.

Diagrams have been used at the beginning of design and after design. The concept of graphic thinking employs diagrams to isolate ideas and has been suggested as an essential part of design cognition. (Laseau 1989). Diagrams have been used to isolate concepts in the description of architecture, a "post-design" analytic function (Clark and Pause 2012). In the BIM-assisted process, the diagram is automatically generated simultaneously with architectural design, leaving the designer solely with the challenge of interpreting, understanding and assessing the diagram and ideas expressed in it. The research is a provocation to those who ascribe extreme importance to diagramming during an early conceptual phase of design. In this approach, the diagram is a mere by-product of explicit architectural thinking and modeling.

In this study, students in sophomore design studios were provided with template files created for Autodesk Revit BIM software to structure their production of printable sheets describing architectural designs. The technique relies upon parameters encoding concepts from architectural theory and standard visulizations. The students developed 3D models in the BIM environment and provided parameter values to express design intent. Although other parameters can be used, example parameters are shown in Table 1.

By applying room plans, area plans, filters to override default graphic qualities, and visibility graphics settings, the software isolates particular concepts and portrays them diagrammatically. As the student produces a design within the BIM environment, visualizations such as diagrams, plans, sections, elevations, perspectives and renderings are produced automatically or with a small amount of effort.

Thus far, the researchers have only devised the diagrams and templates and tested them in several design studios. The method is easy to use and effective in enabling all students to reach a similar high level of quality. The students are better able to focus their time and attention on architectural issues rather than drafting and graphic arts issues. Projects can be evaluated more objectively because the graphic design and drafting is held to a constant high quality, removing graphic design as a confounding variable in architectural design assessment.

Arguably the technique may act as a "crutch" that enables students to avoid thinking carefully to portray their design concepts. However, comparison of design ability of the students who use the technique versus students who use conventional techniques is confounded by too many factors to be achievable. Resolution of the conflicting viewpoints about this approach may only be achieved through many years of experimentation. Researchers at many schools could exchange templates and perhaps even build a standard template for portraying issues in architectural theory. The idea behind this research, that issues in architectural theory may be incorporated into a BIM and visualized automatically by software, may open a new and stimulating direction for further research.

Responsive City

Susannah Dickinson, David Gonzalez, Kyle Szostek
University of Arizona, Tucson, AZ

ABSTRACT: William Mitchell, in ‘E-topia’ wrote that because of the digital revolution of ‘bits’ traditional urban models were no longer valid. He defined the new urban condition as “lean, green cities that work smarter, not harder. Their basic design principles may be boiled down to five points … 1. Dematerialization, 2. Demobilization, 3. Mass customization, 4. Intelligent operation and 5. Soft transformation.” This poster shows the work of a student research proposal from the University of for a desert city set in the year 2087 that would incorporate Mitchell’s design criteria. The project, ‘Isomorphic City,’ develops a truly customizable and ever-adapting built environment which was shaped by environmental issues, virtual reality and social media. While conventional land use is rigid, the proposed relationship of physical and digital space allowed for a dynamic environment that could meet the direct needs of the inhabitants, in real-time, during the course of each day. ‘Programmable matter’ was utilized as the building block for the community, (digitally) creating form-finding aggregation. City dwellers would have direct control over the programmatic functions of their city while at the same time the environment would set parameters limiting the excessive and negligent use of resources. This allowed the city and its inhabitants to become symbiotic within the natural ecosystem of the desert. The vision predicted that digital designers, programmers, developers, architects, and environmental experts would constitute the main demographical work force required to maintain the city. “If you want adaptability, responsive software beats reconfigurable hardware…..it is no longer the architectural programmer who controls space use, and thereby expresses power; it is now the software programmer.” (William Mitchell, Me++: The Cyborg Self and the Networked City, 2003)

The design anticipated that a more advanced form of transportation would emerge for individual transportation. Traditional streets take up space and damage the environment. Roads within the ‘Isomorphic City’ would recalibrate and manifest as they were needed, and their matter would be repurposed when not in use. A Diffuse Limited Aggregation System (DLA) was used to digitally generate a new street grid for the centralized cores. The digital plaza, the new hub of the city, would allow for virtual and surrogate travel; eliminating the need to travel far distances by means of connecting a local space to a long distance digital space.

The poster discusses developments in digital methodologies that incorporate real-time, live data into the parametric model rather than using simulated datasets or archived data that most projects use to date. Form was the result of live information verses the making of form in an ‘object-like’ fashion. Going from a rule based way of simulating the complex urban condition to a more human agent-based approach based on collective data, which is more appropriate in our information age. “It is becoming increasingly necessary, and increasingly possible, for the form-maker to re-immerse himself in the form-giving dialogue.” (John Frazer, An Evolutionary Architecture, 1995)

A Platform for Architecture: Hacking the Franchise Landscape

Sara Dean
College for Creative Studies, Detroit, MI

ABSTRACT: The aesthetic of the franchise landscape is that of flatness, blankness, and horizontality. It is a surface logic; constructed of container structures, predictive repetition, asphalt, surfaces that are truckable or not truckable. Our experiences in this landscape are predictive. They are indifferent to geography, time and proximity.

Although this landscape has proliferated for half a century, I contend that it isn't until now, with the ubiquity of digital platform space, that we are able to respond to the franchise landscape as an architectural act with spatial logics of its own. The spatial apparency of this landscape, and the design potentials of predictable, repeating systems, can be found in its digital counterpart.

Aggregate platforms encompass our digital experiences. Aggregate platforms do not produce content; they are systems for receiving and directing content. The architecture of these systems is their mode of operating, apathetic to scale, program or subject. As a physical counterpart, the franchise landscape can be seen as a similar set of priorities. One-of-a-kind design, icon architecture or monumental acts disappear in a space designed to valorize temporality, accumulation and flexibility.

Digital aggregate platforms make their operations apparent. They broadcast their system logics through related content, trends, views, likes and dislikes. And the apparency of the system leaves them open for opportunistic intervention. To engage architecturally with the franchise landscape, we must similarly take on an aesthetic apparency, using the visual language and cues of the system as our design tools. In a system that neutralizes content and variation, the most potent tools are those that seem to be part of the fabric of the space; that misdirect through their transparency and camouflage. Architecture can have agency by taking up the uncanny valley of surface logics, asphalt and utility structures, to leak, misdirect and hack the space. Agency is found through the understanding of thin, sprawl space as an operational system rather than a spatial condition.

Staging: Making Visible

Peter P. Goche
Iowa State University, Ames, IA

ABSTRACT: Our experience as occupants of a particular setting begins with the impulse to instantaneously scrutinize everything. This impulse is sustained through an often precisely choreographed threshold. As architect and artist, my goal is to assist the occupant in maintaining their initial ontological wakefulness through staging, often-temporary assemblies within a host space and thereby enhance its topographic fidelity.

In this photo-essay, I will illustrate the role of staging as a means to reveal the experiential nature of lived space using a series of video stills developed in effort to document and study the situation of people with respect to Water Hutch, an ethno-specific research assembly designed and constructed by Peter P. Goché. Reminiscent of the many waterways that meander through the Midwest, the work consists of a sinuous line made up of three oxbows. The constituent forms are constructed of built up dimensional lumber. The set of parts serve as an ambiguous measure by which people situate themselves. It might best be understood as a set of objects or trace that indicates the presence of, and makes clearly recognizable, its context as referent rather than source or setting. It operates metaphorically as an open set of shelves onto which people, and thereby, memories accumulate. This work might best be understood as a set of objects or trace that indicates the presence of, and makes clearly recognizable, its context as referent rather than source or setting.

Each inquiry is part of a process by which the humanity and sensual experience of a particular setting is revealed. The resultant staging yields what Joan Simon calls a socio-graph, a support system for the occupation of an environment. To this end, the act of making visible assists in cultivating place-based knowledge. It is an embodiment of an interdisciplinary agenda that embraces the artist as craftsman, choreographer and scribe in an effort to cultivate the cultural essence of lived space.

SOS: The Unnatural Disaster, the Architect, and the Built Environment

Vaughn Thomas Horn
Tuskegee University, Tuskegee, AL

ABSTRACT: Since 2005, “unnatural” disasters caused by inadequate response to weather events and gentrification have unearthed socioeconomic inequities on a global scale. More specifically, the need for shelter in response to such calamity has been grossly inadequate, and at times apathetically dissonant.

In this poster, I argue that events like the “informal” housing crisis of Blikkesdorp in South Africa and the aftermath of Hurricane Katrina which disproportionately affected African Americans, renters, people with low incomes, and the elderly both posed missed opportunities for architects to act as second responders in hazard response. Essentially, how then can the practice and pedagogy of architecture protect every citizen’s right to durable and satisfactory shelter amid widespread destruction of the built environment cased by conflict or natural disaster?

As a full-time professor of architecture at Tuskegee University, I was inspired by an ingenious solution by Tina Hovespian, an alumnus of the University of Southern California, who created Cardborigami, a recyclable cardboard shelter intended to shield displaced citizens from the elements. In her research, Hovespian focused on the residents of Los Angeles’ Skid Row district, characterized by its squalor, drug use, mental and physical health disorders. As a result, I dove-tailed the theme of displacement with the subsequent fall semester in third-year design studio. My students addressed the socioeconomic impact of hazard response through two design problems. First, I challenged my students to construct full-scale, renewable, and water resistant shelter prototypes. These prototypes emphasized privacy, atypical of evacuation shelters. Second, I merged the cap-stone design problem with ongoing research for mass evacuations by the Alabama Rural and Urban Design Action Team (RUDAT) in the wake of the North Alabama Tornadoes. In this poster I examine how architectural pedagogy can supplement governmental initiatives and affect policy making.

Whether a refugee, or evacuee, or displaced resident, theses adjectives describe humans who are victims of circumstance, and I argue that architects should be driven by a higher humanitarian calling to provide adequate living conditions for them in the face of catastrophe. This poster is written to promote collaboration among architects, academics, planners, and government agencies to be proactive against future “unnatural” disasters. These guiding principles address the specific needs of internally displaced persons worldwide.

The Book Stacks at the New York Public Library

Andrea Hunniford
University of Waterloo School of Architecture, Ontario, Canada

ABSTRACT: The New York Public Library, overlooking Bryant Park at 5th Ave and 42nd Street and built just over a century ago, is currently the centre of attention in the ongoing debate of the future of libraries in our increasingly digitized world. Current renovation plans call for Foster + Partners to reimagine the closed book stacks - the seven level book storage system - as a new publicly accessible circulating library, incorporating a book collection, group workspace and greater computer access. The renderings of this space, released in late December 2012, show the complete dismantling of the existing stacks and the creation of several mezzanine levels and a new central staircase, all oriented towards Bryant Park.

Discussions of the dismantling of the book stacks at the New York Public Library raise interesting questions about the architectural importance of this unique example of book storage and retrieval infrastructure. I am interested in how architectural research can be used to tell the story of a space. Drawings, photographs and words can illuminate qualities that may have been taken for granted, can bring to the fore issues that may have been invisible. This story becomes even more interesting as the space in question is on the verge of destruction, transforming from physical reality to existing only in memory. At this point, research can take into account both what is and what has been.

Prototyping for the Homeless: Design-Build as Research

David Kratzer
Philadelphia University, Philadelphia, PA

ABSTRACT: “Architecture is not the first thing that most people think of when they consider how best to help the homeless.” (Sam Davis, Designing for the Homeless, Berkeley: University of California Press. 2004, p. 13). Fourteen architecture students of a socio-political + design-build studio at Philadelphia University were given the task of programming, designing, and prototyping twenty-five new dorm stations for a women’s safe haven homeless shelter in Philadelphia administered by Project HOME, the largest homeless agency in the region. The fabric covered office partitions used for privacy were removed after repeated bed bug infestations. The lack of privacy caused agitation amongst the residents. It was becoming more and more difficult to maintain an orderly and safe environment.

Through initial research methodologies such as client interactive workshops, prototype mockups, and interview of facility staff and residents, three primary design dichotomies emerged. The students were to:

1. Create an “insect unfriendly,” easily cleanable, environment while providing a “person friendly” place.
2. Create durable, cost effective constructions while providing comfortable, appealing places.
3. Create a visible, safe environment for residents and caregivers while providing opportunities for respectful privacy.

The client added the requirement that the dorm stations were purposely not to be too “nice.” If the design was too comfortable residents would not want to leave. Current trends in homeless services support “rapid re-housing,” a national best practice of moving the homeless quickly into permanent housing instead of emergency shelters. Simply providing a “home” does not solve the problems of homelessness and it became apparent that much research would be necessary to tune the designs to the realities of the homeless condition.

Utilizing evidence based design methodologies through prototyping in a workshop format, the project team was able to gather a generous amount of research on the subtle effect the dorm stations have on the behavior of the residents and staff. For example, the area around the resident’s head became a very critical area for impressions of safety, respect, visibility and privacy. Residents complained of the disturbing sensation of waking to find someone watching them. Resident storage areas became markers of territory and the most valuable items are stored at the headboards in drawers or under on the bed. Residents felt safer when others could see/ hear them from a distance while the partitions translucency offered a minimal amount of privacy.

This poster chronicles the “design-build as research” methodologies the studio utilized to understand this problem, program the client’s needs and prototype a solution. The Project HOME client team included the facility director, a social case worker, the director of Project HOME facilities, the VP of property and asset management and a few residents. The interdisciplinary design team included Philadelphia University architecture students, graduate occupational therapy students, and an industrial design thesis student. The stations are currently in fabrication and will be installed by January 2013.

On the Visibility of Computation in the Design Studio

Dave Lee
Clemson University, Clemson, SC

ABSTRACT: This poster addresses the problem of the computer being simultaneously ubiquitous and underutilized in architectural education as a beginning design principle. The current problem is not the lack of accessibility or use of computers, but the task of making visible computational thinking[i] in the education of the design student.

In both cases the computer (and its software) are seen as a passive design tool.[ii] This is because the image is being privileged over design quality – the ‘money shot rendering camp - or as an elitist subculture fetish – the robo-para-generative-digifab group – on the fringe of architecture. Further, they remain to be viewed as pen and ink were before digital technology, as merely tools used to make ideas visual.

Learning how to use a computer, or to think computationally, is often misunderstood with learning how to operate within the parameters of a software package. A computer, in this case, is reduced to a technical device incapable of becoming an integral part of a design process and only useful in ‘aiding’[iii]. For this reason, architecture schools have pushed computer learning away from the design studio – where design fundamentals are introduced – and into elective coursework where it is thought of as secondary to one’s education.
The fundamental design principles of the information age, however, now include computation at their core. It is important to introduce computation early in a design education because of the cumulative learning implications provided by a foundation in computational understanding.[iv]

This poster presents a novel approach to teaching computational thinking in the delivery of a foundation level studio where students are introduced to computing without the use of digital technology. By removing the ‘laptop’ from the design setting, students and faculty are able to approach topics such as constructing an algorithm without fear or preconception of technological implications.
By incorporating analog computing at this early stage of design education, students become more capable of ‘designing with’ as opposed to ‘making with’ when introduced to computer software because they understand how and why the tools they are using work. They are able to resolve problems that are incredibly complex, right away, whereas with digital tools a significant amount of technical learning must occur. Additionally, problems often overlooked when beginning a design strictly in a digital setting, such as the structural intimations of material properties across scales, are made tangible and approachable in a studio setting.

[i] Senske, Nicholas. “A Curriculum For Integrating Computational Thinking” in Cheon, Janghwan, Steven Hardy and Tim Hemsath, ed. ACADIA Regional 2011: Parametricism SPC. University of Nebraska Lincoln, College of Architecture, 2011: 94-95.
[ii] Akin, Ömer (1990) Computational Design Instruction: Toward a Pedagogy, The Electronic Design Studio: Architectural Knowledge and Media in the Computer Era [CAAD Futures ‘89 Conference Proceedings, Cambridge (Massachusetts / USA), 1989, pp. 302-316
[iii] Maeda, John. Design by Numbers. Cambridge: MIT Press, 1999.
[iv] Author, 2012.

Superthickness: A Genealogy of Architectural Control in Interiors from Surface to Volume

Andrew Santa Lucia
Oakton Community College Skokie, IL

ABSTRACT: This poster argues that there is a contemporary practice within the domain of interior space that architects are actively mining for new disciplinary possibilities. I call this graphically derived volumetric practice within the interior, Superthickness. The three iterations of Superthickness on which I will focus are textured/extruded graphics on wall surfaces, ambiguously defined furniture/walls/volume and spatially derived graphic signage outside of traditional way finding. This study will show how a genealogy of graphic oriented surfaces finds origins in the commercial Victorian era, the early 20th-Century Arts and Crafts, and in the 1970’s pop-cultural practice of Supergraphics. In both effect and realization, Superthickness pushes graphics out of flat, decorative and/or abstract surfaces, creating physical volumes within interiors. As a contemporary condition, architects are doing more with interior surfaces than purely dividing spaces. In this practice of activating surfaces volumetrically, architects have enhanced the scope of their cultural production through disciplined transactions with interior decorating, interior design and graphic design.

This focus on surfaces emerges through three different points in modern history. First, Ornate Graphic appliqués and organic patterns on interior walls become mainstay during the late Victorian era between 1890-1915. (fig.1) Second, the Total Graphic of the Arts and Crafts movement during the beginning of the 20th century showed an attempt to graphically control the room in totalizing ways, both visually and physically. (fig.2) Last, during the late 1960s and 1970s, Supergraphics became emblematic of a pop-sensibility that used larger-than-life graphics on wall surfaces to achieve faux-spatial effects. (fig.3) This genealogy will show how the development of autonomous and highly stylized interior surfaces developed, at points trying to emulate architectural effects and at others trying to create new ways to affect the overall interior volume. Superthickness emerges within the last 10 years and has pushed the disciplinary identity of architecture to include techniques and strategies outside of normative practice, yet steadfast in an ultimately spatial commitment. (fig.4)

There has been a recent resurgence of architects pushing the disciplinary boundaries of what they do through interior experimentation. In this sense, Superthickness operates as another entrance point for architects to interject themselves back into the popular discourse on the interior and create a new visibility for contemporary practice in a broader cultural sense. As a result, this study is integral today because it will shift the focus of the interior from surface to volume, and bring the discourse back into the realm of architectural production.

Good Enough for Government Work: Conservation Based Residential Design Criteria for Affordable, High Performance Dwellings in Central Vermont

Matthew Lutz
Norwich University, Northfield, VT

ABSTRACT: Approximately eighty-two percent of households in Vermont earning under $41,000 annually[1] direct more than one-third of their income toward mortgage and housing costs. Couple this statistic with the fact that Vermont ranks sixth highest in the United States[2] in terms of annual heating demand and it becomes clear that the challenges of home ownership for lower-income households can be overwhelming. In addition to the lengthy, sometimes severe heating season, approximately eighty-five percent of Vermont's forty-eight billion BTU's for residential heat demand[3] comes from petroleum-based products. Globally influenced price fluctuation of these products is a financial planning wildcard for households operating on thin margins.

As one of twenty houses planned for exhibition in the United States Department of Energy's Solar Decathlon 2013, this project took the challenge to design, develop, and build a one-thousand square-foot high-performance, solar-powered prototype house that can be afforded by households earning eighty percent of Vermont's median income. With a construction cost estimated at $145,000 and a building integrated photovoltaic array, the prototype house was designed to achieve a net-zero-annual-total of primary energy demands and eliminate dependence on off-site utilities for electrical, heating, and cooling demands.

Using the six basic Passive House U.S. performance characteristics as targets for energy performance, and designing an envelope system that corresponds to factory-based modular housing assembly line conventions, a multidisciplinary group of faculty and students developed an alternative to conventional low-income single family dwellings. The product of this effort, a prototype called the ∆T90 House, will be on public exhibit in Irvine, California during Solar Decathlon 2013. During the competition, the ∆T90 House will demonstrate the scientific, financial, and architectural benefits of exercising a conservation-based approach to residential design.

Energy performance modeling software like Therm 6.2, WUFI 5.0, and PHPP 2007 show fine-tuned balancing of up-front cost and long-term energy conservation and allow for a deliberate, informed approach to the architectural decision making process. Thus, this poster ultimately examines specific building science as well as broad architectural aspirations in an effort to produce widely available affordable high-performance dwellings.

[1] 2007
[2] 2009
[3] ibid

Lessons Learned: Using an Electronic Drop Box to Disseminate Student Originated Research

John McDermott, Mitch Stepanovich
University of Texas at Arlington, Arlington, TX

ABSTRACT: Hard pressed people usually look for available and ubiquitous alternatives to their declining resources. Eons ago when people figured out that wood was more valuable as a cooking fuel than as a building material they responded with mud bricks. Today resources like funding for higher education are scarce. One way for enterprising faculty, staff and students to deal with their two most critical declining resources - money and time is to seek to stem the rate of decline by looking beyond the known potential of search engines to some of their other features. This proposed presentation will focus on the "Lessons Learned" from a one year experiment in using a student initiated and managed "Drop Box" as a learning resource in a fourth year undergraduate architectural design studio.

This drop box unlike the traditional afterhours book return collection box outside every library door is a dynamic informational repository with a continuously updated supply of primary and secondary research outcomes as well as other course related information. It functions as a library without a librarian and it operates as the primary means for sharing information on a just-in-time basis. While it is a ubiquitous 24-7 electronic environment outside the physical limits of the architecture library, it invites student scholars and library staff to check-out its contents at their convenience. Because the librarians are better informed about student research interests they often add to the drop box holdings. Like e-mail and other social media, the contents of this drop box are dynamic and reading them may even be addictive. It was one of several aspects of an architectural design studio course designed to engage a variety of disparate student cultures by means other than over-the-desk criticism and jury review as the primary means of teaching and learning. The instructional design of the course is intended to empower students to address the premise that managing seasonal resources like sun and wind is central to achieving sustainability. The course enables them to undertake self-directed original research, to share the outcomes of that research with classmates and to think critically about these outcomes by comparing them with the work of classmates; and finally, to clearly express their critical thoughts visually as architectural designs in electronic media.

Excessive Variety: The Material Air of Eero Saarinen

Kevin Moore, Robert Sproull
Auburn University, Auburn, AL

ABSTRACT: Differences matter, and this study of twin libraries is a search for meaningful variety. In proposing a renovation of nearly identical buildings, the work of this undergraduate design studio respects each branch library as a vital public institution with a loyal constituency. Located in diverse neighborhoods—one affluent, the other underserved—the proposed renovations enrich subtle physical differences to address critical differences in local culture.

As a form of design research, the studio visited several buildings designed by the office of Eero Saarinen. Saarinen coordinated a huge variety of scales including furniture, architectural surfaces and landscape materials. At Concordia College in Fort Wayne, IN, for example, the campus is structured as a village. A custom brick developed for the project creates a recognizable family of buildings with variations in section and lighting. The Irwin Union Bank also integrates interior and landscape effects. The shallow uplit domes are unmistakably analogous to the surrounding tree canopy specified by landscape architect Dan Kiley. The Miller House in Columbus, IN, too, is a sophisticated collaboration—between Saarinen, Kiley and interior designer Alexander Girard. Although Saarinen is well known for integrating materials at multiple scales, his simple expressive forms have suppressed the thermal, acoustic and luminous variety of his work.

Like the Irwin Union Bank and Miller house, the existing libraries are a basic 100'x100' plenum of air. Unlike the libraries, however, the Saarinen projects structure a complex and unfolding variety. Field sketches and large plenum models help students visualize these experiential effects and propose a similar material

richness. Here, meaningful variety between and within the two libraries is studied as qualities of air—heat, sound, and air-scattered light. A challenge to draw, air is often indistinct. But a cool quiet alcove awash in soft light is a noticeable delight, especially for several hours of summer blogging. A quick tutorial or a weekly meeting may require distinctly different qualities of air. In search of such qualities, students have developed an informed position on interior and exterior materials by further researching lighting, ceramic tile, furniture, curtains and trees. Rather than ignore an adjacent scale or abandon it to a related discipline, material knowledge is approached opportunistically by a single designer.

The civic identity of each library is now redefined as a quality of air. While each project proposes a new image, the icon-making of Eero Saarinen concedes to renovations that are more similar the direct physical experience of his work. Excessive materials create public places with a renewed identity beyond imagery. In this way, contentious differences between the libraries are approached optimistically and obliquely as invisible yet profound effects of air. As final incentive to reimagine the twin libraries, the design research of the studio was exhibited in both branches, making the identity of each visible to the other.

Drafting Standards of Sustainable Stadium Design in Studio: How Scholarship Shares Societal Concern for Health, Safety, and Welfare

Glenn Nicklaus, Peter Nowak, Rory Heggie
University of Nevada Las Vegas, Las Vegas, NV

ABSTRACT: Stadia are among the most visual icons of the built environment. Their capacity for community engagement make them ideal candidates to empower the public with regard to not only aesthetic preference but expectations of building performance. Alternative standards are presented addressing the environmental and social sustainability potentials of stadia design; an archetype that is typically overly consumptive and underutilized. Balance between business acumen and design aesthetic was considered with the former enabling better quality design.

The importance of sustainability in architecture is essentially common knowledge. However, research that only furthers understanding of environmental sustainability misses the opportunity for design to be seen as an integral part of achieving economic and programmatic sustainability (and perhaps even emotional longevity). This poster chronicles the process that unraveled in a graduate studio. The project began as a critique of local developers' proposals for various stadia around town. The studio wanted to contribute to the public discourse with more critical considerations of who could be served by these civic structures and how they might they be built. Green architecture principles familiar amongst smaller archetypes were extrapolated and calibrated to the larger scales of stadia and urban redevelopment. As estimated, costs associated with the integration of environmental considerations rose exponentially due to substantial project size.

The project evolved from a more traditional and authoritative study to a more participatory investigation that saw the integration of community input, consideration of developer investment (thinking like the client*), and larger institutional interest. Efforts to achieve higher standards of environmental design were actually achieved through rethinking programmatic and infrastructural design ideas that drastically improved the return on investment timeframe. Instead of simply concluding, "developers should do this…" the studio effectively communicated findings on how programmatic sustainability (multi-use, continuous occupancy, contextual integration, etc.) could deliver economic and environmental sustainability.

The entertainment capital of the world has the opportunity to learn from stadiums around the globe. While Las Vegas, Nevada continuously seeks the ideal location and funding model for some sort of major sports facility, this poster searches for inventive design solutions for how stadiums (Las Vegas and elsewhere) can take advantage of their location and rethink programming to become environmentally, socially, and financially sustainable. The 330 days of sunshine and 24-hour culture give Las Vegas the opportunity to set a new precedent in ecologically conscious design and integrative programming. Through analysis of several exemplary projects and advanced modeling of potential design solutions, this poster presents an evolving set of standards to which new (and rehabilitated) stadiums could be built. The major impetus of this research stems from observations of these iconic buildings that unfortunately sit idle for extended periods of time. Rethinking included components could add yearlong vitality to the architecture. Additionally, the shear size of the structures and their sites suggest that renewable resources could be harnessed to help offset energy demands. The presentation includes examples of how multiple cities could adapt stadium designs to reach higher standards of sustainability with design research emphasis on Las Vegas.

*Murray, Christine "Architects Must Stop Doing More for Less" AJ Buildings Laboratory, EMAP Publishing, March 2012

Specialization and Spectacle

Glenn Nicklaus, Peter Nowak, Yissa Renteria, Joshua Moser
University of Nevada Las Vegas, Las Vegas, NV

ABSTRACT: Architecture makes some of the most complex integrations of ideas visible. For research situated on the periphery of the profession, the application of the research is critical in expanding architectural discourse and by extension, visibility. Applied research of topics on the margins is often applied within the narrow context supposed to be the most appropriate. This poster examines two complementary strategies for addressing the dilemma. First, commodification of research is demanded in terms of the broadest relevancies of obtuse architectural concepts being studied. And second, in the cases of mainstream issues, means of testing the theses are conducted through unconventional applications to increase awareness and the feedback loop associated with the work.

Case Study 1:
Adaptive Reuses of the Mega-Resort: architectural anomalies and their creative adaptations addressing national issues and community concerns – Germane to this process was a desire to illustrate that the issues concerning public education and the architecture of American academics could be every bit at home on "The Strip" as it could be "on Main Street". Where, if the challenges of delivering a quality education could be solved in one of the more distracting or forbidding environments for young people, it could contain lessons for all.

When challenges with old ideas and major voices (ex. classroom design in public education) are the topics of research, the incremental progresses become less visible while the problems may be expanding exponentially. To make visible (and to jump start new ideas) design experiments that introduce independent variables from the margins have the capacity to bring minor voices into the larger discussions on the dependent variables.*

* http://www.uncp.edu/home/collierw/ivdv.htm

Case Study 2:
New archetypes and emerging social acceptances: architecture's role in negotiating complex realities.
This evolved into a study of macroeconomics surrounding impending decisions to illegalize prostitution vs. legitimize the profession. The process began as a general inquiry about the progression of architectural programing surrounding taboo topics.

What was once marginalized (ex. gambling/casinos), is now practically mainstream (ex. resorts becoming hubs of several communal activities: bowling, movies, restaurants, etc. & more and more states welcoming such establishments into their built environment).* Those ideas or emerging archetypes that are considered on the margins, today, must be envisioned and fully explored as a potential forefront topic of the future… else architect does not make visible but reacts to what everyone else already sees.

* http://www.spectrumgaming.com/trends/

Research and the Future of Architecture Education in East Africa

Mark Raphael Owor Olweny
Uganda Martyrs University, Nkozi, Uganda

ABSTRACT: This poster reports on the implementation of research based teaching in an architecture program in East Africa. This is in light of a global shift from undergraduate to postgraduate professionally accredited architecture programmes following recommendations of the Bologna Declaration (1999). Emphasis on research is required to ensure the professional degree in architecture measures up to the standards associated with Masters level scholarship and research, which increasingly calls for a major thesis as the terminal project. In the context of East Africa, this suggests a change in the approach to research in architecture education, as the traditional tried and tested approach may no longer fulfil the needs of the new teaching paradigm. Nowhere is this more evident than in the requirement for architects to continually adapt to constantly changing circumstances, and be able to address issues for which they have not been explicitly trained.

Research in architecture programmes in East Africa has been presented in stand-alone research methods courses that espouse specific research methods and methodologies (an explicit approach). It could be argued that this has created a research monoculture with a polarisation of research in particular areas. This could be juxtaposed against a broad-based approach in which research is presented as component within specific courses, introducing different research paradigms, methods, methodologies and tools to students (an implicit approach).

The transition from a graduate entry Bachelor of Architecture degree, to a Master of Architecture professional degree also required a fundamental shift in the approach to research at the undergraduate level. The poster presents details of the transition and its implication on student output in design and research, and highlights some challenges faced in the transition to research teaching and learning for both students and faculty.

Solid Surfaces: Innovations in Materials and Construction Visualization

Andrew Phillip Payne
Savannah College of Art and Design, Savannah, GA

ABSTRACT: For the winter/spring quarters of 2011 Dr. Andrew Phillip Payne developed a collaborative architecture design studio that focused on materiality, construction detailing, and fabrication. The success of this collaborative practice was untraditional in the sense that participants included product manufacturers, consumer representatives and shop fabricators instead of the typical designer/contractor. This unique experience exposed the students to the full extents of a project from the design phase to fabrication and installation. Professor Payne led a sponsored studio (ARCH406) with CH Briggs, Inc., a product representative for solid surface materials, headquartered in Reading, Pennsylvania. The studio mission was to assist in the development of interior and exterior cladding design concepts using DuPont™ Corian®. Using the information and established design criteria provided by CH Briggs, Inc. the SCAD team worked in three phases – Opportunity Definition, Design Exploration, and Design Refinement.

Phase I – Opportunity Definition
Phase One consisted of 15 undergraduate seniors and included a visit to the DuPont™ Corian® design studio in Philadelphia for consultations with representatives from CH Briggs, Inc. and engineers from DuPont™. Students conducted case study research to familiarize themselves with solid surface materials and general practices for incorporating Corian® into architectural designs. Student development was enhanced through field trips to view samples of material and completed projects at the Dupont™ Corian® design studio in Philadelphia, Pa., ASST Fabricators, Inc. in Harrisburg, Pa., and the Hilton Hotel in downtown Baltimore, Md.

Phase II – Design Exploration
Students gained an understanding of the market, users, manufacturing details and the established design criteria in an effort to inform the product development process. The SCAD team undertook the task of developing design concepts and explored a wide variety of design
proposals including site furniture, façade cladding, signage, and interior details, all of which were pursued in phase III. During the spring quarter architecture students continued their exploration and were joined by an additional group of eight students in the Craft and Tectonics class (ARCH728). The Craft students' approach was more hands-on. The students, working in the SCAD model shop, physically manipulated samples of the material and tested the limits of bending, cutting, drilling, and installation with various fastening systems. These students produced mock-ups of assemblies and small scale design details which demonstrated the application of the cladding designs. The manipulations ranged from simple power tools to parametric designs and CNC fabrication.

Phase III – Design Refinement and Visualization
The students from the studio and Craft classes refined their designs which were then included in the DesignPhiladelphia 2011 exhibition. The gallery opening was well received and rave reviews were offered by design professionals and invited guests

Rural Sustainability

John George Poros
Mississippi State University, MS

ABSTRACT: Ability. For urban areas, sustainability is a working concept, where goals, measurements, and outcomes have undergone research and implementation. In rural areas, almost no research has been done to see how sustainability would be measured or what sustainability goals make sense. In the sustainability literature, rural areas are either ignored or thought to be treated in the same manner as urban areas. We know that rural areas and urban areas have different resources and problems.

In trying to understand this issue, our questions went back to basics: what is rural? What is sustainability? And what would it mean to be sustainable in a rural environment? Our research has led us to think about the cultural dimensions of sustainability as much as the environmental and fiscal issues. In fact, we believe that in understanding the differences between sustainability in a rural area and an urban area, the cultural differences are the most important to understand.

Sustain
In the effort to define rural sustainability, we are attempting to identify indicators for the triple bottom line of economy, community and environment that relate strongly to rural conditions. While aligning the indicators for sustainability with rural conditions is important, rural communities tend to value solutions to problems of community and economy more than the environment. Yet environmental issues are central to sustainability and impact on the community and the economy. We knew that we had to provide a mechanism for rural communities to understand the impact of the environmental decisions that they made on the socio-economic issues that they cared about the most.

Our analysis involves measuring 140 indicators of sustainability in the areas of society, economy and the environment. These indicators are measured against world, national, state and local goals in order to assess how sustainable a town or region is. The assessment is presented as a radar graph to clearly indicate in which categories the town is more or less sustainable. Once the measurement is complete, projects are developed that address the deficiencies measured. The projects are then assessed for their potential to improve the lagging sustainability indicators and a new assessment is made as illustrated in the diagram. The process allows communities to weigh options for development and conservation and make decisions based on all the factors involved.

Rural
Sturgis, Mississippi is a town of 254 people in the eastern portion of Mississippi. The town has little industry besides an underused saw mill, but has a cafe, hardware store, tire shop, and gas station in its small downtown. The elementary school in town is part of the county system and there are six different religious denominations in Sturgis. The town has a park and an association dirt go-kart track. One of the best assets in Sturgis is a vintage BMW motorcycle shop that is known nationwide for its stock of vintage BMW's and the

ability to repair them. The owner of the shop instituted a motorcycle rally in Sturgis 14 years ago and several thousand bikers attend.

Sturgis has become the test bed for the project because typical rural problems can be seen in microcosm. Despite the typical rural problems of health, education and employment, Sturgis shows some remarkable positives in faith based institutions, number of college degrees, home ownership and average income. By mapping areas with the greatest impact on society, economy and the environment, we will take the indicator measurements and find sites where projects can affect the more negative factors and thus increase sustainability overall.

Implementation

Our planned use of these indicators will be to allow towns like Sturgis to assess new projects or economic development opportunities more holistically. We see this process of measuring sustainability becoming part of the required comprehensive planning process to establish a baseline and goals for a town in regard to sustainability. Sustainability through the base line assessment and requiring the assessment for new projects would give rural communities the tools to stay on the path to a sustainable future.

The Idealized Temple Morphology: Surveying the Public Perception of Sacred Architecture

Brandon Ro
The Catholic University of America, Washington, DC

ABSTRACT: Throughout the global history of architecture, many cultures and religions have built sacred buildings and symbolic monuments under the rubric of 'temples.' In many instances, temple spaces have influenced the world's cultural identity in the spheres of politics, sociology, and religion. The power of architecture lies in its ability to shape human understanding. In other words, human perceptions are often transformed to some degree when people interact with architectural configurations. Yet understanding the impact of the phenomenology of architecture on perception in such encounters is rather difficult to quantify because of the subjectivity of human experience.

In the following study, however, survey research is proving to be a viable method for: 1) testing the relevance and public reaction to conceptual models and theories of sacred architecture, 2) providing empirical and quantitative data documenting sacred architecture's effect on human understanding and perception, and 3) producing an idealized morphology or set of design strategies that can guide architects and religious specialists in the planning phases of new projects. Overall, the study reports data gathered from over a hundred survey respondents from a convenience sampling (n=112) and serves as a preliminary attempt at bringing research into 'sharper focus' by surveying the public perception of sacred architecture.

The survey was designed to first test the relevance of the theoretical framework of comparative historian of religion, Lindsay Jones, in his second volume of The Hermeneutics of Sacred Architecture (Cambridge: Harvard University Press, 2000). Jones' theory is derived from empirical case study observation, thus following the inductive approach to research by identifying patterns from the world's sacred architecture. On the other hand, since the survey tests Jones' theory, it can be viewed as a more deductive method. The survey deals with a different type of empirical observation, namely the quantification of people's subjective perceptions of sacred architecture.

One limitation to the study is that there is a potential bias in the data, since a large number of respondents (96%) agreed that a 'space or building can be sacred and have meaning.' While this may be the case, the fact that there was such a high average acceptance rate (70%) for Jones' thirty-three 'ritual-architectural priorities,' despite the differences in gender, age, education, religion, and occupation, helps validate the significance and value of the results for both designers and religious specialists.

Another limitation to the survey is that respondents do not comprise a scientific sample of a particular population demographic. Notwithstanding this limitation, however, the descriptive statistics of the survey data not only provide us with a preliminary attempt at surveying the public perception of sacred architecture but also provide us with the top ten most important design strategies for temple projects. One potential for the future use of the survey is how it can better gauge a client's (i.e., clergy, congregation, etc.) perceptions

and idealizations of sacred architecture during the initial planning stages of design and then compare that data with post-occupancy evaluations to determine the transformative quality of the new ritual space on human perception.

Activating the Indeterminate: Engaging Sites of Industrial Atrophy

Jennifer Shields, Bryan Shields
University of North Carolina Charlotte, Charlotte, NC

ABSTRACT: Remnants of the technological landscape contain a rich palimpsest of cultural and material history ripe for reactivation, transforming artifacts of industrial obsolescence into cultural catalysts through minimal intervention.

The contemporary city is littered with derelict sites: once active commercial or industrial zones, now void of human occupation, containing architectural remains left to atrophy. These ruins often exhibit a rich palimpsest of cultural and material history, ripe with latent potentialities to be revealed. How can these wastelands, remnants of the technological landscape, be reactivated, transforming artifacts of industrial obsolescence into cultural catalysts through minimal intervention?

In service of attempting to answer this question, the Roofless Gallery for [Con]temporary Art is a design/build project undertaken to reinhabit a specific abandoned artifact. A dry-cleaning facility lies in a state of ruin along a heavily traveled spine in Charlotte, the seam between two underserved urban neighborhoods. The roofless character of the building, a space defined only by walls as a result of neglect and weathering, creates an unintended but fortuitous Terrellian skyspace. The inherent boundaries of its urban context offer solace solely in the vertical dimension, providing the opportunity to transcend physical and societal limitations and reconnect with the boundless firmament. This artifact has the potential to reactivate the urban corridor: interventions into the structure will provide a means of reinhabiting the site and engaging in a dialogue with the community.

This roofless structure has been envisioned as a temporary arts space that would encourage interaction between local artists and residents, provide partially protected but unconditioned space for episodic arts and music events. Recognizing the rich spatial and haptic experience of the space as a result of the ambiguity between exterior and interior, we have explored ways to construct an integument of found materials that preserves the roofless nature of the building. The project culminates in post-installation testing through an arts and music event, bringing together students, artists, and neighbors – the reactivation of a vestigal urban site through minimal architectural intervention.

Daylighting Through a Collaborative Vision

Robert Sproull, Magdalena Garmaz
Auburn University, Auburn, AL

ABSTRACT: Architectural spaces are defined by light – especially natural light, and as Le Corbusier pointed out, one need only trace the history of windows to comprehend the history of architecture. But, as contemporary architecture has been at times partially defined by the dissolving of its heavy load bearing exterior, the process of designing it has been characterized by a struggle to control the temperature of the modern interior. Thermal and luminous comfort may only be achieved through a fine balance between admitting enough light without losing, or admitting, too much heat. This is a significant design challenge, and traditionally the architect assumed responsibility for solving this problem. However, as buildings have grown more complex, creating extraordinary luminous experiences without increasing energy usage has often required design experimentation and careful testing of day-lighting components. This methodology simply cannot be supported by most budgets and is often too time consuming to meet most schedules.

Because of this, the process of making buildings has changed. Over the last five decades, as projects have become considerably more complex, the architectural industry has shifted from the single, visionary designer to multifaceted teams made up of discipline specific experts. The collaborative has replaced the individual. In spite of the fluid nature of design delivery in practice, academia's educational model has remained relatively unchanged; the student, (often working alone), single-handedly develops his/her own concepts. This model succeeds in teaching individuals to harness their own creativity, but falls short in conveying the importance of teamwork in today's design and construction process. However, this methodological inconsistency can be overcome. By connecting students with actual specialists from the field and directing them to work together towards specific design outcomes, the value of collaboration begins to be understood, and the importance of recognizing and working toward the collective vision of a design team as a whole is comprehended.

This poster documents the testing of this notion in a fifth year design studio that focused its investigations on day-lighting in the architectural design process. The investigations combined testing of aesthetical and thermal properties of light in order to produce design solutions that are not only visually appropriate, but also highly inventive and energy-efficient. Students produced physical and digital models, while continuously testing and recording results, hence creating a final presentation that was more about a thoughtful, structured process rather than a finished building. What made this studio unique was a carefully built-in and continuous dialogue with "real world" practitioners. Students consulted world renowned lighting experts throughout their entire design process, met with principal architects from major day-lighting projects in the region, and discussed thermal issues related to day-lighting with the facilities manager of a nationally recognized museum. This framework provided students with a unique experience. It allowed them to explore and develop design possibilities specific to their particular projects through a collaborative process much more similar to that which they will experience upon entering the profession.

Designing a Sunshade Installation for the UT Zero Energy House: An Exploration in Generative Modeling Tools

Edgar Stach
Philadelphia University, Philadelphia, PA

ABSTRACT: The subjective quality of architectural design requires all designers to consider an infinite set of possibilities to a project design. Logically, the faster a designer can visualize and communicate possible ideas within a given time frame, the better their opportunity to discover the best design solution. Ultimately, perfection in architectural design can never be achieved, but its pursuit does lead to a more refined solution.

Computer-aided drafting and modeling has provided designers more efficient visualization of project designs, heightened productivity, and increased workflow; however, with the increasing complexity of contemporary designs, new generative modeling technology must be employed to sustain efficient productivity in the design process. Generative modeling is a computer software technology which allows the designer to provide a set of parameters in which a programming script can be written to generate elements within a given domain. This technology allows the designer to model highly customizable and complex elements which can be generated at the speed of a computer calculation.

What are some the benefits of generative modeling, and does it support practicing sustainable design? This poster will discuss the implementation of Grasshopper, a generative modeling plug-in for Rhinoceros 4.0, and its role in creating a sunshade installation by a research design team for the "zero-energy" house project at the University of Tennessee in Knoxville. More importantly, the instructive description of the design and fabrication process will show that the same steps can be adapted to other architectural projects.

Step-by-Step: Democratizing Architectural Making

James Stevens
Lawrence Technological University, Southfield, MI

ABSTRACT: "Design, like war, is an uncertain trade, and we have to make the things we have designed before we can find out whether our assumptions are right or wrong… 'Research' is very often a euphemism for trying the wrong ways first, as we all must do." 1

The Industrial Age, and most recently the Information Age, has shifted the role of the architect away from that of the "master craftsman" to the professional "knowledge worker."2 As a result, there is a growing divide between "knowledge" and "making" in the practice of architecture. This poster will be a critical examination of the divide between knowledge and making and how the profession and academia have moved, or not, towards a new understanding. The availability of new digital tools and materials, made possible through the democratization of manufacturing and community knowledge, allows for a new opportunity for craft, design, and research.

Presently, architecture publications either focus on theoretical aspects of digital fabrication or vocational techniques. Collegiate level architecture in particular suffers from the absence of how-to research and process-based instruction. If the typical architecture student or faculty member wants to profile cut or slip cast, there is no definitive source for how to start such an endeavor. They must conduct extensive research and use trial and error methods to become acquainted with the digital fabrication equipment and processes.

In order to make digital fabrication processes more visible to students as well as the entire architecture community, a university's digital fabrication lab (name omitted for blind review) is currently working to expand the lab's blog to include an instructional section on such processes. This poster will describe the blog's anticipated how-to section demonstrating easily replicable digital fabrication processes in such a way that balances design theory and vocational information. The poster will describe the blog's method of selecting appropriate processes for inclusion, its use of media to convey architectural making, and its approach to combining theoretical and technical knowledge. The planned expansion of the blog is significant because it democratizes the "how-to" of architectural making. The blog is the ideal forum for disseminating this collegiate knowledge as it has hundreds of followers and the interactive nature of the web allows for clear instruction of design and fabrication processes. Most importantly, it has the potential to not only help the university student, but to mend the divide between knowledge and making in the greater design community.

1 David Pye, The Nature & Aesthetics of Design (New York: Van Norstrand Reinhold Company, 1978) 27.

2 Matthew B. Crawford, Shop Class as Soulcraft: An Inquiry Into the Value of Work (New York: The Penguin Press, 2009) 47, 138.

Café Design Build

Chris Welty
Southern Polytechnic State University, Marietta, GA

ABSTRACT: To paraphrase from John Connell's lecture at "High Octane, what's next?" symposium, the act of making is inherently human. It's what separates man from animal. The act of making is the central most feature to our species. Other species on the planet have specialized exploiting variations in form, habits or physiology, to adapt to specific environments and conditions. Birds have hollow bones so their structure is light, allowing them to fly. Fish have developed gills to breath under water. Man on the other hand has not adapted to any specific condition. He can be found throughout the world and beyond, now even occupying outer space.

The act of making should not be confused with assembling. The act of making is comprised of conceiving and then constructing. Making is telling a story, revealing who we are at that time. Whether low tech or high

tech, you will learn more with the first thing you build bound by constraints such as weather, codes and budget than almost anything else you learned in school.

This focused studio builds on a long history of design-build within the Architecture Department at Southern Poly. Recalling a time of the master builder the studio will focus on the main aspects of design-build; design, construction, and management. Learning by doing the students will explore and experiment with the art and craft of architecture. Simulating an actual design-build practice the studio will present an educational model that reflects a comprehensive design-build environment. The project will follow the entire design and construction covering topics from design, systems selection, detailing, budgeting and procurement, scheduling and construction.

The design-build program proposes a small-scale project sponsored by our chapter of Freedom By Design. Entitled, Café: Design Build the project is envisioned as the moveable kiosk and permanent home for their weekly bake sale fundraiser. The purpose of the kiosk is two-fold, one as social mediator and two as philanthropic revenue stream.

The poster describes the methodology and framework for the design build pedagogy. It outlines the process from start to finish elaborating on studio exercises and student research. In addition the poster presents observations and challenges that were encountered during this process and provides strategies for future successes.