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THE BUILT ENVIRONMENT

SHAPING THE QUALITY OF LIFE

ARCC-EAAE INTERNATIONAL CONFERENCE

PHILADELPHIA

MAY 16-19 2018

Volume 2

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HAPPINESS

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Architectural Research for a Global Community

THE BUILT ENVIRONMENT

SHAPING THE QUALITY OF LIFE

Volume 2

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Ajla Aksamija

Methods for Integrating Parametric Design with Building Performance Analysis

Methods for integrating parametric design with building performance analysis

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ABSTRACT: This paper discusses methods for integrating parametric design with building performance analysis procedures, specifically presenting tools and design methodologies that are suitable for whole building design. In this research, an ideal framework for integration of parametric and performance analysis procedures was developed. Then, the framework was tested using existing software applications, including building information modeling (BIM), non-BIM, parametric design and building performance analysis applications. Current applications that can integrate some form of building performance simulation with parametric modelling include Rhino 3D (non-BIM), Revit (BIM), and SketchUp (non-BIM). Revit and Rhino each have visual programming plugins to aid in the creation of parametric forms. In this research, three different workflows were tested. Specifically, Honeybee and Ladybug (for Rhino 3D), Insight 360 (for Revit) and Sefaira (for Revit) were evaluated. A case study building was used to test and evaluate the workflows, interoperability, modeling strategies and results. Three different building performance aspects were analyzed for each workflow: 1) energy modeling, 2) solar radiation analysis, and 3) daylighting. Simulation results from energy modeling, solar radiation and daylight simulations were recorded and analyzed. However, besides simulation results, the paper compares modeling procedures, parametric capabilities of investigated applications, ease of integration and interoperability. The results show a promising course for integrating parametric design with building performance simulations.

KEYWORDS: Parametric design, building performance analysis, high-performance buildings, BIM, energy-efficiency

INTRODUCTION

Advances in building performance simulations have enabled designers to better understand how environmental factors affect building performance (Aksamija, 2013). Parametric design methods, on the other hand, allow designers to generate and explore geometries of building elements by manipulating certain parameters. There are a number of software platforms that focus individually on environmental analysis or parametric design, but few integrate both. Common parametric design tools include Grasshopper (Rhino 3D), Dynamo (Autodesk Revit) and GenerativeComponents (Bentley MicroStation). Environmental and energy analysis tools include Ladybug and Honeybee (Rhino 3D), DIVA (Rhino 3D), Insight 360 and Green Building Studio (Autodesk Revit), Sefaira (Autodesk Revit + Trimble SketchUp), Radiance, OpenStudio, EnergyPlus, eQuest, DesignBuilder, IES VE, and many others. The most common method of integrating building performance simulations (BPS) into early design work has been by exporting the design model (whole building, partial building, or model of a building component) to a dedicated analysis tool to generate an analysis model, assign inputs necessary for calculations and simulate energy usage, daylighting, or solar radiation. The results from these simulations would be used to adjust the design model in the original design program, and then the model would be exported again, thus repeating the process. By integrating the capabilities of parametric design and building performance simulations, multiple design variables could be tested rapidly, creating a more cohesive design process. These following research objectives were addressed in this study:

- Investigation of methods for integrating performance-based design with parametric modelling, focusing on whole building design.
- Investigation of tools and software programs that can seamlessly integrate performance-based design with parametric modelling, particularly focusing on energy analysis, solar radiation analysis and daylight simulations.
- Testing the procedures on a specific case study and documenting the results.

1.0 BRIEF LITERATURE REVIEW

Typical energy modeling programs are often complex for architects to use during the early stages of design, resulting in building performance analysis being performed at later stages (Bazjanac 2008; Schlueter and Thesseling 2009). The architectural profession lacks established methodologies and protocols that incorporate performative analyses into the early stages of design (Pratt and Bosworth, 2011). However, the most important design decisions that have significant impacts on building performance are made at the conceptual stage of a project, such as building massing, orientation, volume, shading, daylight strategies, etc. Tools that shift the building performance assessment back into conceptual stages of design will have a bigger effect on building performance (Rahmani et al., 2013). This introduces the concept of performance-based design, where the environmental performance becomes the guiding factor in the design process. However, most current design software applications are not capable of integrating the results from performance-based simulations back into the design model. It is the designer who interprets the results and optimizes the model based on simulation results (Oxman 2008).

Parametric modeling relies on geometric representation of a design with components and attributes that can be parametrically varied, where each geometric configuration that derives from parametric variations is called an instance. Instances represent a unique set of transformations based on parametric inputs, generating design variations and different configurations (Turrin et al., 2011). Parametric modeling has the potential to overcome current design process limitations and to facilitate the revelation and comparison of performative solutions. Parametric modeling initially lacked applications in architectural design; however, new architectural tools have been developed, allowing for new directions. The ability to produce many instances that result in unique configurations of the same geometric component is the main advantage of parametric modeling.

Integrating parametric modeling with building performance analysis procedures could enable architects and designers to analyze impacts of design decisions on building performance from the earliest stages of the design. Testing multiple design strategies in an efficient way, and reducing the time necessary for modeling and analysis procedures are the main benefits of integrated performance-based and parametric design.

2.0 FRAMEWORK FOR INTEGRATION OF PERFORMANCE-BASED AND PARAMETRIC DESIGN METHODS

The ideal framework for integrating parametric and performance-based design is shown in Figure 1. Parametric modelling, geometric preparation and analysis preparation should be streamlined and connected to performance analysis. This would combine parametric control of building geometry and building systems with analysis and visualization of results.

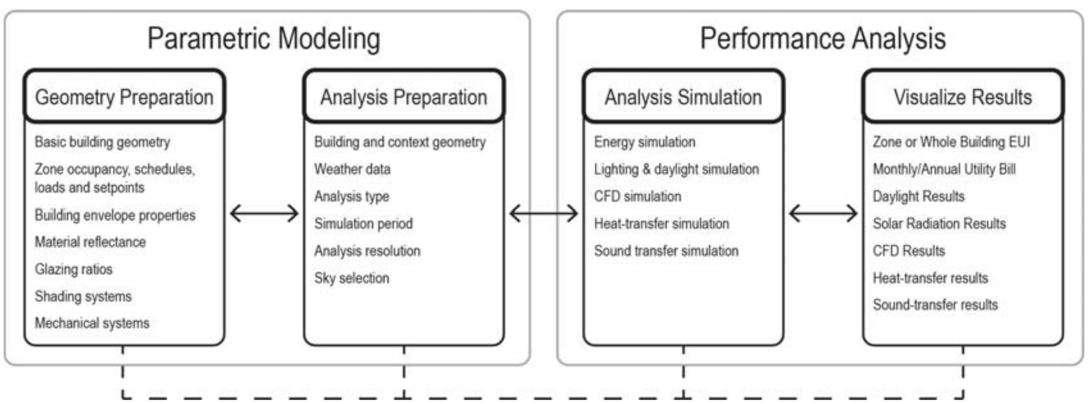

Figure 1: Ideal framework for parametric and performance-based design. Source: (Author 2017)

Current software applications that integrate some form of BPS with parametric modelling include Rhino 3D, Revit, and SketchUp, as shown in Figure 2. Revit is a BIM-based design tool, while Rhino and SketchUp are non-BIM based. Revit and Rhino each have visual programming plugins to aid in the creation of parametric forms. And, a variety of BPS tools are available that address different aspects of performance analysis, including solar radiation analysis, energy modeling and daylight analysis. This research investigated three different workflows, including integration of both BIM and non-BIM design platforms with parametric modeling and BPS. Specifically, Rhino 3D (with Grasshopper, Honeybee and Ladybug plugins) and Revit with Insight 360 and Sefaira workflows were investigated in this research. Figure 2 shows details of all three investigated workflows, and relationships among software applications. The parametric and performance tools discussed are run within Rhino (Ladybug and Honeybee) or Revit (Insight 360 and Sefaira). Honeybee and Sefaira use the same simulation engines for running analysis (Daysim, Radiance, EnergyPlus and OpenStudio). Insight 360 also uses EnergyPlus for energy analysis, but Revit has its own engine for lighting simulations, which has been validated against Radiance. Since all plugins use EnergyPlus as the energy simulation engine, any variations in results are caused by geometry and input differences between the three plugins.

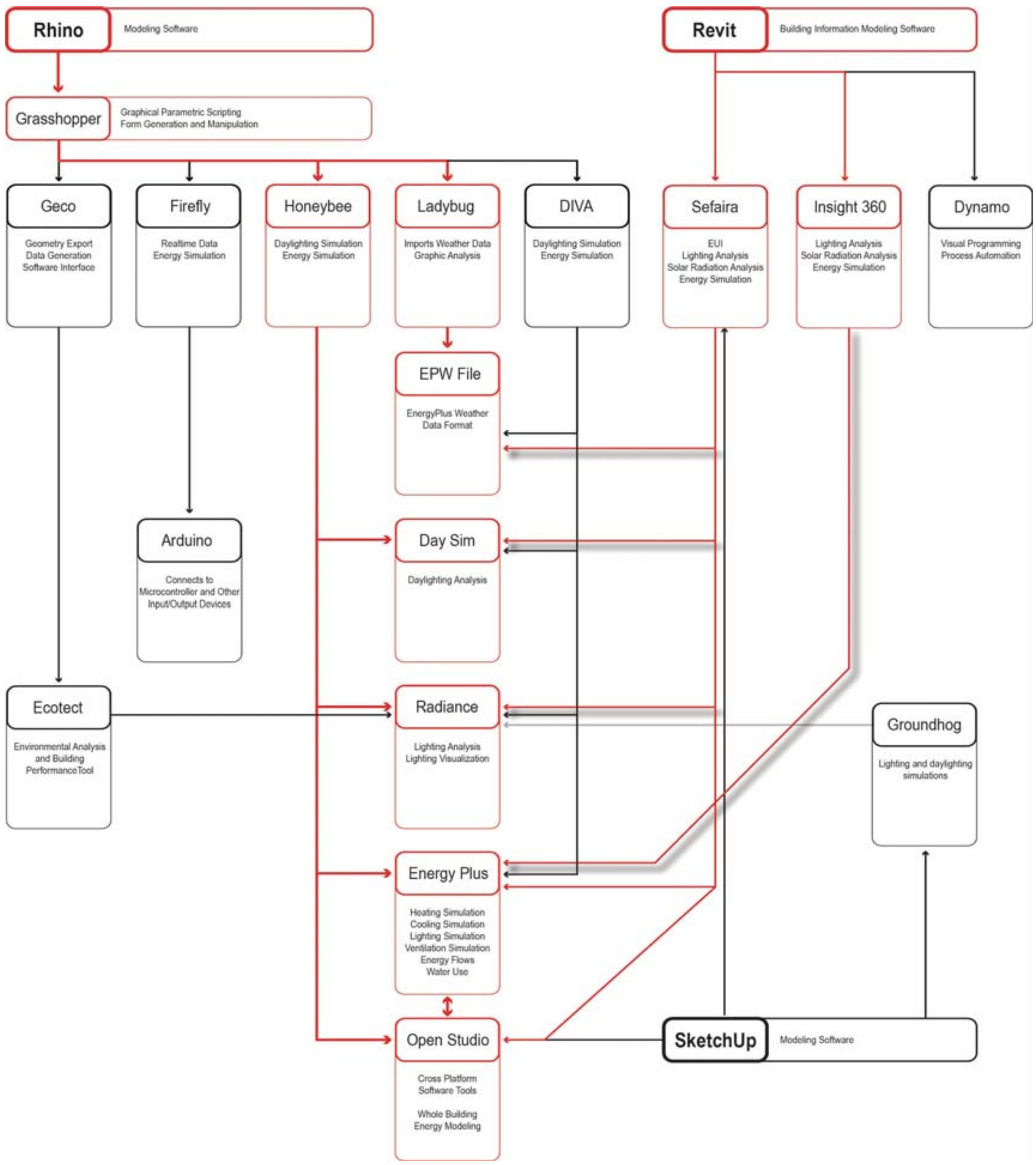

Figure 2: BPS and parametric workflows for Rhino, Revit and SketchUp. The workflows and software applications explored in this research are shown in red. Source: (Author 2017)

The next section reviews a case study, which was used to evaluate this framework.

3.0 EVALUATION OF THE FRAMEWORK AND CASE STUDY

A prototype building located in the financial district of Boston was used as a case study to evaluate the above discussed framework, and the building site is shown in Figure 3a. The evaluated workflows included Honeybee and Ladybug (Rhino 3D), Insight 360 (Revit) and Sefaira (Revit) software applications. The building is divided into a low-rise portion of five stories, and a high-rise portion of 15 stories. Floor-to-floor height was 3.7 m (12 ft), with a total height of 73.2 m (240 ft). The perimeter zone depth was 14.6 m (48 ft). The surrounding buildings were modelled from GIS data, and were included in the site model. Figure 3b shows Rhino model with surrounding buildings, and Figure 3c shows Revit model. Energy, solar radiation, and daylight analysis were run for the case study building using the three investigated workflows.

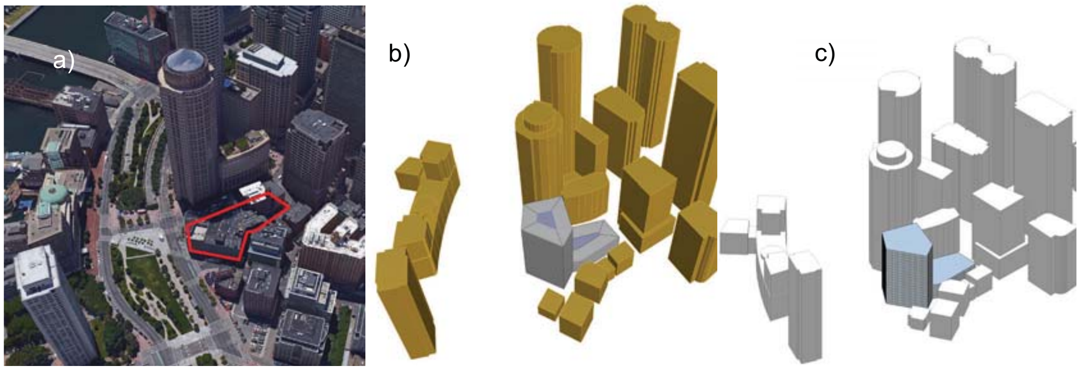

Figure 3: a) Case study building site outlined in red; b) Rhino model of the case study building, with surrounding buildings; and c) Revit model of the case study building, with surrounding buildings. Source: (Author 2017)

3.1 Rhino, Grasshopper, Ladybug and Honeybee Workflow

Figure 4 shows the Grasshopper definition used for the analysis and simulations within Rhino. Due to the graphic nature of Grasshopper, the organization of components is vital for understanding the user's own definition. As more components and connections are added to the canvas, the file becomes increasingly visually complex. The components are divided into four stages: geometry preparation, analysis preparation, analysis simulation and visualization of results.

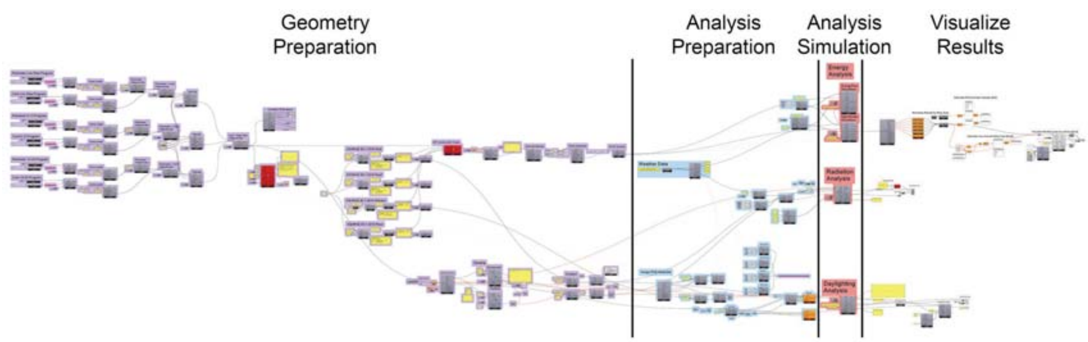

Figure 4: Grasshopper definition used for the analysis. Source: (Author 2017)

Honeybee exports model geometry and settings to EnergyPlus, which performs the energy simulation. The simulation options that were parametrically controlled in Honeybee included window-to-wall ratio (WWR), temperature set-points, wall and roof R-values, glazing U-values, SHGC and Vt, infiltration rates, HVAC systems, and lighting power density. Since the building geometry was complex, each run ranged from taking 20 to 60 minutes to complete. The number of windows had a direct impact on simulation time. Table 1 shows properties of investigated models and respective EUI results.

Table 1: Energy simulation results (Rhino and Honeybee).

Run Name	Variables	EUI kWh/m^2 (kBTU/ft^2)
Baseline	50% WWR; VAV w/ Reheat, 72°F/78°F Set-points; Wall: R-19; Roof: R-30; Window: .45/.38/.42 (U/SHGC/VT); Infiltration: .8 ACH; Lighting power density: 10.54 w/m^2	216.7 (68.7)
Low WWR	30% WWR	205.1 (65)
High WWR	80% WWR	237.8 (75.4)
Setpoints	68°F/82°F Set-points	161 (51)
Higher R-Values	Wall: R-40; Roof: R-60; Window: .2/.38/.42 (U/SHGC/VT)	185.7 (58.9)
Infiltration	Infiltration: .2 ACH	129.5 (41)

Lighting Power Density	Lighting power density: 3 w/m^2	212.4 (67.3)
HVAC Alternate	Fan coil units + DOAS	127.3 (40.4)
Best Case	50% WWR; Wall: R-40; Roof: R-60; Window: .2/.38/.42 (U/SHGC/VT); Fan coil units + DOAS, 68°F/82°F Set-points; Infiltration: .2 ACH; Lighting power density: 3 w/m^2	45.3 (14.4)

The Ladybug Radiation Analysis Tool uses the location of the sun for every hour of the year to determine how much radiation the exterior surfaces receive. Surrounding buildings are taken into account during this analysis. Simulation options that were parametrically controlled in Honeybee included analysis period, sky type, grid size, grid distance off surface, and legend (low and high bound). Results are shown in Figure 5a. Honeybee exports model geometry and settings to Radiance, which performs daylight simulations. The simulation options that were parametrically controlled in Honeybee included analysis period, sky type, grid size and distance off surface, radiance rendering parameters, and simulation type (illuminance, radiation, luminance). Typical results are shown in Figure 5b.

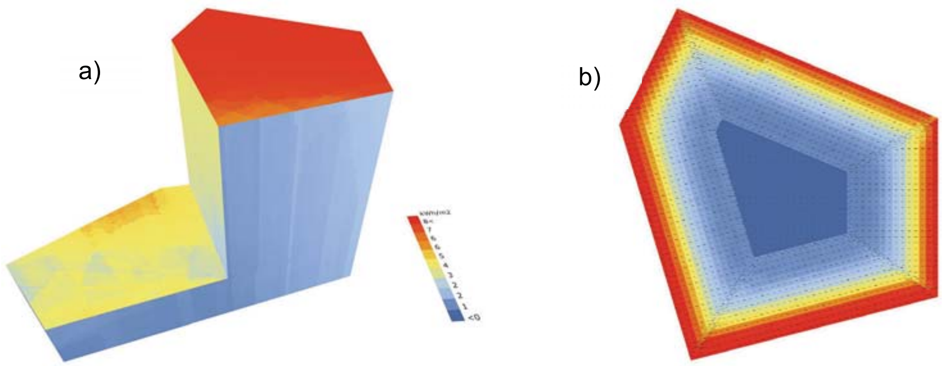

Figure 5: a) Solar radiation analysis results (cumulative, June 21); b) Daylight simulation results (June 21, WWR 80%). Source: (Author 2017)

3.2 Revit and Insight 360 Workflow

Two Revit models were built to simulate the same conditions that were set up in the Rhino model, primarily for the lighting analysis. One contained individual windows to simulate WWRs between 20% and 50%, while one large window per facade orientation was needed for a WWR ratio of 80%. The solar radiation analysis model utilized the massing model, as radiation results were desired for multiple facades, and not detailed elements. Revit exports the model geometry and settings to the cloud, where the simulations are run through EnergyPlus. Alternative design factors can be simulated by varying building loads, model geometry and systems. Table 2 includes a series of options that represent all of the alternate design factors that were simulated.

Table 2: Energy simulation results (Revit and Insight 360).

Run Name	Variables	EUI kWh/m^2 (kBTU/ft^2)
Baseline	50% WWR, no shading; ASHRAE VAV; Wall: R-19; Roof: R-30; Slab: R-23; Window: Double Low-E; Infiltration Rate: .8 ACH; Lighting: 1.1 W/SF; Daylighting: None; Building Type: Office, Schedule: 12/6	225 (79.1)
Low WWR	30% WWR	245 (77.6)
High WWR	80% WWR	271 (86)
Higher R-Values	Wall: R-38; Roof: R-60; Slab: R-23; Windows: Triple Low-E	241 (76.4)
Infiltration	Infiltration Rate: .17 ACH	233 (73.7)
Daylighting	Daylighting and occupancy Controls; Horizontal shading south and west (¼ window height); Lighting: 3 w/m^2	232 (73.7)
HVAC	High Efficiency VAV	218 (69.2)

HVAC alternate	High Efficiency Package System	144 (45.7)
Best case	30% WWR; Horizontal shading south and west (¼ window height); HVAC: High Efficiency Package System; Wall: R-38; Roof: R-60; Slab: R-23; Windows: Triple Low-E; Daylighting and occupancy Controls, Lighting: 3 w/m^2	87.5 (27.7)

The solar analysis tool was used to study the south facade of the building for average, cumulative and peak insolation. Figure 6a shows cumulative insolation values for June 21, where the effects of adjacent buildings can be seen on the low rise portion of the building. Insight 360 uploads the Revit model to the cloud, where daylight simulations are run. The 10th floor was simulated according to the LEED v4 EQc7 opt 2 analysis type, which measures the percentage of floor area that is between 300 and 3,000 LUX at 9am and 3pm on the equinox averages. Figure 6b shows the results of daylight simulation.

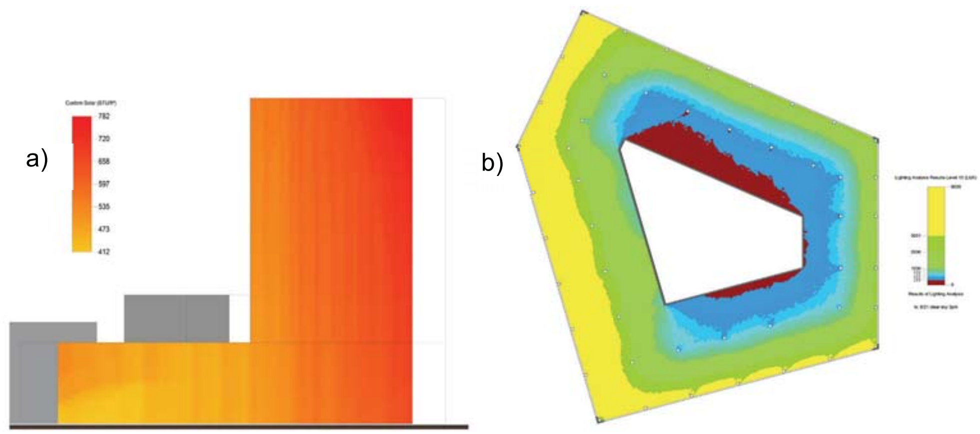

Figure 6: a) Solar radiation analysis results (cumulative, June 21); b) Daylight simulation results (June 21, WWR 80%). Source: (Author 2017)

3.3 Revit and Sefaira Workflow

Sefaira is able to use the same Revit model as Insight 360, with some changes. The total number of glazing planes cannot exceed 1,500. The window design for WWR of 30% and 50% had to be changed to one window per orientation, instead of multiple windows, so that Sefaira could process and run the analysis. When an energy analysis is run, the model is uploaded to the cloud, where it is run through EnergyPlus. The results are either displayed in the web-based application, or within the plugin in Revit. On average, it takes three to five minutes for each energy analysis run. Runs utilizing thermal comfort or natural ventilation factors take significantly longer to process. Runs can be cloned to use as alternates with different design options within the same model. Results are shown in Table 3. Solar radiation analysis cannot be performed in Sefaira. Radiance and DAYSIM are used to perform daylight simulations, and an example is shown in Figure 7.

Table 3: Energy simulation results (Revit and Sefaira).

Run Name	Variables	EUI kWh/m^2 (kBTU/ft^2)
Baseline	50% WWR, no shading; VAV - Return Air Package; Wall: R-19, Roof: R-30; Slab: R-23; Window: .45/.38 (U/SHGC); Infiltration Rate: .8 ACH; Lighting: 3 W/m^2	290 (92)
Low WWR	30% WWR	290 (92)
High WWR	80% WWR	296 (94)
Higher R-Values	Wall: R-40; Roof: R-60; Slab: R-23; Window: .2/.38 (U/SHGC)	271 (86)
Infiltration	Infiltration Rate: .17 ACH	148 (47)
Shading	.3 m horizontal shades; Internal blinds	296 (94)
HVAC Option 1	Fan coil units and central plant	243 (77)
HVAC Option 2	Radiant floor	180 (57)

HVAC Option 3	Active Chilled Beams	252 (80)
Best Case	50% WWR, no shading; Wall: R-4; Roof: R-60; Slab: R-23; Window: .2/.38 (U/SHGC); Infiltration Rate: .17 ACH; HVAC: Radiant floor	76 (24)

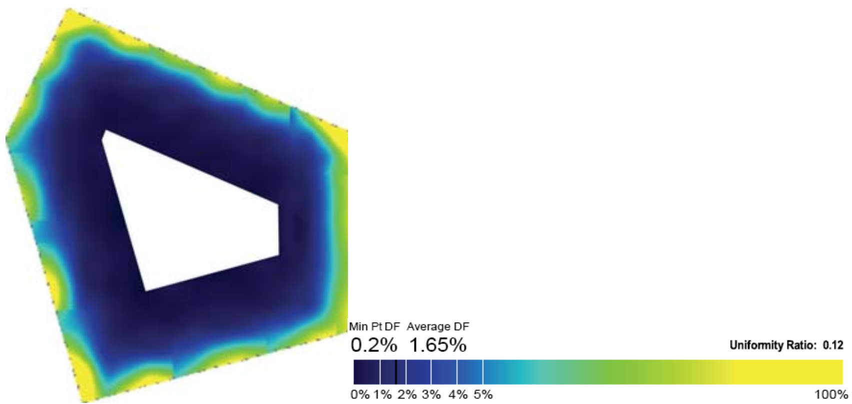

Figure 7: Daylight simulation results showing daylight factor. Source: (Author 2017)

4.0 DISCUSSION OF RESULTS

All simulations followed similar procedures for geometry preparation and visualization of results. Rhino, utilizing Grasshopper, Ladybug and Honeybee, provides significant customizability for parametric control of geometry, and offers different simulation types. The parametric nature of Grasshopper means that there is an infinite number of forms and strategies that can be investigated. One major drawback of this workflow is that the components have to be configured before the initial use. Once they are configured, the Grasshopper definitions can be repeatedly used on the same or different projects. Another drawback is the learning curve required to use the software. While other software programs utilize a series of dialog boxes to configure the parametric and simulation options, this workflow requires the user to set up all the components before visualizing the results. In terms of BIM-based workflow, Revit is the widely adopted BIM software, but both Insight 360 and Sefaira have certain benefits and drawbacks. Learning curve for Insight 360 is fairly light. With the energy and daylight simulations being run in the cloud, the results are quickly generated. The customizability of the daylight and solar radiation analysis is adequate, but the energy simulation parameters are limiting. Further, the lack of parametric tools to generate different WWRs or shading methods based on building orientation is a shortcoming. Additionally, the parametrically generated energy model cannot be used for daylight or solar radiation analysis. Sefaira is easy to install, as well as to use. The organization of energy analysis options within the web-based application makes tracking model changes straightforward. Sefaira's use of the cloud for simulations decreases the time necessary for calculations. The daylight analysis tool is excellent for analyzing the overall light levels and daylighting metrics, although its capabilities for showing specific values on a floor plan are limiting. Additionally, the plugin lacks support for solar radiation analysis.

Although the accuracy of the simulations was not the focus of this research, the energy analysis results were compared to each other, as shown in Table 4. All three program use the same engine, EnergyPlus, for the energy calculations. The only differences between the three tools are variation in inputs and geometry discrepancies between Rhino and Revit. The EUI results from Honeybee and Insight 360 were compared to Sefaira, and the differences were expressed as a percentage. Insight 360 and Sefaira results were the closest to each other, with the EUI results for Insight 360 baseline run being 16% lower than the Sefaira run, and the best case run 15% higher. The Honeybee baseline EUI result was 34% lower, while the best was 66% lower. The parameters for daylight and occupancy controls cannot be set in Sefaira. Insight 360 does not allow for control of the temperature set-points. Ladybug and Honeybee have support for both of these variables, but daylight and occupancy sensors were not simulated. The results from the daylight analysis are difficult to compare since detailed illuminance values were not collected for Sefaira. In addition, the reflectance values of floors, walls and ceilings cannot be set in Sefaira, so the illuminance values would not match even though the simulation engine is the same. Further testing would be needed to compare the accuracy of the daylighting analysis for Honeybee, Insight 360 and Sefaira.

Table 4: EUI results comparison (Honeybee, Insight 360 and Sefaira).

Run Name	EUI (kBTU/ft^2, kWh/m^2)	Difference (%)
Honeybee Baseline	68.71 (216.74)	-34%
Insight 360 Baseline	79.1 (225)	-16%
Sefaira Baseline	92 (290)	0%
Honeybee Best Case	14.4 (45.3)	-66%
Insight 360 Best Case	27.7 (87.5)	+15%
Sefaira Best Case	24 (76)	0%

CONCLUSION

The objective of this research was to investigate methods for integrating parametric design with building performance analysis. An ideal framework for integration of parametric and performance analysis procedures was developed. Then, the framework was tested using existing software applications, including BIM-based and non-BIM design software, parametric design and building performance analysis applications. Specifically, Honeybee and Ladybug (for Rhino 3D) were evaluated as a non-BIM workflow, while Insight 360 (for Revit) and Sefaira (for Revit) were evaluated as BIM-based methodologies. A case study building was used to test and evaluate the workflows, interoperability, modeling strategies and results. Three different building performance aspects were analyzed for each workflow: 1) energy analysis, 2) solar radiation analysis, and 3) daylighting. The framework applied to Rhino, Grasshopper, Ladybug and Honeybee offers a lot of options and customization for the parametric and simulation options. The lack of BIM integration in this framework is a drawback, which means that many designers may use it for conceptual and/or schematic design, but will migrate to a BIM-based software for schematic and design development phases. Insight 360 is able to integrate building performance simulations within a BIM environment. However, Insight 360 has only been available for a short time, and the functionality of the tool has its limits. Sefaira takes the customizability of Ladybug and Honeybee and the accuracy of Insight 360 and integrates it into a BIM environment. The energy and lighting analysis can be simulated quickly. The daylighting simulations have a few drawbacks, which include lack of support for detailed illuminance values at specific points on the floor plan, an analysis grid that cannot be adjusted by the user, as well as the inability to modify reflectance values of materials. Solar radiation analysis is also not included in Sefaira. However, the overall results show a promising course for integrating parametric design with building performance simulations. This would allow designers to evaluate the effects of design decisions earlier in the design stages. Moreover, by integrating the capabilities of parametric design and building performance simulations, multiple design variables can be tested rapidly, creating a more cohesive and effective design process.

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Ming Hu

Net Zero and Resilience: Similarities and Divergence

Net Zero and Resilience: Similarities and Divergence

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ABSTRACT: Two important contemporary domains in the built environment are “resilience” and “net zero,” both of which are associated with high-performance design and have their origin in the field of ecology. The energy efficiency and performance of buildings are common measuring indices accepted by multiple fields. The ultimate goal of net zero building has become a hot trend, and off-grid building has become the ultimate “high-performance” standard. Another emerging index is to measure and improve the resilience of buildings, capturing performance attributes such as environment, safety, durability, and functionality. Resilience has a broad range of implications in the built environment, such as recovery time during extreme events, emergency supply storage in buildings, off-grid/stand-alone potential, injuries during construction, and self-deconstruction capability (in order to minimize damage to the surrounding area in extreme events). Each of these categories uses different metrics. This paper provides an overview of research activities on the net zero building movement and the concept of resilience in the building and construction industry over the past 40 years. The purpose of this overview is to determine the main research areas within each domain and gain insight into the size of the different areas; explore how these research areas relate to each other and their intellectual origins; identify the most influential studies and thinkers; and identify potential research gaps. Conclusions are drawn relating to the major difference between the development of the net zero movement and resilience theory in the built environment and their respective relation to their ecological origin.

KEYWORDS: Net zero, resilience, ecology, divergence

INTRODUCTION

The built environment is responsible for a significant use of final energy (62%) and is a major source (55%) of greenhouse gas emissions (Anderson et al., 2015). Achieving environmental goals such as climate change mitigation, risk management, and disaster relief requires comprehensive methodologies to accurately assess the impact of buildings and the construction sector. The research to date focuses on either energy performance or resilience building. A large body of research has addressed quantifying building energy performance, and robust methodologies have been established and developed. With respect to resilience, some methods have been implemented and tested to quantify the ecological impact of large built environments that include multiple buildings. However, the assessment of the environmental impacts of built environments has been largely confined within either the energy field or the resilience field. This paper bases a review of contemporary studies in the net zero building movement and the resilience concept in the built environment on a systematic screening of peer-reviewed articles using title, keywords, and abstract. The purpose of this work is to create an overview of the scientific literature in the resilience and net zero domains within a built environment context, in order to understand its future direction.

1.0 THE CONCEPT AND DEVELOPMENT OF “NET ENERGY”

1.1. 1920–1930

The concept of “net energy” has always had its origin and a close relation to ecology. In 1920, Frederick Soddy, an English chemist and Nobel prize winner, first offered a new perspective on economics rooted in physics—specifically, the law of thermodynamics. Soddy suggested the importance of energy for social progress based on real wealth formation, as distinct from virtual wealth and a debt accumulation process (Hassler, 2014; Spash, 2017). He suggested that detailed accounting for energy use could be a good alternative to the monetary system, since the conventional monetary system treated economics as a perpetual motion machine, while in reality, as with any commodity, the actual wealth flow should obey the laws of thermodynamics (Spash, 2017; Hernandez, 2010). He argued that real wealth derived from the use of energy to transform materials into physical goods and services (Hernandez, 2010; Soddy 1933). However, his theory was largely criticized and ignored in his time, since he came to orthodox economics as a critic instead of a student. The contempt was mutual; in one of review of his book *Wealth, Virtual Wealth, and Debt*, the *Times Literary Supplement* remarked that "it was sad to see a respected chemist ruin his reputation by writing on a subject about which he was quite ignorant…" (Soddy, 1933). The ignorance and criticism of Soddy's theory contributed to the long-term silence of associated research development between 1930 and 1970.

1.2. 1930–1970

There is large gap in relevant literature between 1930 and 1970. The only notable development is the "Technical Alliance," a group of architects, engineers, economists, and ecologists who formed a professional association in 1919 that disbanded in 1921. It started an energy survey of North America with the aim of documenting the wastefulness of the entire society, the first recorded attempt to quantify "net energy" (Rapoport, 1976).

1.3. 1970–2006

In the 1970s, Romanian-American mathematician and economist Nicholas Georgescu-Roegen further developed ecological economics, or "eco-economics," based on Soddy's concepts. Eco-economics is a transdisciplinary and interdisciplinary field of research that includes ecology, economics, and physics. Georgescu-Roegen proposed the application of entropy law in the field of economics, where, he argued, all natural resource consumption essentially is irreversible. This approach had a profound impact on thinking about net energy flow or the life cycle of natural resources. Georgescu-Roegen was the first economist of some standing to theorize on the premise that all Earth's mineral resources will eventually be exhausted at some point (Boulding 1981); the concept of depletion of natural resources eventually led to the movement now known as sustainable development. He stated, "An unorthodox economist—such as myself—would say that what goes into the economic process represents valuable natural resources, and what is thrown out of it is valueless waste" (Georgescu-Roegen, 1971).

Another important development in the 1970s was the publication of the article "Energy, Ecology, and Economics" and the book *Environment, Power, and Society* by ecologist Howard Odum, who tackled the economic issue using ecological theories based on energy fundamentals. His system of energy economics was based on the concept of energy as the foundation for all forms of life, and transformable: he stated that "the true value of energy to society is the net energy, which is that after the costs of getting and concentrating that energy are subtracted (Odum, 1973). In the latter part of his career, in the 1990s, he developed a concept of "emergy": "emergy is a measure of energy used in the past and thus is different from a measure of energy now. The unit of emergy is the mjoule, as distinguished the evolution of self-organising open systems" (Odum, 1996). Emergy has attracted attention from academic researchers and is being applied to research in the building and construction industry as well as in natural ecosystems (Pulselli et al., 2007; Pulselli et al., 2009).

1.4. 2006–the present

The last recession, which officially lasted from 2007 to 2009, started with the bursting of the housing bubble. The so-called Great Recession played a role in the decline of fossil fuel CO_2 emissions. In the United States, CO_2 emissions decreased by 11 percent between 2007 and 2013. During this period, a variety of federal agencies and industry regulators proposed defined guidelines to measure and quantify net zero energy building across the globe. In 2008, the National Science and Technology Council (NSTC) issued the Federal Research and Development Agenda for Net-Zero Energy, High-Performance Green Buildings (NSTC, 2008). The National Institute of Standards and Technology defined net zero energy buildings as those that produce as much energy as they consume, over a defined period, and proposed measurement techniques (NIST, 2010]. Those guidelines set an agreed-upon platform and consistent technical guidelines worldwide so that practitioners, researchers, and regulators could communicate in a common language.

2.0. THE CONCEPT AND DEVELOPMENT OF "RESILIENCE"

2.1. 1940–1970

Resilience emerged in the field of ecology at the same time that net zero studies started to catch researchers' and practitioners' attention. Resilience has since developed into another important emerging concept in built environments. In the 1960s the ecological resilience concept was first introduced in studies of the stability of ecosystems. One of the pioneers was C.S. Holling, who is considered by many to be the father of ecological resilience theory, and who also introduced this use of the word "resilience." Holling believed that extending the ecological framework to other fields would be useful for understanding how society, individuals, and communities interact with natural ecosystems. The origin of this term has deeper roots that may be linked to the origins of ecosystem and systems ecology and attempts to mathematically model dynamic ecosystems in the 1940s and 50s (Lindseth, 2011). The concept of resilience emerged from concepts and approaches that drew from cybernetics and were critical of existing (perceived) simplistic approaches within population ecology. The idea that nature was composed of systems that may have properties such as resilience set the stage for more formal conceptualizations of the term by Holling and colleagues throughout the 1970s and 80s (Lindseth, 2011).

2.2. 1970–the present

Holling describes resilience as dynamic and complex, in juxtaposition to views of a stable and simple nature. This established view defines stability in ecological systems as their ability to return to an equilibrium state following a disturbance. In contrast, Holling suggests that resilience “is a measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables.” In this early formulation by Holling, it is the instability of a system that conveys its resilience.

These ecological origins for the modern concept of resilience are in some ways at odds with notions of resilience from other disciplinary uses. Engineering resilience refers to how a system responds to disturbances in light of the system’s stability with respect to an equilibrium steady state (Holling, 1996; Liao, 2012; Wang & Blackmore, 2009). Engineering resilience derives from notions of resistance to and recovery from disturbances, focusing on the ability and speed of a system to bounce back to its initial, equilibrium conditions following a disturbance event (Liao, 2012; Wang & Blackmore, 2009).

The ecological concept of resilience has seen extension of its domain to include both social-ecological resilience and a paradigm that is applicable to resource management (Berkes & Folke, 1998; Folke, 2006). This evolution parallels the development of the Resilience Alliance, a collective of institutions and researchers that implement “resilience thinking” for the study and management of systems from an interdisciplinary perspective. Here, resilience extends from a concept focused on buffering stress and maintaining function to one where the focus is on the adaptive capacity to transform and innovate a system to sustain and reorganize in the face of stress and disturbance (Folke, 2006). These principles can be put into practice to manage a system for resilience (Adger, Hughes, Folke, Carpenter, & Rockstrom, 2005; Biggs et al., 2012; Walker & Salt, 2006).

3.0. LITERATURE REVIEW METHOD AND MATERIALS

Academic research documents on resilience and net zero within the built environment were reviewed to: 1) identify the main research areas within the domains; 2) gain insight into the size of the different areas; 3) gain insight into how the areas relate to one another; and 4) identify any research gaps. The screening and review entailed three steps. First, key search terms on the net zero movement and resilience concept were used to scan the Web of Science database and Elsevier’s Scopus database. The screening excluded non-scientific or technological literature, and multiple combinations of the search terms were used. Combinations of terms included “resilience” with “city,” “building,” and “built environment,” and “net zero” with “buildings” and “built environment.” Articles, conference proceedings, books, and book chapters were included. In total, 1821 papers were found from a variety of disciplines in the resilience research domain, and 592 papers were found in the net zero research domain.

After screening, a computer program (VOSviewer) was used to analyze and determine influential studies, thinkers, and concentrated research topics and their correlations. VOSviewer is a tool used for citation analysis, a method used to quantitatively evaluate scientific and academic literature to assess the quality of an article or the impact of an author, journal, or institution. Citation analysis is also the “examination of the frequency, patterns, and graphs of citations in documents” (Wikipedia). For this project, VOSviewer was chosen for its ability to create a two-dimensional distance-based map based on a co-occurrence matrix; this process consists of three steps. The first step is to obtain a similarity matrix; in the second step, a map is constructed by applying the VOS mapping technique to the similarity matrix; and in the final step, the map is translated and reflected (Van Eck et al., 2010). In this review several types of maps were created: 1) Map of terms: Use all text data to generate a term map based on the frequency of the occurrence of specific text, in order to understand the research topics/clusters in one domain; 2) Map of keywords: Use co-occurrence of keywords data to construct a map representing the relationships between knowledge groups and different research fields; 3) Map of authors: Use citation data to construct a map to identify the influential thinkers in research domains; 4) Map of journal: Use citation data to construct a map to identify the influential journals/sources in the research domains.

As a last step, after creating an overview of research activities, more selective and focused reviews were carried out on 20 of the most influential papers in each track, as a means of drawing conclusions.

4.0. FINDINGS

4.1. Research topics on resilience

First, in order to identify the research focus areas, a term map was created based on a corpus of scientific publications amounting to 1821 articles. The co-occurrence frequencies of terms (text) of these articles were determined based on a minimum number of 20 occurrences of a term (10 is the default and recommended number, according to program manual; in order to narrow down the research, we used double the default number); out of the 39,855 terms, 496 met the threshold. For each of the 496 terms, a relevance score was then calculated, based on this score, the most relevant terms were selected; the default choice in the program is to select the 60 percent most relevant terms. Altogether, 275 terms were selected for the resilience research study; the result is shown in Fig. 1. Based on the VOSviewer clustering technique, the terms in the data set were divided into four clusters, with the colors indicating the different research clusters.

- Cluster 1 (red): technology, application, energy efficiency, performance, event (left)
- Cluster 2 (blue): factor, finding, relationship, health (right)
- Cluster 3 (green): urban resilience, governance, understanding/theory, ecosystem/eco service (middle)
- Cluster 4 (yellow): disaster, hazard, mitigation (upper)

These clusters represent four separate focus areas across different scales, which may be referred to as ***techniques and application of resilient practice*** (cluster 1), ***cause and relation of resilient factors*** (cluster 2), ***the understanding of the mutual influence of urban resilience and ecosystem*** (cluster 3), and ***disaster and hazard relief*** (cluster 4). The four focus areas can be tied to Hollings's clearly described resilience definitions: cluster 2 is derived from ecological resilience, cluster 3 is a continuation of social-ecological resilience, and cluster 4 is related to engineering resilience. Cluster 1 is about the translation or transformation of theory to application.

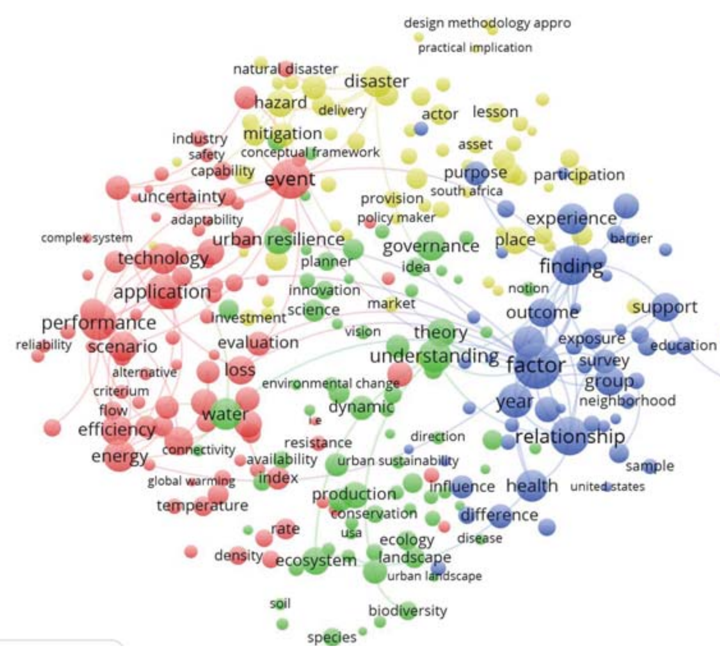

Figure 1: Term map representing the main research areas on resilience in the built environment.

4.2. Research topics on net zero

The same process used in studying the research domain on resilience was applied to the net zero research domain. A term map was first created based on a corpus of scientific publications, using keywords, titles, and abstracts from 519 documents: articles, book chapters, and books. This is many fewer than the quantity of research activities in the resilience domain. The co-occurrence frequencies of terms (text) of journals were determined based on a minimum number of 15 occurrences of a term, out of the 15,438 terms, which is only half of the terms associated with resilience; 167 met the threshold. For each of the 167 terms, a relevance score was then calculated. Based on this score, the most relevant terms were selected; again, the default choice in the program is to select the 60 percent most relevant terms. Altogether, 100 terms were selected for net zero research; the result is shown in Fig. 7. Based on the VOSviewer clustering technique, the terms in the data set were divided into four clusters, and the colors indicate the different research clusters.

- Cluster 1 (yellow): effect, rate/period (left)
- Cluster 2 (red): project/standard, net zero energy/practice, home (right)
- Cluster 3 (green): emission, energy source, water (middle)
- Cluster 4 (blue): zero energy building, heating/cooling/temperature, ventilation (upper)

These clusters represent four focus areas across different disciplines related to net zero research activities, which may be referred to as ***net zero impact*** (cluster 1), ***net zero energy practice in industry (***cluster 2), ***net zero emission*** (cluster 3), and ***techniques to achieve net zero energy building*** (cluster 4). Cluster 4 has the most research activities, which center around net zero building and temperature control. It is commonly known that net zero energy building mainly focuses on operating energy reduction, as heating and cooling together account for more than 50 percent of overall operating energy consumption, and the outside ambient temperature has a large influence on building heating and cooling load. Those factors could explain why heating, cooling, and temperature appear as critical sub-topics in cluster 4. Cluster 2 and cluster 3 are almost the same size, with cluster 2 containing more items and cluster 3 having items aggregating towards one major focus area: "emission." Cluster 1 has the fewest research items and is connected to both cluster 3 and 4, but has no connection to cluster 2. The disconnection between clusters 1 and 2 indicates the limited verification and measurement of the effectiveness of net zero development, particularly in the building industry. This lack of verification and measurement causes some suspicion and challenge to the validity of net zero building design and approach, which present a challenge and a gap as well as opportunities.

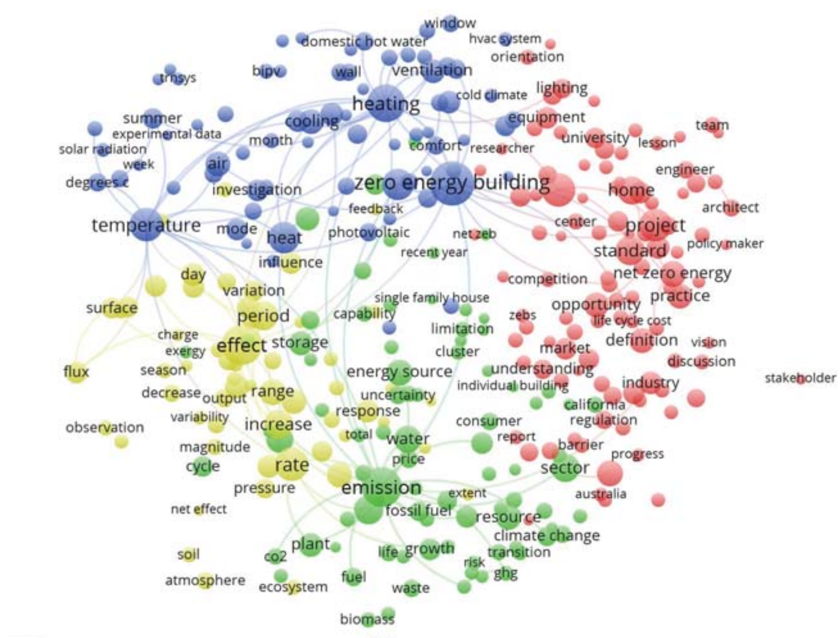

Figure 2. Term map representing the main research areas on net zero in the built environment.

5.0 Findings and discussion

The major findings from the review are as follows:

- A substantial gap exists between disaster mitigation, ecosystem service, and green infrastructure development.
- There is a disconnection between scientific understanding of resilience theory and translation of resilience attributes into practice.
- There is limited verification and measurement of the effectiveness of net zero development and practice, particularly in the building industry.
- The search for a consistent and commonly accepted definition of net zero building has been a singular focus in the past five years due to the strong interest and the quantity of new construction projects around the world.

The major differences between the research domains in net zero and resilience are: 1) singular versus transdisciplinary focus; 2) the distance and separation from the ecological origin; 3) developing countries versus global countries; and 4) top-down versus bottom-up. Each is discussed below.

Singular versus transdisciplinary focus: In terms of research activities, resilience studies in the built environment cover a variety of disciplines with a holistic approach, and the major activities and development have not shifted or moved away from its ecological origin. With the exception of building resilience, most studies and findings are, at a high level, aiming to provide a framework to respond to major natural disasters and man-made events. Beyond this high-level framework, some research activities focus on measurement, performance, and applicable strategies, which are the response to natural events happening in the built environment (urban context). One big gap discovered in this review is that there is a large disconnection between ecosystem and disaster relief: green infrastructure and ecosystem services have not been systematically integrated in future disaster mitigation and management work. Future research could bridge this gap. Unlike resilience studies, research activities on net zero have moved away from its ecological origin, and currently have a relatively narrow focus on operating energy and related environmental impact. The life cycle approach of the original net energy concept developed from ecology has been replaced by a performance-driven, building-types-driven engineering approach. In general, resilience studies in the built environment take a more holistic and comprehensive approach and incorporate long-term strategies, while net zero studies has a more limited scope. In urban resilience studies, the research recognizes the urban ecosystem's vulnerability and the necessity to adapt to the impact of climate change. In net zero studies, the research only addresses the CO_2 emissions from buildings that impact climate change, and does not consider the influence of climate change on the building industry; the net zero work also has limited attention to how climate change or ecosystem change could affect net zero building design strategies.

Developing countries versus global trends: With respect to influential studies, thinkers, and regions, the United States is the most active country in the past 45 years, particularly in the resilience domain, as the resilience theory was originated in the US. Net zero research is most distributed in developed countries, including the United States and western European countries. The United States does not have a clear lead in net zero research for two reasons: policy mandates and available resources. Unlike the EU countries, with their clear net zero building goals and objectives to be met, the United States still operates on a voluntary basis with any target related to high performance and net zero building: LEED, the living building challenge, and the 2030 challenges are all voluntary programs. It appears that resilience not only covers a wide range of fields, but also has research contributions from both developing and developed countries, since the developing countries are more vulnerable to natural disasters due to their lack of robust infrastructure and prevention methods. The dependence on active systems and photovoltaics as renewable energy sources makes it difficult and expensive to promote net zero energy building in developing countries. Integrating the holistic and multi-disciplinary resilient approach in net zero development will be helpful.

Top-down versus bottom-up: Current resilience practice in the building and construction industry follows a top-down approach, with the aim to solve immediate and short-term problems and respond to immediate shocks and stresses. The US Department of Housing and Urban Development (HUD) leads the initiative to incorporate resilient building codes into housing programs. HUD published a climate change adaptation plan in 2014 and identified major vulnerability and risks related to climate change (HUD, 2014). The Federal Emergency Management Agency (FEMA) is exploring strategies to incentivize the adoption and enforcement of building codes at a state and local level through a variety of programs. The National Institute of Standards and Technology (NIST) has organized and conducted research and published results to be shared with the building industry, such as tornado hazard maps; NIST hopes to better equip design and construction teams with sufficient information in order to build more resilient cities. The US Army Corps of Engineers launched a website to promote the latest building regulations and codes in the hope that the information will be integrated into urban and town planning. In 2016, the Department of Homeland Security released a toolkit to help communities develop a resilient infrastructure building plan in order to reduce the risks and damage caused by natural disasters. Other federal agencies such as the Department of Energy, Environmental Protection Agency, and US Department of Agriculture have their own resilience initiatives and activities. This kind of top-down approach has inherent limits, however, including inflexibility and lack of integration of adaptive capacity development. Also, the broad definitions of resilience suggest multiple methods to measure the resilience of built environment, which have not yet been synchronized. Furthermore, there is no clear outline of a path for practicing resilience in building design, and the outcome of resilience is difficult to define and measure.

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An Analysis of Energy Efficiency of a Smart Envelope Package in Residential Buildings

An Analysis of Energy Efficiency of a Smart Envelope Package in Residential Buildings

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ABSTRACT: In the 1980s and 90s, the construction codes of South Korea did not require substantial insulation, which resulted in a large amount of cooling and heating energy uses in high-rise residential complexes. About 3.6 million residential units were constructed during that period. Since 2014, the Korean government initiated an incentive program to remodel the aged residential units, and only about 2,000 units have taken advantage of the incentive in the last 3 years. Over the last two to three decades, residents have extended living spaces to the balcony areas which were designed to serve as a sun space using passive solar principles. The energy consumption has consequently increased significantly due to the loss of thermal buffer area and an addition of the conditioned space. This study proposes a Smart Envelope Package that can replace an existing exterior window enclosing the living room area of such residential units. This smart envelope package is designed to reduce building's energy use functioning as a Double Skin Façade, and comes with Building Integrated Photovoltaics (BIPV) to generate electricity, an Energy Storage System (ESS), an A/C condenser, sun-shading devices, automated operable windows and an air filtration system. The Smart Envelope Package aims to reduce cooling and heating energy consumption and to produce electricity during daytime as well, which will be stored in the ESS and used during peak hours and nighttime. The trend of adopting prototype floor plans with very little modifications 20-30 years ago makes the package possible to be modularized and pre-fabricated. This paper discusses optimal sustainable design strategies for the development of the Smart Envelope Package system. The main goal and result of this paper is to find a new product to reduce the energy consumption in old high-rise residential building in South Korea.

KEYWORDS: Smart Envelope Package, Energy Efficiency, High-rise residential building, EnergyPlus

INTRODUCTION

Buildings use 40% of total energy in the world, and this is steadily increasing due to industrial development (EIA, 2017), which means, to reduce the total energy consumption, building energy has to be reduced. In order to reduce it, researchers and governments take advanced approaches through innovative design and smart controls. High-efficiency equipment has been introduced to improve energy efficiency and reduce energy consumption of existing buildings. South Korea made a dramatic economic growth (Chang, 2006), and in terms of the residential spaces, high-rise building became one of the most dominant types of housing (Yuen, 2011). Research shows that in South Korea there are 10 million multi-family residential units (called "apartment" in South Korea), which is 60.1% of all the housing. Out of the total apartments today in South Korea, 36.2% or 3.6 million apartments were built 20 years ago or earlier (Statistics Korea, 2016). New buildings consume relatively less energy than buildings built in the past due to the added efforts such as utilizing highly efficient insulation, lighting and equipment. At the time of construction of the old buildings, the construction codes were not strict enough to require good insulation, which resulted in a large amount of cooling and heating energy uses. Out of the 3.6 million residential units constructed about 20 years ago or earlier in South Korea, only very few (about 2,000 units) have been remodeled through a government incentive program since 2014. In terms of the energy sources, South Korea ranked 7th for CO_2 emissions per person in 2016. To reduce the CO_2 emissions, each country has to use and develop renewable energy following an effort in making high-performance buildings. Unfortunately, South Korea ranked 8th for electricity production from fossil fuel, non-ranked for solar power production and ranked 10th for other renewable energy in 2016 (Olivier et al., 2017). To reduce the CO_2 emissions, South Korea revised its policies in 2001 for enhanced building regulations and policies; and apartment buildings were required to be energy-efficient buildings. As a result, 1,380 residential buildings have received preliminary Building Energy Efficiency Certification from 2001 to 2014. In 2001, however, only one residential building was able to get it. After that, the number of certified buildings increased every year, and 267 new residential buildings obtained this certificate in 2014 (Park et al., 2015).

This paper presents the development of a Smart Envelope Package (SEP) that integrates multiple passive and active strategies that aim to reduce CO_2 emissions and increase renewable energy market.

Various research projects are underway to reduce the building energy uses and CO_2 emissions by using high efficiency heating, ventilation, and air-conditioning (HVAC) systems, high performance insulation, and optimal control systems. Even if high efficiency equipment is used, high efficiency would not be readily realized without optimal control. Optimal control algorithms can be developed by utilizing Artificial Intelligence (AI) technologies. An AI control system will be developed and used to control the devices and equipment installed in the SEP, such as window, blind and ESS. This paper is focused on confirming the potential of building energy savings through SEP itself and control strategies. The application of optimal control to achieve the maximum energy efficiency will follow in the future.

1.0 LITERATURE REVIEW

The significance and prevalence of the reduction of building energy consumption and CO_2 emissions enabled a number of studies to be carried out. In order to reduce building energy consumption and CO_2 emissions, a number of studies suggested remodeling or retrofitting of existing housing. Morelli et al. conducted research on three ways of retrofit-measures, which were implemented in a test apartment using practical experiences. The three types were i) changing interior insulation, ii) hanging exterior window, and iii) installing a decentralized mechanical ventilation system with heat recovery in an old Danish multi-family building to make a nearly-zero energy building. The results of this study were that it is difficult to achieve a nearly-zero energy building without generating renewable energy on site, although these methods could reduce 68% of building energy. Dallo et al. (2012) conducted research about the methodology for evaluating the energy saving from retrofitting residential buildings. This methodology, which contained a survey, changing windows, roof, insulation, and facades, could reduce energy used by residential buildings in European Union (EU) up to 24.8% by 2020. Arumagi and Kalamees (2014) analyzed building energy use for historic wooden apartment buildings. The results of this study were that building energy use could be reduced by 20% to 65% with an improvement of HVAC system and building envelope.

Most of the studies have been conducted to reduce residential building energy use by means of improving the efficiency of building envelope and HVAC system. Remodeling by changing the envelope and the HVAC system is time consuming, and residents might not be able to use their rooms while the remodeling takes place. The proposed SEP is a new style of Double Skin Façade (DSF). There is no such study directly related to SEP, but there are many studies about DSF. Most of the studies about DSF focused on reducing building energy consumption. Gelesz and Reith (2015) compared DSF with triple glazing. They found that DSF could reduce 9% to 12% of cooling energy without increasing heating energy in Central Europe. However, the DSF system in the study was used only for buffer effect. Gratia and Herde (2007) conducted simulation study to analyze heating and cooling energy depending on whether DSF was installed (south, north, east and west). They found that the amount of decrease in energy was different. Heating load decreased but cooling load increased regardless of the installed direction. The DSF system was not the best way to reduce building energy. They reported that weather and building conditions had to be considered before the application of DSF systems. This was a simple DSF system where only a window was attached on the exterior. It did not combine BIPV, ESS or other systems for multi-functional DSF system like SEP.

The objective of this study is to make a new style of DSF system and investigate the heating and cooling load variation caused by this new SEP which includes BIPV and ESS. The DSF system will act as a thermal buffer area and a new exterior envelope of apartment. It is expected that the DSF system with a window control (On/Off) has potential to improve energy efficiency of building. The BIPV will generate electricity, which will be stored in the ESS. The electricity stored in ESS will be used to reduce peak heating and cooling loads and supplement the energy required in building.

2.0. RESEARCH SCOPE

This paper presents the results of an early-stage research that develops a SEP for building energy savings of old high-rise residential buildings and proposes an optimal control of the envelope interacting with the residents. This paper lays out the initial design of the SEP and an analysis of how much energy can be saved through this SEP system. This paper focuses on old high-rise residential buildings built more than 20 years ago in South Korea. The 2016 Population and Housing Census (2016), which is an annual report published by Statistics Korea, reported that an average area of high-rise residential units built before 1979 is 80.4m^2, the one from 1980 to 1989 is 65.6m^2, and the average built during 1990 to 1999 is 70.0m^2. Seoul Housing & Communities Corporation, founded by Seoul Metropolitan Government (SMG), provides three common floor plans of high-rise residential buildings as 59m^2, 85m^2, and 115m^2. This study used a common high-rise residential building floor plan (59m^2) to analyze building energy use. These areas do not include the balcony, the area to which many residents have extended their living room. Since this study focuses on the SEP system to be installed in this extended balcony area or an additional floor space of an apartment, the total floor area of the simulation model is 69.3m^2 which became the Base Model. Then a design model was developed with SEP being attached without BIPV and ESS for comparison of building energy use and the impact by SEP itself. After that, the BIPV and ESS were integrated with SEP to know how much electricity it generated and how much building energy and peak energy could be reduced by the generated electricity from the BIPV.

3.0. SIMULATION MODELING OF SEP

3.1. Simulation program

The EnergyPlus program (version 8.8) was used to create a sophisticated simulation model, which is a robust building energy simulation program developed by Department of Energy (DOE) in United States (Wall and Bulow-Hube, 2003). EnergyPlus is capable of dynamic analysis of thermal conduction, radiation, and convective heat transfer, and it can mathematically verify the energy and thermal environment of the building that changes according to building envelope and indoor and outdoor weather conditions. EnergyPlus uses a heat balance method which is recommended by American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). EnergyPlus can calculate and analyze building energy, and it is possible to accurately predict and analyze the amount of building energy to be reduced through the SEP that is covered in this study. EnergyPlus also has PV and ESS modules (U.S. DOE, 2017a), which is suitable for this study. In addition, the basic control of window opening (On/off control) can be performed since the user can input the desired control.

3.2. Simulation model development

A middle unit was selected out of a multi-story apartment complex shown in Figure 1. Based on the most common floor plan of old residential units in South Korea, a simulation model was made using EnergyPlus version 8.8. To avoid the effect from the ground and external roof, the SEP was applied to the middle floor as shown in Figure.1. In order to analyze in more detail, this study considerd four cases as shown in Table.1.
Case 1 was the base model, Case 2 was the SEP case without window opening control, BIPV or ESS to analyze the reduction of building energy consumption through the passive effect from the SEP itself. Case 3 added a window opening control to see the change in building energy use. Case 4 was the final case of this study with BIPV and ESS being added to the Case 3 to know how much electricity was generated and how much building energy could be covered by the BIPV and ESS.
The size of this package was 6.6m (W) x 0.8m (D) x 2.2m (H). There were total 12 windows, 4 of which were set on the top of the wall that were motorized and another 4 were set in middle of the wall operable by occupants. Four large windows were fixed with double glazing in the Case 2 and 3, and BIPV in the Case 4.

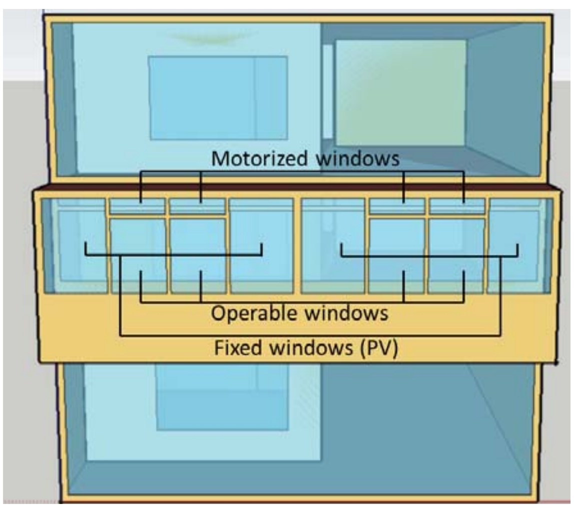

Figure 1: Simulation model

Table 1: Description of the cases

Case 1	*Base model*
Case 2	*Smart Envelope Package*
Case 3	*Case 2 + window opening control*
Case 4	*Case 3 + BIPV and ESS*

To make the simulation model, building materials provided by “Energy Technology Transfer and Diffusion” which was published by Korea Institute of Energy Research in 2007 were used. This report provided common building materials and construction of the residential units in South Korea. Tables 2 and 3 show the building construction and characteristics of materials used to develop the simulation model. All windows were double glazed of which each pane is 6 mm. The blind, which was set between SEP and building, has a slat width of

25 mm, slat separation of 25 mm, slat thickness of 1 mm, and the solar reflectance for both front and back side of 0.5 which are default values in the EnergyPlus simulation program.

Table 2: Construction of simulation modelling

	Layers			
Interior wall	Gypsum	air	Gypsum	
Exterior wall	Stucco	Concrete	Insulation	Gypsum
Floor	Carpet	Concrete		
Roof	Roof membrane	Insulation	Metal Decking	
Window	6mm clear	air	6mm clear	

Table 3: Characteristics of building materials

Material	Conductivity (W/m·K)	Density (kg/m³)	Specific Heat (J/kg·K)
Stucco	0.6918	1858	837
Concrete	1.729	2243	837
Insulation	0.0432	91	837
Gypsum	0.16	784.9	830
Roof membrane	0.16	1121.29	1460
Metal Decking	45.006	7680	418.4

3.3. Simulation conditions

A TMY3 weather file was used for the weather condition of Incheon, South Korea. The internal heat gain and cooling and heating setpoints are shown in Table 4 which is also provided by Energy Technology Transfer and Diffusion 2007 report. Schedule of each internal heat gain also follows Energy Technology Transfer and Diffusion 2007, and the cooling and heating in the building were in operation all day.

Table 4: Internal heat gain and cooling and heating setpoints

Internal heat gain	People	22.4 m^2/person
	Lighting	4 W/m^2
	Equipment	14 W/m^2
Set-point	Cooling	26℃ (May-Oct.)
	Heating	22℃ (Nov.-Mar.)

4.0. Analysis

Before analysis of building energy consumption of all cases, to confirm the energy efficiency of the SEP itself, a comparison of the heating and cooling energy between Case 1 and Case 2 was carried out. Figure 2 shows the results. When the SEP was set on the southern exterior wall (Case 2), the heating and cooling loads were decreased. The annual heating and cooling loads for Case 1 and Case 2 were 65.24 kWh/m²·year and 49.77 kWh/m²·year respectively. This means the heating and cooling loads can be reduced by 23.71% by the SEP itself. As mentioned above, Case 2 is the SEP without any control, BIPV, and ESS, which implies the reduction of the heating and cooling energy will probably be larger through the use of control, BIPV, and ESS.

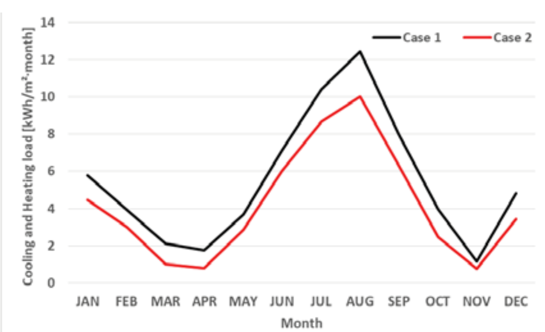

Figure 2: Comparison of cooling and heating loads between Case 1 and Case 2

Figure. 3 shows the hourly temperature of zones where the SEP is applied and the living room. The living room was a conditioned zone of which temperature changes were based on the heating and cooling schedule. In terms of the package zone temperature, it was an unconditioned zone of which range of temperature was higher than the living room. During the daytime, the package zone temperature was higher than the living room temperature, and it was lower than the living room during the nighttime. Based on this result, the window opening schedule was created. EnergyPlus does not have a function for the control of the window, thus it is always closed in the modeling.
To solve this problem, this study made use of “Zonemixing” and “Air Flow Network” to create a window opening control. The Air Flow Network model is able to simulate the heat transfer of airflow caused by wind pressure or thermal pressure (Wang et al., 2017). This model was used to assume the window opening control. But the Air Flow Network could be used for exterior windows of the double skin only. Therefore, “Zonemixing” function was used for the interior window control. “Zonemixing” function was used for indoor air mixing between two or more zones. The Air Flow Network model removed the heated air from the package to reduce the cooling load during the summer. This study assumed that “Zonemixing” function could be used for opening control of interior window, and “Air flow network” function could be used for exterior window opening control.

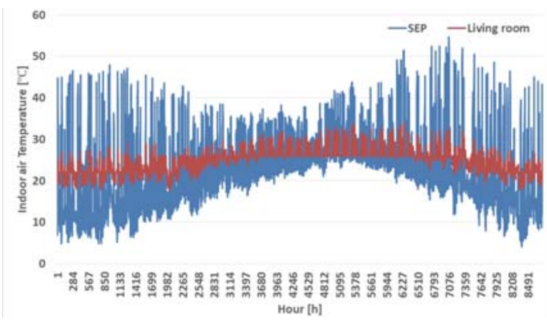

Figure 3: Zone temperatures of the SEP and the living room.

Table 5 shows the window opening schedule. “T_{OA}” means Outdoor air temperature, “T_{LR}” is the living room temperature, “T_{PKG}” is the package temperature, “*Window-$_{Ex}$*” is exterior window opening schedule, and “*Window-$_{In}$*” is interior window schedule.
When outdoor air was higher than indoor temperature, if the package zone temperature was higher than both the living room temperature and outdoor air temperature, both interior and exterior window would close. If the package zone temperature was higher than living room temperature and lower than outdoor air temperature, exterior window would open and interior window would close. If package zone temperature was lower than living room temperature and higher than outdoor air temperature exterior window would close and interior window would open. And if the package zone temperature was lower than both living room temperature and outdoor temperature, both exterior and interior window would open.

Table 5: Window opening schedule

		$T_{PKG} > T_{LR}$	$T_{PKG} > T_{LR}$	$T_{PKG} < T_{LR}$	$T_{PKG} < T_{LR}$
$T_{OA} > T_{LR}$ (Cooling)	*Window-$_{Ex}$*	*Close*	*Open*	*Close*	*Open*
	Window-$_{In}$	*Close*	*Close*	*Open*	*Open*
$T_{OA} < T_{LR}$ (Heating)	*Window-$_{Ex}$*	*Open*	*Close*	*Open*	*Close*
	Window-$_{In}$	*Open*	*Open*	*Close*	*Close*
		$T_{OA} > T_{PKG}$	$T_{OA} < T_{PKG}$	$T_{OA} > T_{PKG}$	$T_{OA} < T_{PKG}$

When outdoor air temperature was lower than indoor temperature, if the package zone temperature was higher than both the living room temperature and outdoor air temperature, both interior and exterior window would open. If the package zone temperature was higher than the living room temperature and lower than outdoor air temperature, exterior window would close and interior window would open. If package zone temperature was lower than the living room temperature and higher than outdoor air temperature exterior window would open and interior window would close, if package zone temperature was lower than both living room temperature and outdoor temperature, both exterior and interior window would close.
In this study, only “Close” (or “0”) and “Open” (or “1”) are used for the control, which means the value here are fractions. To make more detailed control, the “Schedule:File” object in the EnergyPlus is used. A one-year control schedule was created in the MS Excel program by comparing the temperatures, then that schedule was used for the simulation model.

Figure. 4 shows a comparison among Case 1, 2, and 3. By using the window opening control, the heating and cooling loads were reduced even more than Case 2. As mentioned above, by installing the SEP, the heating and cooling loads were reduced by 23.71%. Annual heating and cooling load of Case 3 is 44.10 kWh/m²·year, 32.40% less than Case 1 and 11.39% less than Case 2. It can be seen that the load reduction is possible by a simple window opening control. When an advanced control algorithm such as control by Artificial Intelligence (AI) technology is implemented, more load reductions are expected.

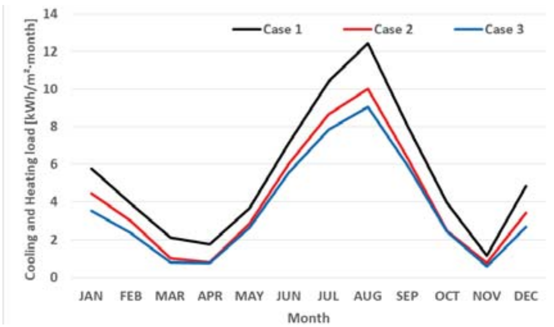

Figure 4: Comparison of cooling and heating loads among Case 1, 2 and 3.

To implement the BIPV and ESS to the SEP, the basic information is available in the EnergyPlus simulation program. An amorphous silicon photovoltaic (a-Si PV) window was used for its aesthetic value. EnergyPlus offers three different PV options to predict the electricity generation produced by solar electric PV panels (U.S. DOE, 2017b). They are Simple, Equivalent One-Diode and Sandia model and each type has a different algorithm and an equation. This study used Sandia model which was developed by Sandia National Laboratory (U.S. DOE, 2017b). All data and schedule for the Sandia model was derived from the Schedules Library issued with the BLAST program (U.S. DOE, 2017c). For a-Si PV module power generation, Sandia Array Performance Model (SAPM) was chosen to simulate the electricity generated by PV modules. The SAPM model can simulate power generation accurately although it is empirically based because all the 39 coefficients in the SAPM model are from experimental tests of the same a-Si PV module (Peng et al., 2015). The properties of the a-Si PV are U-Factor of 2.725 W/m²·K and Solar Heat Gain Coefficient of 0.398 (Martellotta et al., 2017). The efficiency of a-Si PV is 5.3% which is not a laboratory but a simulation result. A-Si PV was installed on four fixed windows of the SEP. The size of each window was 0.85m by 1.2m. This study used a 3.3 kW Electric storage system which is suitable for the residential unit. The efficiency of ESS used was 90% (International Electrotechnical Commission, 2011). Figure 5 and Table 6 showed the comparison of the cooling and heating loads for all four cases. Case 4 showed the lowest heating and cooling loads of 43.57 kWh/m²·year. Case 4 showed 33.21% less heating and cooling loads than the base model, 12.46% less than Case 2, and 1.2% less than Case 3. Due to the change in the window from double glazed window to the BIPV window, the heating load was increased by 2.75%, while the cooling load was decreased by 2.33%.

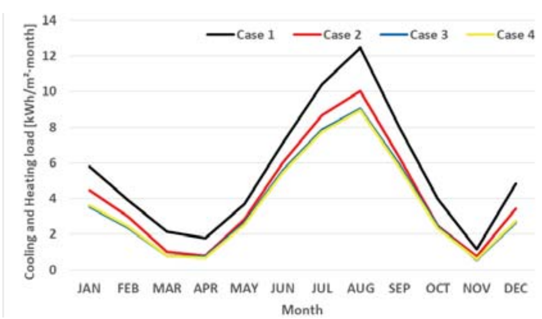

Figure 5: Comparison of the cooling and heating loads among Case 1, 2, 3 and 4

Table 6: Comparison of the annual Heating and cooling load among cases

Case	*Heating and cooling load [kWh/m²·year]*	*Percentage [%]*
Case 1	*65.24*	*100*

Case 2	*49.77*	*76.29*
Case 3	*44.10*	*67.60*
Case 4	*43.57*	*66.79*

Figure. 6 shows electricity production by a-Si PV. The production of electricity in heating season (Nov – Mar) was higher than cooling season (May – Oct). As shown in Figure 7, beam solar radiation on the surface where PV was installed was higher during the heating season than the cooling season. Based on the equation of electrical power produced by BIPV in EnergyPlus, the solar radiation and the electrical power produced are proportional (U.S. DOE, 2017a).

Annual electric power production by the BIPV was 132.74 kWh from 4.08 m² of BIPV area. The electricity consumption of the apartment per year was 5,199.95 kWh. So, the produced power by BIPV could cover 2.55% of electricity and lighting energy need of the apartment. It is not a large portion of the total electricity consumption of the apartment unit, but it can be increased by making the optimal ESS control logic, or using more high-efficiency PV, or changing from a-Si PV to crystalline (c-Si PV) which has higher efficiency than a-Si PV, and the produced electricity can be used more efficiently such as lower peak load. These aspects will be studied in more detail in the future.

The vertical installation of the BIPV is disadvantageous compared to horizontal or tilted in terms of the electricity production because properly tilted surfaces get more solar radiation than vertical. Installation of the BIPV in this study does not mean covering all the electric energy requirement but it can be used effectively when the building is at high demand or as a temporary electricity supply to electric equipment such as refrigerator during power outage.

By installing a-Si PV and ESS in the SEP, 33.21% of heating and cooling load was reduced when compared to base model, and 2.55% of lighting and equipment electricity could be covered by electricity produced by BIPV.

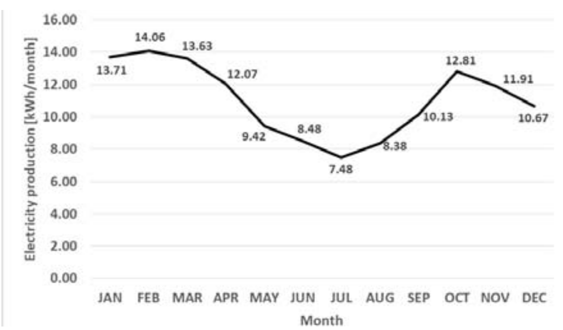

Figure 6: Electricity production by a-Si PV.

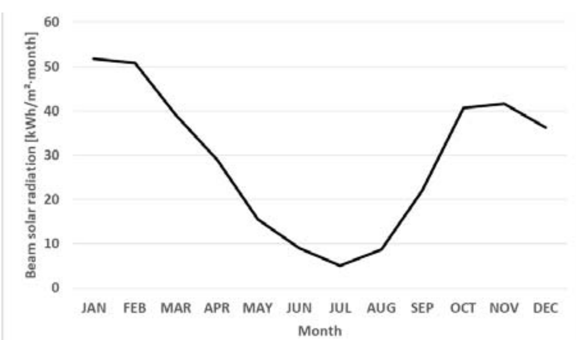

Figure 7: Beam solar radiation on the Southern wall

CONCLUSION

This paper presents the results of an early-stage research. The ultimate goal is to develop a fully functional SEP optimized to achieve maximum energy savings from old high-rise residential buildings. An initial design of the SEP was proposed to analyze how much energy could be saved through the SEP unit. Key results of this study are as follows:

- Comparison between base model and SEP shows that the base model showed 65.24 kWh/m²·year for heating and cooling and the SEP (Case 1) 49.77 kWh/m²·year. This indicates that installing the SEP into the old high-rise residential unit could reduce 23.71% of the heating and cooling loads.
- The SEP with window opening control (Case 3) showed the heating and cooling loads of 44.10 kWh/m²·year. Case 3 showed 12.45% less heating and cooling loads than Case 2 and 32.40% less than the base model. This means when the SEP is used for residential units, control is an important part and needs to be developed further to achieve more energy efficiency.
- Case 4 showed the lowest heating and cooling loads of 43.57 kWh/m²·year. Case 4 had 33.21% less heating and cooling loads than base model, 12.46% less than case 2, and 1.2% less than case 3. Due to change in window from double glazed window to BIPV window, heating loads were increased by 2.75%, but cooling loads were decreased by 2.33%.
- Annual electric power production from BIPV was 132.74 kWh. This amount was 2.55% of total electricity requirement.

In future studies, we will develop an optimal design of the SEP with considerations, including optimal controls of windows corresponding to the outdoor conditions, automated blind control, and higher efficiency BIPV. To make simulation models more accurate, the CFD analysis results will be integrated with the EnergyPlus simulation processes. Another future study will be along the lines of application of the SEP, its marketability, and appeal to the occupants of the apartments.

ACKNOWLEDGEMENTS

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Real-time Measurement of Building Envelopes to Improve U-Value Characterization

Real-time measurement of building envelopes to improve U-value characterization

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Abstract
Approximately 40% of total US energy consumption in 2016 was attributed to commercial and residential buildings. In comparison with other building systems, energy is most heavily consumed by systems regulating thermal comfort. Thus, building energy consumption is strongly related to the thermal performance of building envelopes. Architects, engineers and owners have utilized energy modeling and simulations as a way to predict future energy consumption for new and existing buildings. Energy models are also used to evaluate the change in potential energy consumption when comparing multiple design options. Most building energy modeling software utilizes material properties databases for individual envelope components and calculates an assembly overall heat transfer coefficient, known as the U-value. For historic buildings the use of materials from existing databases may be inaccurate, since the actual assembly and materials may be unknown or may not have been previously tested. Low-cost non-destructive in-situ testing can be performed to determine actual U-values for existing building envelopes. Heat flux sensors, thermocouples and air temperature sensors can be used to measure real-time heat flow through building envelopes. These measurements can be used to calculate the transient U-value of the envelope assembly. Although most databases provide a static U-value for an assembly, the actual U-value of assemblies can vary over time in relation to indoor and outdoor temperatures. When measuring in-situ U-values, time averaging can be used to develop a baseline for energy modeling purposes. This paper presents research regarding the determination of in-situ U-values for two historic buildings using heat-flux sensors and time-averaging methods. The results of the study are compared with typical database U-values and show that there is a significant range and difference between the in-situ values and those that might be typically used in energy models. Energy simulations were performed for both the typical and in-situ cases to understand the difference and impact on predicted energy consumption.

Keywords: energy modeling, simulation, in-situ testing, heat flux, U-value

1.0 Introduction
Building energy consumption and indoor environmental comfort are often closely related to the material properties and assembly configurations of building envelopes (Echenagucia et al. 2015). Approximately 40% of total US energy consumption in 2016 was attributed by the US Energy Information Agency (2016) to commercial and residential sectors (mostly building related). In comparison with other building energy uses, site energy is most heavily consumed by systems regulating thermal comfort (space cooling 10% and space heating 37%) (Energy 2010). The building envelope is usually designed to provide protection and separation of indoor spaces from the exterior climate. Heat gain and heat loss between in the indoor and outdoor environments is directly influenced by the thermal resistance of the materials in the envelope assemblies. The thermal resistance of building materials is commonly referred to as the R-value (IP units: $h{\cdot}ft^2{\cdot}°F/Btu$, SI units: $m^2{\cdot}°K/W$). Generally a material with a higher R-value has greater resistance to heat flow. Building envelope insulation is typically installed in envelope assemblies to increase the resistance to heat flow, improve thermal comfort and reduce energy consumption. The reciprocal of resistance is conductance. The U-value for an envelope assembly is known as the overall heat transfer coefficient and provides a metric for the overall conductance of the envelope (IP units: $Btu/\ (h{\cdot}ft^2{\cdot}°F)$, SI units: $W/(m^2{\cdot}°K)$). Generally a high R-value, low U-value assembly is desirable to reduce heat flow through the building envelope.

Architects, engineers and owners often select materials for building envelopes based on expected thermal properties. To estimate the impact of envelope material choices on energy consumption, energy models have been used to simulated annual outcomes. When developing the models for the simulations, most commercially available energy modeling software will require the user to either input the thermal properties of the envelope materials or ask the user to select known materials from a database. There are at least two known issues with this practice. First, is that the resistance values for most building materials may change depending on moisture content and temperature (Kumaran 2002a). Second, is that the resistance values that are often quoted in databases typically do not provide characterization of statistical variation due to installation quality, material non-uniformity, and degradation. For historic buildings there also may be the difficulty that the precise assembly materials may not be known and/or that the materials used in the assembly do not have published material properties for thermal analysis. Many historic building envelopes lack modern insulation materials and as such have lower overall thermal resistance. Energy models of envelopes that have lower thermal resistance values can have greater sensitivity to error since small absolute value changes in thermal properties can have a large proportional impact on the calculated heat flow and energy consumption results. For instance, if a modern wall assembly with insulation has an estimated R-value of 20 h·ft²·°F/Btu, then a mischaracterization of 0.5 h·ft²·°F/Btu will only change the R-value by 2.5%. For a historic envelope assembly with an estimate R-value of 3 h·ft²·°F/Btu, a 0.5 h·ft²·°F/Btu error would represent a change of 16.7%. Since heat transfer through building materials is directly related to conductivity (thus inversely related to R-value), mischaracterization of the thermal properties can have a significant impact on estimated results.

1.1 Testing Methods

Most modern commercially available building envelope materials that have published thermal properties have been tested in a laboratory using ASTM C1363 (*Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus*) (C1363 2011) and ASTM C177 (*Steady-State Heat Flux Measurement and Thermal Transmission Properties by means of the Guarded-Hot-Plate Apparatus*) (C177 2013). Both of these tests are primarily focused on determining properties under steady state conditions meaning that the simulated indoor and outdoor climate conditions are held steady and are not intended to represent fluctuating environmental conditions. Both of these test also require that the material and/or assembly can be isolated in a controlled chamber so that the heat energy input to the testing apparatus is precisely known and can be used to calculate the heat flow rate through the material(s). Figures 1 and 2 show schematics of the testing apparatus used in ASTM C1363 and C177.

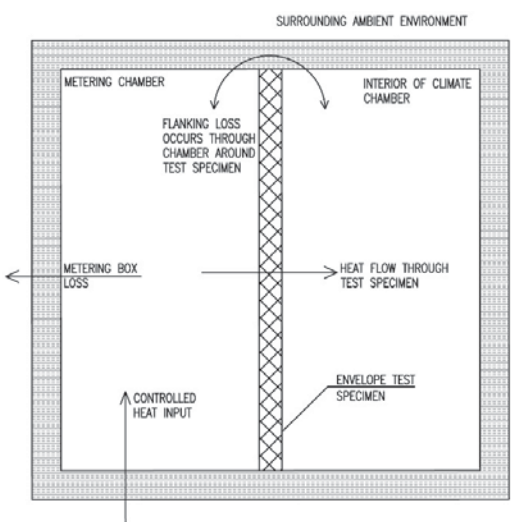

Figure 1. Schematic of Hot Box (C1363 2011)

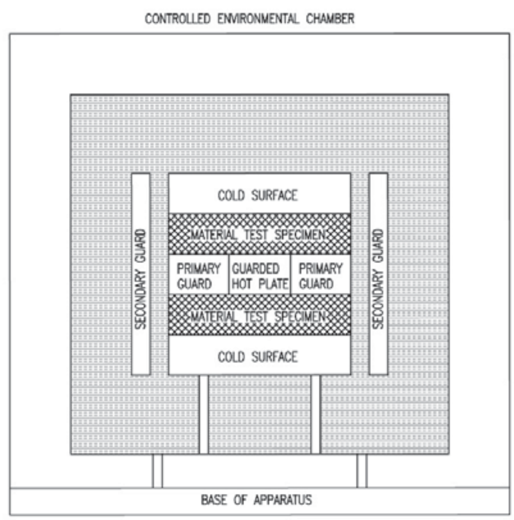

Figure 2. Schematic of Guarded Hot Plate (C177 2013)

The basic equation that relates the heat flow rate (due to conduction) to a material's thermal conductivity is based on Fourier's law of heat conduction. This can be expressed as:

$$q = -\lambda A \frac{\partial T}{\partial x} \tag{1}$$

q is the total heat transfer (W)
λ is the material conductivity ($W \cdot m^{-1} \cdot K^{-1}$)
A is the surface area (m^2)
T is the temperature (°C)
x is the thickness (m)

And since the conductance of the material, U = -λ/ ∂x then equation 2 can be rewritten as:

$$q = -UA\partial T \qquad (2)$$

U is the overall heat transfer coefficient (W·m^{-2}·K^{-1})

This can also be rewritten in terms of the heat flux which is the heat transfer over the surface area:

$$U = \frac{Q}{|T_1 - T_2|} \qquad (3)$$

Q is the heat flux (W·m^{-2})
T_1 is the surface temperature on side 1 (°C)
T_2 is the surface temperature on side 2 (°C)

Temperature transducers are used in these tests methods to determine the surface temperatures and in combination with the known heat inputs (thus also the heat flux) the U-values for the material or assembly can be determined.

Some of the reason these tests are not used for in-situ analysis is that it is extremely difficult to recreate the scenario of precise steady state conditions, known heat input to the system, and an isolation chamber. To evaluate the in-situ thermal properties a heat flux transducer can be employed to directly measure the heat flow rate through a small area of the envelope. ASTM C1046 Standard Practice for In-Situ Measurement of Heat Flux and Temperature on Building Envelope Components provides a method to observe the real-time heat flow and surface temperature values needed in equation 3. Although ASTM C1046 provides a method for measuring the heat flow, transient environmental conditions will create fluctuations in the heat flux measured. This fluctuation will be due to the change in temperatures and due to the thermal storage capacity of the envelope materials that influence the materials' thermal time constants. By definition, the thermal time constant for a material is the time necessary for a change in temperature on one side of the material to cause a change in heat flux on the other side of the material. Many lightweight building materials have short time constants, whereas heavy and denser materials often have longer time constants. While precisely controlled steady state conditions may not be achievable, near steady state conditions should provide a reduced amount of fluctuations from temperature fluctuations. Also the largest possible steady state temperature difference between the indoor and outdoor environments should reduce the magnitude of noise and error in the heat flux and temperature readings. Since heat flux is measured over a small area, spatial variation can also create errors and inconsistency. Thus ideally heat flux should be spatially and temporally sampled for in-situ applications.

In an attempt to improve building envelope thermal property characterization of existing historic buildings a research project was devised to build upon ASTM C1046, augmenting the in-situ method with thermographic imaging and near steady state environmental conditions. The project examined two historic buildings located in Philadelphia, Pennsylvania and compared typical material thermal properties used in energy modeling of the two buildings with the thermal properties derived from in-situ testing.

2.0 Methodology

2.1 Buildings and Environmental conditions

The two buildings that were studied in this research project are Roxboro House on Philadelphia University's campus and the RittenhouseTown Homestead in Fairmount Park (both in Philadelphia, PA). These two buildings are registered historic buildings and either they have a substantial portion of their original building envelope assemblies intact or they have been recently restored to their original conditions. RittenhouseTown Homestead has load bearing stone masonry walls that were originally constructed in 1707. Roxboro House is a Georgian period house constructed of wood frame and clapboard that was at least partially constructed in 1779. Both buildings lack modern insulation in their wall assemblies. Since both buildings have original construction materials within their assemblies that have not been previously tested for thermal properties and have elements of non-uniform construction they were identified as good candidates for this project.

Since changing environmental conditions can alter the flow of heat through the envelope, near steady state conditions with large temperature differences between the indoor and outdoor areas were considered desirable. To achieve near steady state outdoor conditions with the least impact due to latent heat, wind and radiation, the north side of the buildings were used during a calm winter weather period. Further since the outdoor temperature fluctuates with higher temperatures during the day and lower temperatures during the night, surface and air temperatures were monitored to determine the time period with the lowest amount of temperature change. Typically after midnight and before sunrise, the radiation of the sun and the longwave radiation from the sky have the least amount of impact on heat gain to the envelope. Winter climate conditions in Philadelphia are favorable for this study's near steady state conditions for three reasons: (1) the greatest amount of temperature difference between in the indoor and outdoor air typically occurs in the winter and thus represents the conditions where the most heat flow will occur, (2) winter climate often has less absolute moisture in the air, thus potential latent heat and moisture transport issues are minimized, and (3) the night time period is longer, thus reducing outdoor radiation impact.

2.2 Material Properties within Energy Models

Based on field survey and/or existing drawings the dimensions and material assemblies for the two buildings were approximated and used in the creation of energy models using IES Virtual Environment 2014 as the simulation software. Using the material database available within the IES program the nominal U-value for the 23 inch thick stone masonry wall at RittenhouseTown was 0.3756 Btu/h·ft²·°F (R-value of 2.66 h·ft²·°F/Btu). The nominal U-value for the Wood framed wall with wood clapboard was 0.2779 Btu/h·ft²·°F (R-value of 3.60 h·ft²·°F/Btu). These were used to create baseline models that represented energy models based on best-practice assumptions without in-situ testing. Further details of the energy modeling parameters such as air exchange rates, mechanical systems, user schedules, indoor set points, and micro climate conditions although outside of the scope of this paper are available in the research project's final report (Chung 2016).

2.3 Experiment Set-up

This research was funded by a grant from the National Center for Preservation Technology and Training. The following equipment was purchased through these funds and used for collecting thermal data.

- FLIR E6 thermal IR camera with 160x120 resolution, $1,262.00
- Hukseflux HFP01-05 heat flux plate (used with the Omega datalogger), $640.00
- (8) Standard k-type thermocouples (used with the Omega and Amprobe dataloggers)
- Omega Engineering, OM-DAQLINK-TEMPRH hand held datalogger, $506.00
- (2) Amprobe TMD-56 Multi-logger Thermometer, $109.84
- REED Temperature & Humidity Datalogger model ST-171, $77.42
- Extech RHT10 Humidity and Temperature Datalogger, $70.84
- Davis Instruments 6250 Vantage Vue Wireless Station, $665

The in-situ tests were performed over approximately a twenty-four-hour period at each building. During the tests, thermocouples were connected to a temperature datalogger as seen in figure 3. Thermocouples and a heat flux sensor were arranged on the inside wall surface as shown in figure 4. The heat flux plate was connected to a handheld datalogger that also recorded ambient air temperatures. Additional thermocouples were located in the same configuration on the corresponding outside surface of the wall as seem in Figures 6 and 7. At least three thermocouples were used on each surface to provide spatial averaging and redundancy. Thermal imaging was used to help locate an appropriate location for the tests. Areas with strong contrast and brightness changes in the thermal images indicate locations of large surface temperature changes and generally would not be appropriate for using the heat flux plate for this test. Figures 5 and 8 are images taken with the thermal IR camera at RittenhouseTown Homestead. Ideally the areas selected should be relatively uniform and not in an area of strong air currents to reduce the influence of surface irregularities and convective heat transfer. With the thermocouples in place on the inside and outside surfaces along with the heat flux plate on the interior, the U-value of the wall assembly at the location of the sensors can be determined using equation 3. Sensor readings were recorded in 60 second intervals.

Figure 3. Temperature datalogger

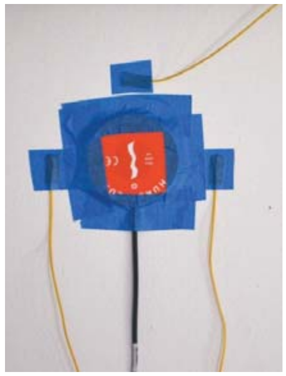

Figure 4. Heat flux plate on inside wall at RittenhouseTown

Figure 5. Full 160x120 pixel image, North wall at 6:59 AM

Figure 6. N.wall at thermocouples, RittenhouseTown

Figure 7. Thermocouple

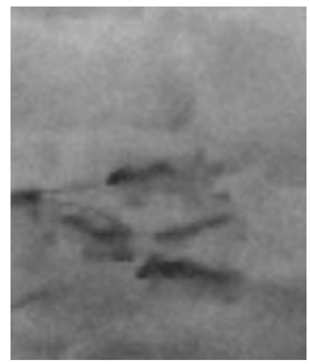

Figure 8. Thermal image at sensors

The thermal IR camera was also used to detect variation and non-uniformity so that a spatially averaged thermal resistance value could be calculated when used in conjunction with the heat flux plate and thermocouples. Although the experimental details and methods of calculation related to the use of the thermal IR camera for determining a spatially averaged resistance value are outside the scope of this paper, the full details were previously published (Chung 2015).

3.0 Results and Discussion

Figures 9 and 10 show the recorded temperatures, heat flux and calculated thermal resistance values for the two historic buildings. These are dual vertical axes graphs with temperature units on the left side. Heat flux and R-values units are on the right side. Over a 24-hour period the envelope at RittenhouseTown Homestead had an averaged calculated resistance value of 5.74 $h \cdot ft^2 \cdot {}^{\circ}F$/ Btu. During the six-hour period of near steady state conditions (from midnight to 6AM) the calculated thermal resistance of the wall at RittenhouseTown Homestead is 7.83 $h \cdot ft^2 \cdot {}^{\circ}F$/ Btu. These resistance values are much higher than the nominal value used for sandstone 2.66 $h \cdot ft^2 \cdot {}^{\circ}F$/ Btu and appears to reflect the uncertainty that exists due to material variations that occur in a naturally forming sedimentary rock. Thermal storage of the masonry wall most likely influenced the heat flux readings. This can be inferred since although the air temperature was relatively steady from midnight to 6AM, the surface temperature on the masonry continued to decrease until approximately 9AM when both the sun was visible and the air temperature began to rise. At 23 inches thick, the masonry wall has considerable thermal storage capacity. Sandstone is often estimated to have a heat capacity of 0.203 Btu/lb•°F (850 J/kg-K) and a density of about 125 lb/ft^3 (2000 kg/m^3) (Krus 1996). This leads to a thermal capacity of approximately 25.375 $Btu/ft^{3} \cdot {}^{\circ}F$ (1,700,000 $J/m^{3} \cdot {}^{\circ}K$).

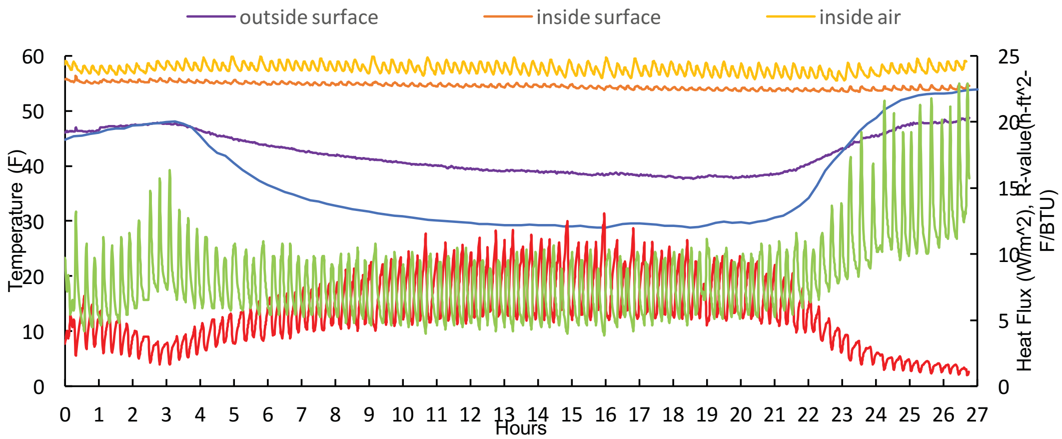

Figure 9. Transient temperature and thermal behavior of a masonry wall over 27 hours at RittenhouseTown Homestead, Philadelphia, PA. Time = 0 at approximately noon on December 26, 2014.

For Roxboro House the time averaged thermal resistance value (over a 23-hour period) was 4.29 h·ft²·°F/ Btu. During the 4-1/2 hour period (from 4AM to 8:30AM) of near steady state conditions, the calculated thermal resistance of the wall at Roxboro House was 3.92 h·ft²·°F/ Btu. These resistance values are higher than the nominal value of 3.60 h·ft²·°F/ Btu, yet much closer to the nominal values than the resistances for RittenhouseTown Homestead. This may be due to the fact that the construction of Roxboro House is more thoroughly documented and comprised of manufactured materials that have more consistency in terms of thermal properties. It also may be related to the weight and thermal storage capacity of the assembly. While wood is often estimated to have a relatively high heat capacity 0.449 Btu/lb•°F (1880 J/kg-K), its density is about 25 lb/ft^3 (400 kg/m^3) (Kumaran 2002b) which is much lower than masonry. This leads to a thermal capacity of approximately 11.225 Btu/ft^{3}•°F (752,000 J/m^{3}•°K). The wood framed wall has an air cavity and is much thinner than the masonry wall. Thus the thermal lag due to thermal mass of the wood framed wall should have less impact on the Roxboro House measurements.

Indoor temperature fluctuations can be observed in both graphs. Since both of these buildings have integrated modern ducted forced air heating systems, the indoor temperature is controlled via a thermostat with set points that allow for some range before the heating system turns on or off. The automated and regular time intervals of the indoor air systems produces corresponding fluctuations in the observed heat flux and calculated R-values. From the oscillations in the graph for RittenhouseTown Homestead the thermostat appears to have operated in 16 minute cycles. For Roxboro House the thermostat appears to have operated in 10 minute cycles. The shorter interval should produce more steady state conditions and reduce the amplitude of the oscillations. Future work using this in-situ method should try to minimize the thermostat cycling time and also limit any other heat gains both indoor and outdoor to improve the near steady state conditions.

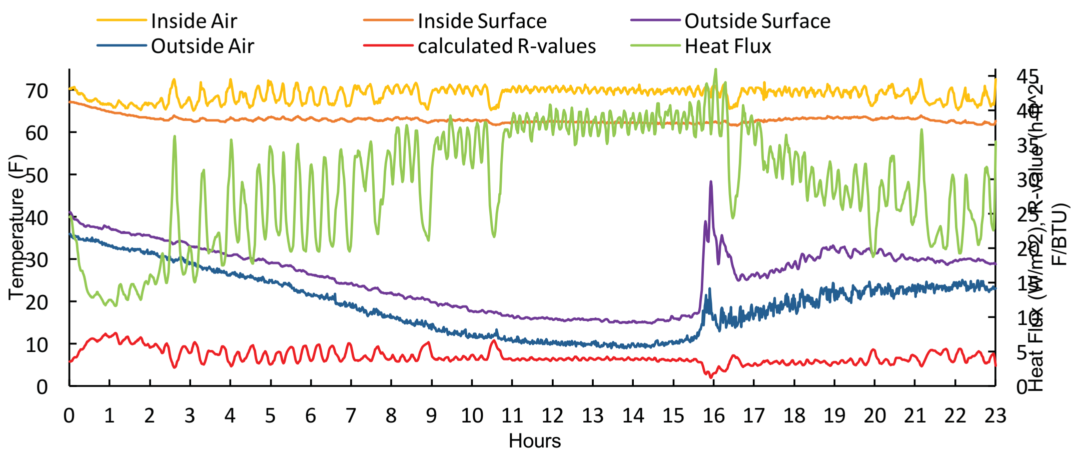

Figure 10. Transient temperature and thermal behavior of a wood framed clapboard siding wall at Roxboro House, Philadelphia, PA. Time = 0 at approximately 5PM on February 12, 2015.

Using the thermal properties of the baseline models and the in-situ models, both buildings were simulated over a typical meteorological year. These results are shown in tables 1 and 2. Looking at the results one can see that in both buildings their simulations with baseline models predicted a higher amount of energy use when compared to the simulations with in-situ models. This was primarily due to the fact of having much lower thermal resistance values for the walls than what was measured in the field tests. The calculated total annual energy costs for RittenhouseTown Homestead in the simulation with the in-situ model is approximately 10% less than the simulation with the baseline model. The calculated total annual energy costs for Roxboro House the simulation with the in-situ model is approximately 14% less than the simulation with the baseline model. Historical energy consumption records for Roxboro House were not available. Some recent energy use records for RittenhouseTown Homestead were available. Natural gas consumption in 2014 was 1344 CCF. Electricity consumption in 2012 was 4381 kWh. These historical data points suggest that the energy models may be overestimating the future energy use. This may be due to the difference between the simulated and actual indoor temperature set points and occupancy schedules.

Table 1: RittenhouseTown Homestead Building Energy Simulation Annual Energy Consumption Results

	Baseline Existing	In-situ Model Existing
electricity (kWh)	9,025	6,030
natural gas (CCF)	1,876	1,988
electricity cost	$1,367.27	$913.53
natural gas cost	$1,899.89	$2,013.78
Total annual cost	$3,267.16	$2,927.31

Table 2: Roxboro House Building Energy Simulation Annual Energy Consumption Results

	Baseline Existing	In-situ Model Existing
electricity (kWh)	66,491	57,397
electricity cost	$10,073.40	$8,695.63

4.0 Conclusions

This paper provides a brief background, context, methodology and results of an experimental study in using in-situ testing to improve building envelope thermal properties. The benefits of the methods are that historic building envelopes can be assessed using non-destructive methods, in the field with relatively low cost equipment and a short time frame. The method allows for observation of the thermal time lag due to thermal mass and requires user judgement in selecting appropriate envelope sites and time periods for testing. This method is sensitive to fluctuations in heat gains/losses and as such requires near steady state conditions which may limit its application both in regards to location and times during the year when it can be performed.

Although the method provides improvement over using nominal values, further study is needed to better understand the magnitude of impact regarding thermal mass.

5.0 Acknowledgements
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Mahesh Daas, Andrew John Wit

The Affordances of Robotic Production

The Affordances of Robotic Production

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ABSTRACT: The paper delves into the unique affordances of robotic production in architecture and their growing potential to reshape the discipline when paired with Artificial Intelligence (AI). Over the past decade, a range of robots have been engaged within architectural production processes including fabrication, assembly, construction and real time responsiveness to materials and situational variances. The paper emphasizes the differences between the two-decade old paradigm of digital fabrication and the emerging paradigm of what we have termed and defined as robotic production.

KEYWORDS: Robotics; Manufacturing; Robotic Production; Computation

INTRODUCTION

Over the past twelve years, we have witnessed a shift in full force through the rise of robotics, and more specifically, robotic production within the discourse of architecture and design. Driven through interdisciplinary collaborations and corporate/government partnerships and the advancing of AI, we are witnessing the moving of robots from far-off factory floors into classrooms, studios, laboratories, fabrication shops, design firms and more recently, out onto streets (Daas and Wit 2018). Rapidly becoming indispensable tools and collaborators for designers, architects and fabricators, robots are aiding designers in revolutionizing our known world through the redefinition of materials, processes as well as in how space is imagined, made, assembled, constructed and sustained (Bloem, Van Doorn et al. 2014, Gramazio and Kohler 2014, Rouse, Villagaray-Carski et al. 2015). Whether at the scale of the component, artifact or more recently the building, designers are quickly beginning to understand and exploit the affordances associated with what we are defining as “robotic production.” In this paper we examine the affordances of robotic production through the lens of various typologies of robotics, and their potential for rapid evolution and assimilation through the integration of AI.

Although over the past several years we have witnessed a rapidly increasing number of robotically produced projects and typologies appear within the discourse of architectural research, we have yet to see the development of a comprehensive framing of how these projects, the tools developed/used as well as how the affordances of robotics are furthering the discourse of architecture and design. For this reason, we often witness researchers struggling to initiate and complete robotics research that in most cases, has already been investigated, tested and completed by others. We also see a lack of coherence and understanding of what constitutes robotics research in architecture, especially when viewed from the outside by other disciplines. Expanding on a taxonomy laid out in or recent book “Towards a Robotic Architecture” which describes (Daas and Wit 2018) the current state of architectural robotics, this article aims to further document, categorize and explain how robots can/are reshaping how designers, architects and fabricators are approaching design.

1.0 WHAT ARE ROBOTS?

The simplest definition of a robot is physical agency that can sense, think and respond to its environment. Robots are often termed embodied intelligence, which distinguishes them from computational agents that operate solely within virtual environments without physical repercussions. Robots are also called “computers turned inside out.”(Long 2012) The stereotypical image of a robot is either a humanoid or an industrial articulated arm robot. From this standpoint though, we can see how most tools we currently define as robots do not actually embody the necessary intelligence nor sensing abilities to be considered a true robot in fields outside of architecture. For instance, many factory based industrial robots function more similarly to the computer numerically controlled (CNC) machines such as CNC mills, laser cutters or water jet cutters that we have grown accustomed to in digital fabrication paradigm. These tools are automated, preprogramed, and do not respond to changing environments, materials or designs without human input. Hence, error compounds if the tool is left unattended. Despite this, robots are already more pervasive in our society than we realize.

Robots come in many forms:

Table 1: Morphological Framework: Robots considered by form (Daas 2018)

A. Biomorphic	**B. Mechanomorphic**	**C. Polymorphic**	**D. Amorphic**
Robots that resemble animals, humans, insects, trees and other living beings.	Robots that resemble machines or embody mechanical characteristics in their form.	Robots that assume different forms.	Robots with no identifiable form.
RUR, iRobot, C-3PO, AIBO toy robot pets, ASIMO	R2D2 (Star Wars), Wall-E, Roomba vacuum cleaners, drones, industrial robots, automated farming machines	Transformers, TARS (Interstellar)	HAL 9000 robot ship

Another way to look at robots is through the role robots play in the design and construction process:

Table 2: Process Framework: Role of robotics in architecture (Daas 2018)

A. Robots for design	**B. Robots for fabrication**	**C. Robots for construction**	**D. Robots for operation**
Robots used in the design process, to inform the design process, observation and prototyping.	Robots used for bespoke or mass-customized manufacturing off-site.	Robots employed in the building construction process working alongside human workers.	Robots with autonomous, teleoperated or semi-autonomous robots integrated into building operational tasks such as surveillance, hazard mitigation, maintenance, etc.

Robots as tools have found their way into architecture predominantly by way of industrial manufacturing, similar to the tools associated with digital fabrication. However, robots come in different forms and formats. Some predefined, others created by designers for specific tasks. Industrial robots, mobile robots, drones, humanoids and custom fabricated non-standard autonomous machines are redefining how designers look at and solve complex problems within their design, manufacture and assembly processes. Whereas in digital fabrication designers were constrained by fixed toolsets and preprogrammed numerical controls, as seen in many recent examples around the world, robotic production opens new avenues of making.

Traditional digital fabrication tools allowed for the realization of digitally designed forms into physical artifacts by means of a pallet of standardized material systems, manipulated through the implementation of numerically controlled devices, robotics now allows for emergence of a completely new typology of forms and structures. A typology not centered around individual, pre-determined machine-based operations (i.e. geometry, tool pathing, fabrication, etc.), but rather based on holistic and/or haptic approaches where design, computation, materials, manufacture and assembly function as a single continuous process, with the inherent ability to be manipulated, redefined and simultaneously verified by human or machine at any point throughout the design and production process in real- time. This bridging of the realms of design, simulation, production, feedback and revision creates new opportunities where the lines between digital environments, machines and humans are blurred.

2.0 THE SPECTRUM OF AFFORDANCES

Following James J. Gibson's framework, affordance could be understood as a particular relationship between an entity and its environment by virtue of the entity's innate abilities to effect change. Affordance points to the space of possibilities offered by the physical, kinetic, cognitive, formal and positional abilities of an entity. In the case of robots, its form, adaptability, maneuverability, malleability, kinetic abilities and levels of artificial intelligence all point to a set of affordances. The affordances of robotics are distinctive and different from other kinds of tools such as digital fabrication technologies exemplified by CNC mills, 3D printers, laser cutters, etc.

Unlike digital fabrication, the list of affordances of robotic production is ever expanding because of the inherent flexibility within robotic systems. Milling, drilling, cutting, carving, welding, printing, photographing, spatial positioning, bending, brick laying, sewing, folding, fastening, forming, assembling, weaving, spraying, dynamic casting and any number of other pre-existing or novel tasks can be accomplished through the implementation of different effectors. Although these affordances allow for the expansion of the designer's production capabilities, they currently lie within the same realm as digital fabrication, rather than pushing beyond the pretexts that were established by previous CNC based systems. As Mark Cabrinha describes,

> Conventions of use in digital fabrication have already formed that instrumentalize these tools as printers of form without engaging material as a medium in itself. These conventions of use amplify the tendency in digital design to output to material at the end stage of design, rather than the preparatory and evaluate role of digital fabrication as material feedback into the design process. (Cabrinha 2010)

The problem with the default affordances of robotic production are similar to those with digital fabrication. They can tend to be fixed to a specific standardized tool, (i.e. the articulated robot arm), and are applied similarly in most applications without any awareness of, or feedback to the given materials, their programmer/collaborator and their environment.

Where robotic production sets itself apart from previous tools and techniques is with the integration of mobility, machine customization, machine learning, haptic feedback/responsiveness/programming, awareness and artificial intelligence into a continuous design/production loop. (Daas and Wit 2018) Previous methods of fabrication were based around the simple pre-programming of a machine through numerical code. Robots though, through the application of internal or external sensors, can begin to not only verify their work, but also begin to situate and understand themselves within space without human intervention. This can afford robots the ability to adapt in real-time to given, changing or unknown conditions such as variations in material properties, human or externalized feedback or even changes within the robots' work area without needing the designer to manually reprogram the robot and their work paths. This flexibility allows for robots to move from the realm of mere tools of production, into the realm of active collaborators, throughout the design and production process.

Figure 1: Innochain: Adaptive Robotic Carving. Source: (Giulio Brugnaro)

These affordances can be witnessed in research and projects realized in projects such as "A Bridge Too Far" by Paul Nicholas discussed below (Zwierzycki, Nicholas et al. 2018); "Innochain // Adaptive robotic carving" by Giulio Brugnaro where Artificial Neural Networks are leveraged to train adaptive robotic systems in the carving of wood based on human craft (Brugnaro and Hanna 2017); the “ICD/ITKE Pavilion 2014-15” by the ICD/ITKE Institutes at the University of Stuttgart where real-time feedback between sensor data, software and robot allow for the placing of carbon fiber roving’s on the interior of a constantly changing surface of a large-scale ETFE balloon (Doerstelmann, Knippers et al. 2015); “Force-Adaptive Hot Wire Cutting” by Gramazio Kohler Research where a robot team consisting of two robots work together to coordinate the movement of a hot wire cutter with the ability to adapt wire tension based on the creation of a desired ruled or doubly curved surface as well as to the resistance of a given cutting material (Rust, David Jenny et al. 2016); “On-site Robotic Construction” also by Gramazio Kohler Research which investigates adaptive building systems for robotic production on-site in uncertain environments (Dörfler, Sandy et al. 2016); among others.

Although currently production robotics are typically viewed through the lens of the traditional industrial robot, there is a rapidly expanding realm of semi-autonomous or fully autonomous mobile/non-standardized robotic systems that are being developed and implemented, expanding the potential affordances of robotics within design and construction. While typical robotic production methods are limited to a fixed area such as a fabrication shop, these mobile robots will allow for autonomous navigation and production not only on the ground level of the site, but also on walls, navigating upstairs or even flying overhead.

Figure 2: Mobile Robotic Fabrication System for Filament Structures. By Maria Yablonina. @ICD. Courtesy ICD.

These affordances can be witnessed in research and projects realized through the use of autonomous fabrication robots such as those utilized in “Swarmscapers” completed within the Digital Craft Lab at the California College of the Arts where swarms of custom built autonomous mobile robots can 3D print structures in difficult terrain using locally harvested materials (Kudless 2016); the “Minibuilders” project completed at the IAAC where three custom fabricated robots (wheeled, gripper and wall climber) work sequentially, controlled through sensors and positioning data to create structures much larger than themselves (Nan 2015); the “Mobile Robotic Fabrication System for Filament Structures” by Maria Yablonina at the ICD institute at the University of Stuttgart where a custom wall climbing robot was created that could, through sensing, navigate and compute paths through unpredictable vertical environments while winding carbon fiber roving’s between intersecting walls (Yablonina, Prado et al. 2017); which looks at the use of large-scale autonomous cable-based robots for on-site construction with the ability to adapt their trajectories and work paths based on live sensor feedback taken from ever changing construction site conditions over long periods of time “SpideRobot” (Sousa, Palop et al. 2016); the mobile, legged construction co-robot “OSCR” prototypes that can navigate complex terrain and even climb stairs as they assist in the human brick laying process (Silver 2018); or even with the aerial rope bridge building drones (i.e. drones) utilized in “Aerial Construction” (Mirjan, Augugliaro et al. 2016), or the 18' tall autonomous foam block laying drones utilized in the project "Flight Assembled Architecture" (Gramazio, Kohler et al. 2012) and most recently in the ICD/ITKE Pavilion 2016-17 which utilizes a drone to span carbon fiber rovings between two articulated arm robots. (Doerstelmann, Knippers et al. 2015).

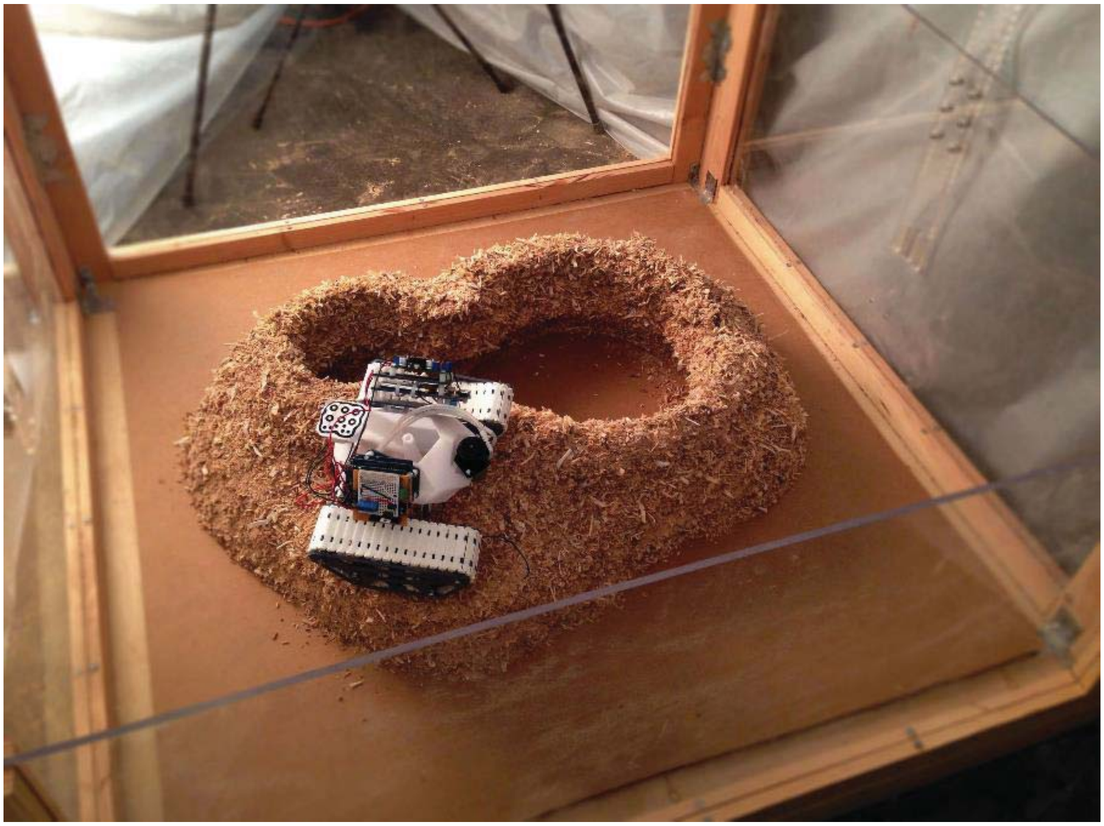

Figure 3: Swarmscapers. Source: Alan Cation, Clayton Muhleman and Adithi Satish, CCA. Instructor: Jason Kelly Johnson

3.0 DUETERO CUSTOMIZATION

Unlike traditional machines utilized in digital fabrication that are limited to specified end effectors (drill bits, print nozzles, etc.), industrial robots can work with virtually any tool attached to them—analog or digital, pre-defined or custom built—allowing for a new level of flexibility in prototyping and fabrication. Simply attached to the end of the robot, defined within the computational model, and linked into the robots control hardware if necessary, these "end effectors" allow for the rapid manual, programmed or automatic reconfiguration of the robot as well as its fabrication and assembly capabilities.

In addition to flexibility afforded by end effectors, additional degrees of freedom can simply be added to a robotic production system allowing for the expansion of a robot's capabilities. Additional axes can come in many forms, including but not limited to the addition of an external secondary device such as a 2-axis positioner the addition of additional robot arms working together as a robo-team, adding degrees of freedom and expanding the working area. Degrees of freedom can also be added to the robot directly by fastening the robot to another axis such as a vertical gantry expanding the Z - direction as seen in the project "Rock Print" by Gramazio and Kohler Research with the Self-Assembly Lab (Aejmelaeus-Lindström, Thoma et al. 2017); to a linear track expanding the work area in the X & Y directions as seen the project "Periscope: Foam Tower" by Matter Design (Clifford and McGee 2011); to a multi-axis gantry as seen in the ETH Zurich's new "Robotic Fabrication Laboratory" (Gramazio Kohler Research 2018); or to a mobile platform as was previously mentioned with Gramazio and Kohler Research's project "On-site Mobile Construction" (Dörfler, Sandy et al. 2016).

Mass customization was a phrase used with a range of traditional digital fabrication technologies. Mass customization refers to the ability to customize the end product without incurring costs throughout the manufacturing process. With robotic production, we not only achieve mass customization, but gain the ability to customize the manufacturing process itself, which unleashes many new possibilities. Moving beyond digital fabrication, we can see the affordances of robotic production systems expand even further, allowing for an exponential shift in scale, as well as the blurring between the processes of design, manufacture and assembly.

4.0 TOWARDS AI AND INTELLIGENT PRODUCTION

Just as computers, computation and digital/robotic production have reshaped how architects currently design, build and view the world, recent advances in AI assisted robotic production within the realms of design, production and post-occupancy will no doubt and opens the doors for virtually unprecedented possibilities that broaden the affordances of robots. For the robots to have awareness of immediate context, their sense making abilities provide us a limitless palette of affordances that we are only now beginning to understand in architecture.

At the scale of construction, we are beginning to witness the growing integration of robotics driven by AI in countries such as Japan. Fueled by the countries shrinking workforce teamed with their demands for a high level of construction quality, robots are not only being utilized for their ability to interact with, and aid human workers with complex tasks in real-time, (Yasuhara 2017) but have also began to appear being utilized for the large-scale control of construction sites. For instance, Komatsu has integrated ground scanning drones into construction sites in Tokyo, which relay data to semi-autonomous diggers which sculpt the construction site. (Firth 2018) The merging of real-time data collection, machine learning and robotic production will no doubt have the ability to reshape how buildings are assembled but are currently still focused around current production techniques. Where architectural production can be redefined can come through the utilizing of AI for the redefining of architectural materials, fabrication and assembly methodologies.

For instance, the project “A Bridge Too Far”, by Paul Nicholas (Nicholas, Zwierzycki et al. 2017) employs machine learning, neural nets, real time sensing and a continual feedback loop that inform the robot arms to adaptively form sheet metal. Nicholas’s project goes well beyond the typical digital fabrication methods that rely on predictive models to translate desired forms into material realities. Instead, he employs real time measurement of material deflection and thickness using 3D scanning. He integrates sensory data into the feedback loop of modeling and fabrication. The more the machine operates on sheet metal, the more the model learns the material conditions and is able to predict a more accurate material response, which informs the tool paths and operating parameters. Given all the advances taking place in AI applications virtually in every field, we can expect some breakthroughs in broad applications in robotic production of architecture.

CONCLUSIONS

Understood through the framework of affordances, robotics open up a whole new world of possibilities in architecture that were previously not available. The complexity of robotics can be framed through their form, their physical or cognitive agencies, through their relationship to humans and their environments, and through their adaptability. Understandably we are at the beginning of comprehending robotic production and artificial intelligence applications in architecture. The combination of these AI and robotics technologies opens new avenues of designing, making, and operating our built environment.

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Ahmed K Ali, Patricia Kio

Finding Perfection in Imperfection: A Case Study in Designing Waste in Circular Economy

Finding Perfection in Imperfection: A Case Study of Adding Value by Design in Circular Economy

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ABSTRACT: The United States' manufacturing industry generates approximately 7.6 billion tons of non-hazardous solid waste each year, a significant portion of which is either recyclable or reusable. Emerging ecosystem concepts such as cradle-to-cradle, design for disassembly, sustainable manufacturing, and most recently circular economy, are promoting the reusing or recycling of non-hazardous industrial waste. Empirical evidence suggests that there are significant economic, environmental, and social benefits to reusing industrial waste rather than recycling it. This paper presents, discusses and synthesis five speculative case studies in designing exterior building skins using standard automobile stamping by-products. The goal of the design experiment was to transform the linear approach in making building components, particularly, exterior metal skins and cladding systems, to a closed-loop approach, which ensures multi-dimensional economic, social, and environmental benefits. The results of the study are expected to aid in the reduction of energy used for extracting new materials and change the focus of the current waste management practices in the manufacturing industry from conventional recycling to creative reuse. The imperfection of the manufacturing industrial waste despite optimization measures, and the aging of zinc (patina) can both be transformed into novel unconventional architectural products.

KEYWORDS: Automobile solid waste, Circular economy design, Metal building skins, Galvanized sheet metal

INTRODUCTION

Imperfection is a quality that is fundamentally inseparable from any human effort, particularly in the act of building. Imperfection in architecture carries aesthetics worth in itself that should be accepted and celebrated. The work of Louis Kahn profoundly elevated materials and construction imperfections to a poetic notion of perfection. This refinement, for example, was elaborated in his cast-in-place concrete work at both the Salk Institute and the Kimbell Art Museum by preserving the marks of the construction process, which profoundly revealed how elements were constructed. While Kahn's concrete work exposed the imprints of its formwork and the pour joints became a tectonic expression, contemporary work of architecture has heavily invested in shiny complex surfaces that are often cladded in a variety of sheet metal from zinc to titanium. Metal fabricators in the United States such as Zahner have shifted their focus, in the last decade, to architectural metal surfaces and have assisted well-known architects in the realization of their work. Development of sheet metal cladding systems has undoubtedly benefitted from digital fabrication processes; however, reliance on sheet metal production methods and the open-loop supply chains has remained the same. This study aims to provide alternative methods in designing exterior metal skins using sheet metal by-products from the car industry that can be populated and extended directly by architects.

Metal has been used for assemblies and ornaments in buildings for more than 9000 years. In the 19th century, the use of metal grew substantially, and metal was even being used for cornices and storefronts. Literature suggests that the Alcoa Company in Pittsburgh had a keen interest in construction with sheet metal exterior walls, which was reflected in the design of their headquarters (Yeomans 1998). The interest in sheet metal as a cladding material grew substantially with the technological advancement in galvanizing techniques. Galvanization using a process called "hot-dipping" was first introduced in the 1840s, and it made iron more suitable for exterior applications. Over the years, experiments carried out resulted in the mass production of metal thereby reducing its cost and making it available for construction purposes. Metal cladding made from galvanized steel was adopted because painting only was unable to protect the metal from rust over an extended period of time. Exterior cladding was perceived as lightweight, non-load bearing (skin), and able to be used as a membrane for the building, allowing air and daylight to pass through to occupants. The trade catalog was the chief marketing tool for sheet metal and created the link between manufacturers and consumers. Contractors collected brochures from building journals, to show potential customers the possibilities of metal cladding. As the uses of metal in interior and exterior cladding began in the late19th century, sheet metals were not coated but painted on site with bitumen. The introduction of galvanized sheet metal cladding accelerated construction time and enabled designers to introduce more significant building spans and more complex shapes (Howell 1988). In particular, the coatings based on zinc were widely used to protect steel structures against atmospheric corrosion (Ferretti, Traverso, and Ventura 1976). It is in the nature of architecture that the appearance of new building materials would be accompanied by experimental explorations of its possibilities, and therefore aging of zinc was introduced (Yeomans 1998). Natural aging of zinc coating comes with a variety of change in the appearance of zinc coated galvanized sheet due to aging known as patina. This study highlights the relationship between design and application of by-products sheet metal cladding and its aging.

1.0 STATEMENT OF THE PROBLEM

The rise in sheet metal market size comes with an inevitable increase in scrap and by-products waste, even with maximum optimization measures in place. Existing literature on scrap management of sheet metals shows that stamping operations, particularly in the automobile industry, generates an enormous volume of scraps. For example, almost two decades ago at the General Motors Company, 1.6 million tons of scrap metal per year was generated (Koros, Hellickson, and Dudek 1995). Scrap management of sheet metal (particularly steel and aluminum) consists mostly of recycling, which introduces problems such as enormous energy consumption for sorting, smelting, and de-galvanizing. As the current practice of blanking and stamping sheet metal continue to generate a substantial volume of galvanized scrap, the creative reuse of scrap as suggested in this study, offers the most logical solution over recycling processes. The problem of recycling galvanized steel has its roots in the chemistry of steel making. Steel mills require specific raw material “recipes” to produce steel products with the properties needed by the builders and manufacturers who will ultimately use the steel. These recipes contain narrow margins of error. Scrap shipments to mills that have too much zinc, the material present in galvanized auto bodies, create problems and reduce the quality of steel during the melting stages.

1.1. Sheet metal scrap

According to a recent report published by the GVR group, the world's largest and most trusted market research database, the market size of global metal stamping (a manufacturing term for forming sheet metal) was estimated at 204.6 billion dollars in 2016 and is expected to reach 299.6 billion dollars by 2025, The increasing use of sheet metal particularly in the automobile and consumer electronics industries, is expected to drive the demand for stamping due to its use in manufacturing automotive chassis, transmission components, and interior & exterior structural components of electronics. Technological innovations in the form of improved stamping processes have seen commercial usage in the recent past. In addition, regulatory policies aimed at improving working conditions & safety standards, waste disposal, and materials used are imperative for shaping growth and sustainability strategies of the stamping companies over the forecast period (Grand View Research 2017). The scraps discussed in this paper, are limited to the category of bulky ferrous metals consistently generated from the automobile industry, known as “offal”. It is primarily generated when blanking out the car windows, openings, and doors parts. The American Society for Testing and Materials (ASTM) has guidelines for treatment of scraps stated in ASTM E702. This study is limited to standards governing galvanized sheet metal for the automobile industry.

1.2. Automobile stamping offal

General Motors (GM) sheet metal offal is a surplus material generated by its blanking operations as seen in Figure 1. The GM offal is a resilient material comprising of light gauge steel sheet (24-22), and zinc coating on both sides (approximately 60 microns); it is galvanized to preserve the steel in a process known as hot-dipped galvanization or electro-galvanization. This waste-flow is generated as consistently sized; high-quality irregular shaped sheets that are produced when windows and other car components are stamped out of body panels on the assembly lines. Because of their predicted volume and consistent size, shape, and quality, these pieces are assumed to be valuable for much more than traditional scrap market value. Offal pieces are usually sized between 0.5mm to 3.2mm thick, have various coatings thicknesses (mostly zinc), and total at 1,500 metric tons per year. Promising cost-benefits are available through the reuse of these materials for GM and future users of the reclaimed steel. One plant in Flint, Michigan for example, generates approximately 40,000 pieces per month in about 11 different shapes and sizes (Figure 1). In 2014, GM claimed that it generated nearly one billion dollars in annual revenue through reusing and recycling its by-products and avoided releasing over 10 million tons of CO2-equivalent emissions into the atmosphere.

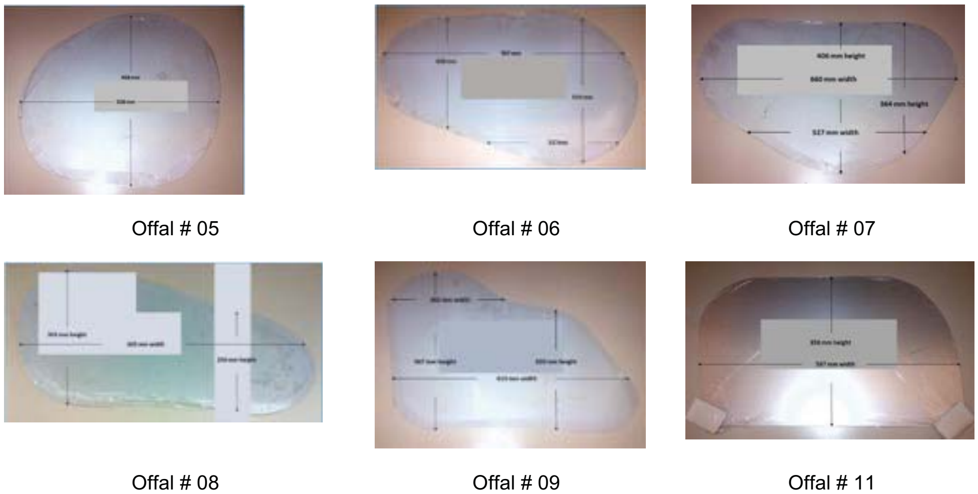

Figure 1: Six different sizes of Offal available as scrap materials from General Motors Source: (GM, 2016)

1.3. Imperfection in stamping/blanking processes and zinc patination

Although the car industry has pushed stamping and blanking operations to the maximum optimization measures, it is yet unable to achieve zero waste strategies. It is inevitable that the car industry will continue to generate a sizable amount of sheet metal by-products as long as the stamping operations are the dominant manufacturing process in the making of the car. On the other hand, architectural zinc has had a long history of application on buildings for almost three centuries and has been increasing in popularity in North America since the early 1990s (Kweton 2017). Zinc is a resilient material and is used for many purposes in the environment. According to the American Zinc Association, the average vehicle now contains 37 pounds of zinc (17 pounds in the form of corrosion-protection coatings and another 20 pounds in the form of zinc die cast parts) such as door handles and locks. Imperfection in zinc is often related to its aging patina. Zinc cannot be specified without an appreciation for the patina and aging process. The material is long-lasting, lends itself to unique detailing, and is versatile, but an understanding of the maturation process manages client expectations and allows a specification to leave a legacy long after the project is complete. Zinc, if specified properly can last for 100 years (Kweton 2017).

Figure 2: Car Stamping Diagram Source: (USA 2009)

2.0. RESEARCH METHODOLOGY

In this study, the authors utilize a quantitative approach limiting variables to one single material (galvanized sheet metal) in one single thickness (1mm) investigating its possibilities. The study was conducted in two phases. First an ideation phase, and second, an assessment phase. Five designs proposed by the authors' affiliated Resource-Based Design Research Lab (RBDR) were designed, illustrated and modeled, then were quantified based on the feasibilities of manufacturing processes and the comparison cost of the raw versus the upcycled materials used. The design and engineering team worked in an interdisciplinary model which involved feedback and feedforward process in an academic collaborative setting. The focus was limited to the process of production implied by each design solution and the cost of obtaining material for each design. The cost of production of each design proposal was compared to show the effect of the use of new material for building skins against the use of a consistent waste-flow material. In the following sections, a description of each design followed by illustrations is presented. Then a comparison in manufacturability and cost savings are discussed.

3.0. PROPOSED DESIGN SOLUTIONS FOR METAL BUILDING SKIN

It is common for individual industries to develop its processes without involving other industries' sustainability goals. And too often in manufacturing, engineers may not have the time or the opportunity to work closely with designers. Some of the specific properties of the metal offal included their lack of stiffness, the vulnerability of their edges, their tendency to be shaped or dented by powerful forces, along with the noise that would be generated when they came in contact with another force, for example, heavy rain/hail. All these factors had an impact on the design process. To develop a synergy between the car industry and the building industry, the following proposals are primarily focused on exterior building skin applications that ranged from metal cladding to sun-shading screens. Each design solution utilized a different offal shape and size to match the unit geometry closely and to minimize materials waste. See Table 1 and 2 for design proposals analysis.

3.1. Design #1: Passive cooling perforated skin

The proposed triangulated skin allows fresh air to flow from a positively pressured exterior into a negatively pressured cavity space and then the air would be captured as potential cooling by an in-ground passive cooling system. While minimal waste is still being produced through the maximized geometry of the offal, the function of the skin and the passive cooling system allows for more significant energy waste reduction over time. Offal #6 has an estimated monthly production of 1,000 pieces. Using 80 percent of the offal, with an area of about 592 square inches, yields two pieces per offal. Upon folding and perforating, the offal is transformed to a standard panelling system which contains 60 pieces per panel.

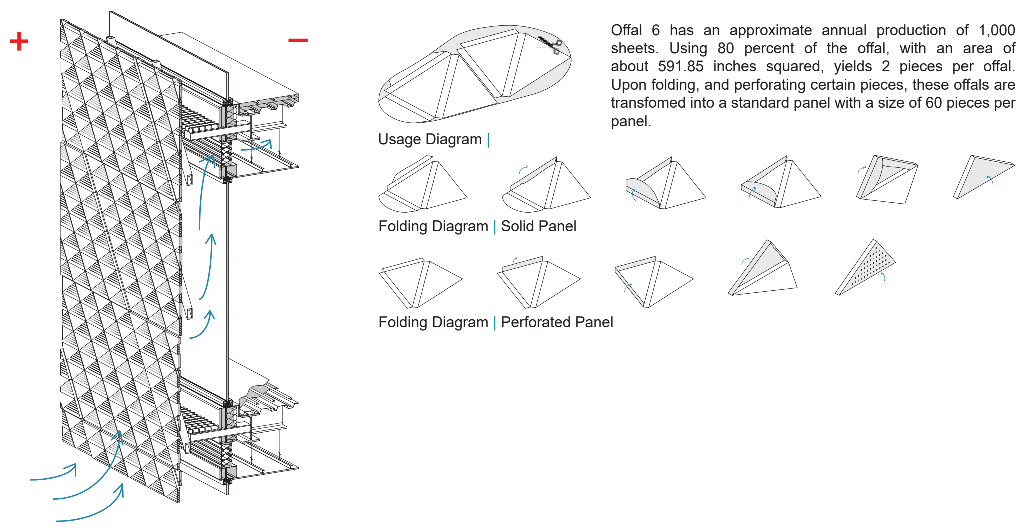

Figure 3: Passive cooling skin made from offal #6. Source: (Buckley, 2017)

3.2. Design #2: Breathable Skin

The design allows air and light to penetrate the building exterior skin. By altering the geometry of # 8 offal, four different degrees of bending were created. The pieces were bent at varying degrees at the center of the panel, bringing the two-dimensional flat offal into a three-dimensional object. When assembled, these components can create an opening of varying sizes in the building envelope, allowing the building to breathe. The "breathing" of the envelope encourages the circulation of fresh air against the facade of the overall structure, thereby reducing the need for cooling systems within the interior spaces. Additionally, by strategically placing the openings in front of the subsequent fenestrations, the envelope can bring natural light into the building.

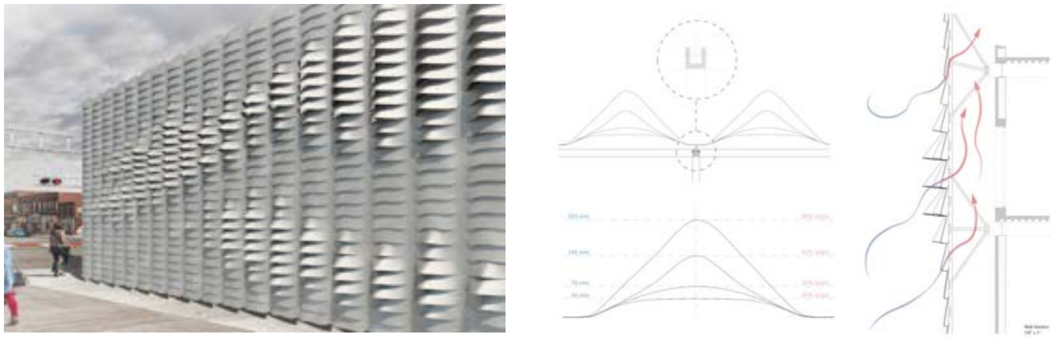

Figure 4: Breathable Skin made from offal #8. Source: (Lopez, 2017)

3.3. Design #3: Faceted Complex Curvature Skin

The design introduced a triangulated modular system for building skins. By folding offal #5, which has the closest geometry to a circle, a triangular pyramid emerged. Placing the pyramids in groups of six created hexagons, which were assembled to form a complexly curved surface building skin.

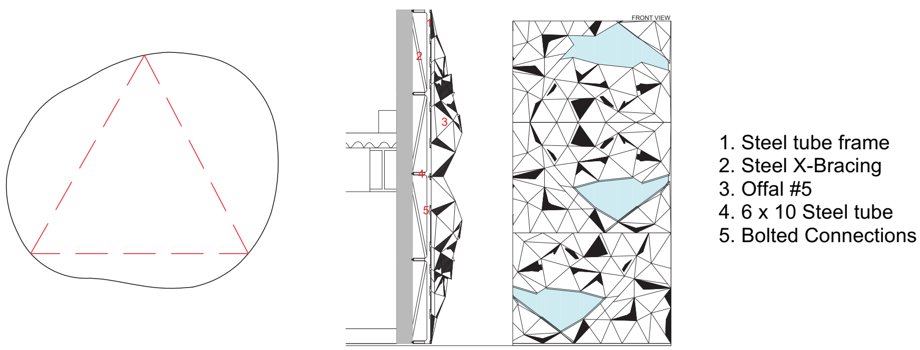

Figure 5: Faceted complex curvature skin made from offal #5. Source: (Escalente, 2017)

3.4. Design #4: Metal Brick Façade System

This metal-masonry system is made from offal #11, which is the closest to a rectangular shape and would create minimum waste while shaping a volumetric module. Four pieces of the offal were folded to form a rectangular box module measured at 500mm x 285mm x 140mm in size. Utilizing this offal module as a veneer façade element creates a building envelope visually similar to an exposed masonry façade. A dry sealant is used as an adhesive for units to prevent water penetration.

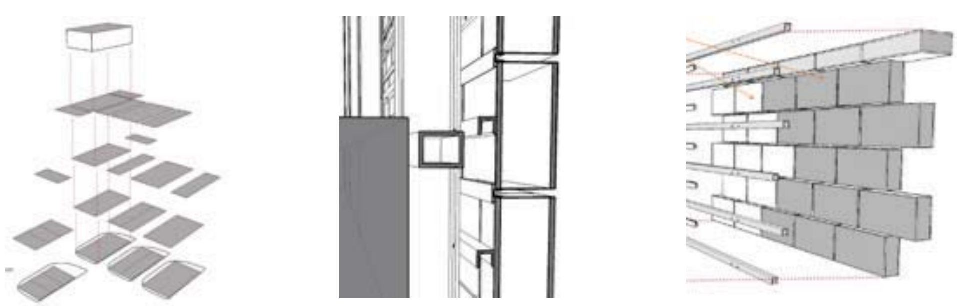

Figure 6: Metal brick insulated units envelope made from offal #11. Source: (Mathews, 2017)

3.5. Design #5: Trapezoid Zigzag Sunscreen

The skin system is made from offal #9 and maximizes the surface to create a triangular box. Two triangles were made into one object to form a box; holes were drilled for connections. The two-triangle units make trapezoids, which are arranged in a zigzag pattern as a shading screen for the building exterior.

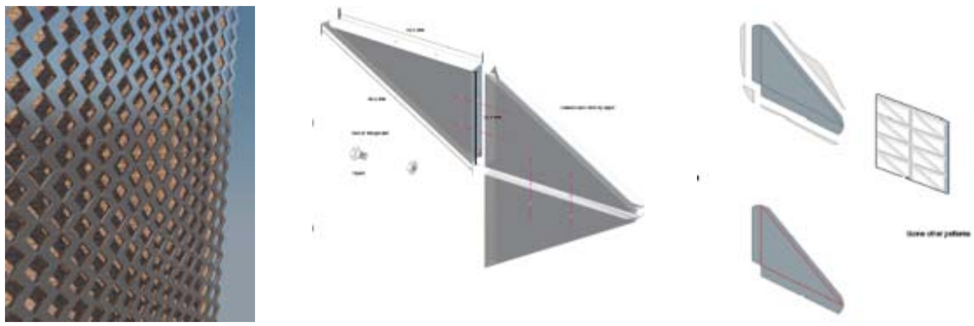

Figure 7: Trapezoid zigzag sunscreen made from offal #9. Source: (Lang, 2017)

4.0 COST COMPARISON BETWEEN RAW AND SCRAP GALVANIZED SHEET METAL

The current cost of raw galvanized sheet metal was obtained by comparing prices from different companies, see table 2. Alibaba, an online retailer, sells coils of sheet metal ranging from $0.25/lb to $0.5/lb (Alibaba 1999), the cheapest of which places a minimum on the quantity of the order. The cost of scrap metal was obtained from recycling companies such as Montgomery Scrap Corp. at $0.07/lb. (Scrap 1949), Rockaway Recycling Company rate is at $0.06/lb - $0.1/lb. (Recycling 1977) and Scrap Monster at $0.11/lb. (Monster 2009). The cost for raw galvanized sheet metal is averaged at $0.45/lb., and for Offal as scrap, it is at $0.08/lb.

4.1. Manufacturability analysis

To understand the cost of the automated manufacturing processes performed on the five proposals, a basic quantitative assessment was performed. This process revealed the influence of design on the manufacturability of the materials for use. Assessments of manufacturability specify a choice of cutting done by a waterjet cutter to calculate cutting energy; for the purpose of this study, design proposals were analysed based only on the number of folds and cuts. The proposed designs were analysed according to the number of units of offal used in the system, the number of cuts per unit, the size of cuts, the number of folds per unit, the size and degree of folding, the number of joints in the system and the types of joints as shown in Table 1 and 2. Further precise analysis regarding the cost of manufacturability will be presented in future publications.

Table 1: Manufacturability of the design proposals. Source: (Authors 2018)

Design Solution	# of Units in the System	# of Cutting per Unit	Size of Cutting	# of Folding per Unit	Size/Degree of Folding	# of Joints	Type of Joints
1	15 units / m^2	3-4 (irregular)	60 cm	6	30 cm/90°	60 bolts / m^2	Bolts
2	5 units / m^2	0	0	1	0	30 bolts / m^2	Bolts
3	10 units / m^2	3	40-50 cm	0	0	60 bolts / m^2	Bolts
4	5 units / m^2	15-20	30-60 cm	0	0	50 bolts / m^2	Bolts
5	2 units / m^2	16-20	30-60 cm	6	30-60 cm/90°	20 bolts / m^2	Bolts

Table 2: Analysis of five design proposals. Source: (Authors 2018)

Design Solution	# of Units in the System	Type of Offal	# of Cuttings per Unit	Mass of Offal per square meter	Cost of raw material @$0.45/lb.	Cost of scrap@ $0.08/lb.

1	15 units / m^2	Offal #6	3-4 (irregular)	2340.95 x 15 =35,114.25g (77.4lbs)	$34.83	$6.2
2	5 units / m^2	Offal #8	0	1116.98g x 5 =5584.9g (12.3lbs)	$5.54	$1
3	10 units / m^2	Offal #5	3	1087.53 x 10 = 10,875.3g (23.98lbs)	$10.79	$1.9
4	5 units / m^2	Offal #11	15-20	1068.63 x 5 = 5343.15g (11.78lbs)	$5.3	$0.9
5	2 units / m^2	Offal #9	16-20	1244.862 x 2 = 2489.724g (5.49lbs)	$2.47	$0.4

While each design proposal is unique and different in its building application, the design proposal with the lowest cost is #5 as shown in Table 2. Figure 8 illustrates a comparison of cost when manufacturing the proposed solutions using offal versus raw materials. From this comparison, one observes that designers who were presented with the same materials provided unique solutions for building skins. After an analysis of optimized use and material flow, results show that design plays a significant role in the final cost of using the waste-flow material. Further studies will be conducted to emphasize the need for manufacturability and embodied energy analysis at the early stages of design to save both cost and energy.

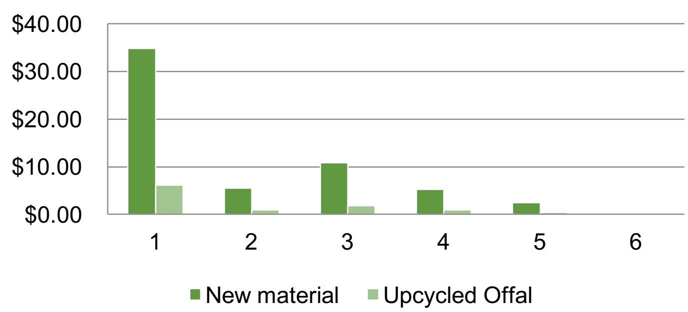

Figure 8: Cost comparison between raw and offal sheet metal Source: (Authors, 2018)

CONCLUSION

This paper introduced a novel approach in designing a symbiosis between non-hazardous automotive waste and the building industry. Particularly, creating building skin systems from by-product galvanized sheet metal from the automotive industry. A similar resource reuse revolution is making way for a new architectural paradigm shift, which is emerging through the integration of creative reuse, synergistic business processes, and a circular economy. To establish a market for reusing galvanized metal scraps, the design should be considered as a value-adding factor of which both the building industry and the car industry could benefit from. Factors responsible for the total cost of production of the design proposals are design, materials, and manufacturing. Using the sizable scrap metal encourages a return of materials at the end of the life of a project. When there is a strategy to use returned materials for building skins, the cost is reduced, and the supply chain of the automobile industry is closed. The fraction of GM offal produced yearly, 1.6 million tons compared to 7.6 billion tons of total waste is minimal. This study has also shown the cost savings for the reuse of and appreciation for the imperfection of the materials aging and its process. The results of the investigation reveal that design of galvanized sheet metal for reuse influences the cost of production. There is no fixed formula to determine the savings of one particular design proposal, but by a unified triangular approach, perfection, in a sense of mitigating wasteflow production, can be sought. In the future, scrap management can include more processes centered on reuse. Improved scrap management will ensure that there is an established chain of supply for scrap metal, which will increase opportunities for job creation. The environment will improve as it will reduce the demand for raw materials. This will, in turn, reduce the carbon footprint of products that involve the use of metals. A circular economy will be further established, and there will be an elimination of waste and established perfection in the imperfect waste.

ACKNOWLEDGEMENTS
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The Raw Earth Brick: A Building Material to Meet the Needs of Local Populations

The raw earth brick: a building material to meet the needs of local populations

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ABSTRACT: This study tests the ways of improving compressed earth bricks by the addition of sugar cane bagasse, alluvial sand and fine aggregates. The objective is to contribute to the valorization of clay resources, with the aim of developing the production of sustainable, local and energy-saving building materials, particularly in the peri-urban areas of Kinshasa in D.R.Congo. Two raw clays were characterized and then mixed with the different additives to obtain raw earth bricks. Those bricks were then submitted to flexural and compression tests to evaluate their mechanical properties. The addition of 0 to 7.5% bagasse increases the flexural strength from 0.66 to 0.99MPa and the compressive strength from 2.54 to 3.14 MPa. The addition of 0 to 50% sand increases the flexural strength from 0.56 to 0.71 MPa and the compressive strength from 2.28 to 3.09 MPa. The addition of 0 to 35% of fine aggregate does not affect the flexural strength, but increases the compressive strength from 2.28 to 3,10MPa. Stabilization with sugarcane bagasse, sand or aggregates is an interesting prospect to improve by a factor of the order of 1/3 the mechanical properties of raw earth bricks. In addition the mechanical properties are also affected by environmental variation in humidity. The durability of the bricks (i.e., its resistance to water) was therefore evaluated by “the wetting drying test” after an addition of cement. The compressive strength after six cycles of wetting-drying decreases by 25% for the bagasse mixture, 6% for the sand mixture and 2% for the aggregate mixture. Likely an addition of cement allows to significantly increase the durability.

KEYWORDS: Raw earth, valorization, stabilization, durability.

INTRODUCTION

The Kinshasa region and its surroundings are experiencing strong spatial and demographic expansion with, as consequence, the development of peri-urban zones in which the habitat quality is a crucial problem (Lateef et al. 2010). To face this challenge, it is essential to value the use of local and regional natural resources. The use of raw earth in construction is a solution that could meet this demand. This study aims to contribute to the valorization of the clay resources of Kinshasa and its surroundings, with the aim of developing the production of sustainable building materials. The choice of the region is justified by the abundance of clay raw materials and by these very important needs.

Clay is a building material widely used in this region. Its exploitation in construction is generally artisanal. The extracted clays are largely used for the manufacture of wood-fired bricks, with the resulting problem of deforestation (Schure et al. 201 1; Wetshondo 2012). Family societies and craftsmen produce quantities of materials which are not accessible to a large part of the population due to their high prices (Wetshondo 2012). Since the early 1990 and the bankruptcy of the Kinshasa Brickyard, the abandonment of building in clay materials was systematic in Kinshasa. Nearly the whole population turned to a local material: the concrete brick. It is a brick made by manual or mechanical compression by mixing grinding fines of a sandstone rock (the Inkisi sandstone) locally called “dust”, alluvial sands (alluvial deposits of the Congo River or the Mbinza, Kalamu and Ndjili rivers) and cement. Sand is taken directly along the rivers. Three companies located in the neighboring province of Kongo Central provide good quality cement. These concrete bricks of 10, 15 or 20 kilograms cost on average, 1, 1.5 and 2 $ the brick. Despite this high cost for most households, concrete brick architecture remains dominant in Kinshasa.

The use of raw earth should limit the cost of production and produce a resistant construction material. Earth is widely available at low cost. The use of raw earth also reduces environmental impacts because they are renewable, biodegradable, CO_{2-} neutral and energy efficient to produce materials (Baley 2005).

The use of the earth as a building material is an old tradition. Due to his abundance, earthen construction is widespread in the history of this region, especially in rural areas. Most of traditional constructions are made with earth associated with other materials such as plant or mineral additions.

However, the earth has the disadvantage of having a low water resistance (durability) and low load bearing resistance. Different techniques are used in earthen construction to improve its strength (Stulz and Mukerji

1988; Houben and Guillaud 1989). The most used technique is stabilization. Stabilization is a set of physical or chemical processes aimed at irreversibly improving the characteristics of raw earth (Gressillon 1978; Bahar *et al*. 2004). For instance vegetal fibers are used to provide a reinforcement to the earth. They reduce drying cracks and increase tensile strength. They accelerate drying, lighten the material and improve its insulation properties. They contribute to the earth's resistance at the grain scale. The fibers can also be associated with other inorganic stabilizers like sand, cement, lime or bitumen (Houben and Guillaud 1989). The addition of sand and aggregates to the earth modifies its grain size and improve its compactness by making the earth denser (Houben and Guillaud 1989). Cement creates an inert skeleton. It improves the resistance to water by creating bonds between sand and gravel particles. An addition of 5 to 8% of cement or lime generally produces an improvement in the compressive strength and an insensitivity to water (Doat et al. 1979; Rigassi 1995).

In this article, we study the behavior of a stabilized raw clay with the incorporation of sugarcane bagasse, sand and fine aggregates in order to increase their mechanical resistance, water stability and durability of earth bricks. The main objective is the study of the impact of the addition of these stabilizers on the resistance of a raw clay.

The research is based on the traditional technique of Compressed Earth Block (CEB) in order to respect the local habitat and reduce the energy consumption for construction material production. The mechanical properties of the compressed earth bricks will be compared to choose the most appropriate stabilizing agent and optimal proportions between the raw clay and the additives. The improvement of the durability of the selected mixture will be done by adding cement, and then tested by the humidification-drying test or alternating wetting drying cycle.

1.0 MATERIAL PROPERTIES

1.1. Raw clays

The samples were taken in two areas from the Kinshasa province and Mbanza Ngungu (Figure 1).

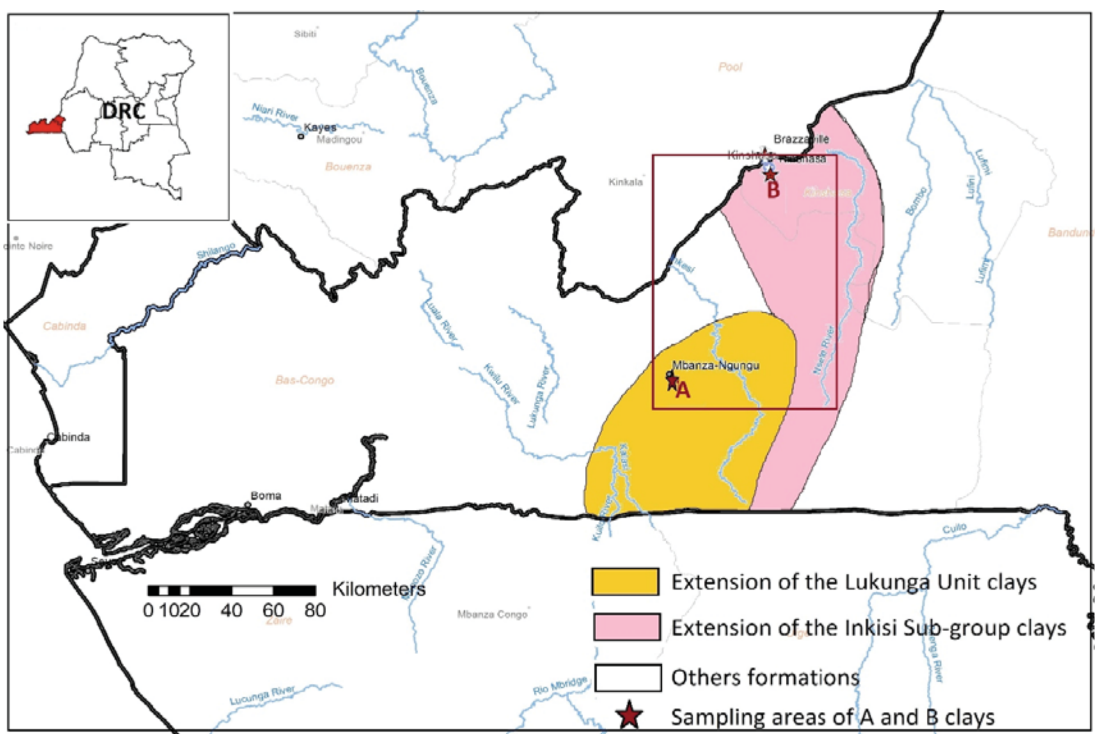

Figure 1: Location map of the study area (red box) showing the sampling zones chosen in the Kinshasa province and Mbanza Ngungu, D.R. Congo. The studied raw clay materials are derived by the weathering alteration of the geological substrate. The colors represent the extension of the two regional geological formations observed in the study area.

The tests focus on two raw clays formed by the alteration of geological formations located in the West Congo Belt. The sample A is formed by the alteration of carbonates rocks from the Lukunga Unit. The sample B is formed by *in situ* alteration of Sandstone from the Inkisi Subgroup. Both clay samples present a yellowish color that is appreciated for the brickyard, widely present in the region.

Each clay sample was stabilized with a stabilizer available in the sampling area where it was taken. Sample A was stabilized with vegetal fibers of sugar cane; sample B was stabilized with sand and aggregate.

1.2. Stabilizers

Bagasse

Sugar cane is an herbaceous tropical grass. Bagasse is the fibrous residue of sugarcane obtained after extraction of the juice. Bagasse is a waste largely present in the southern part of the explored region. It is mainly produced by a local sugar factory located in the region near Mbanza Ngungu. It has been used to stabilize the clay sample A.

The average composition of the bagasse is 45% of fibrous fraction, 2 or 3% of insoluble solids (inorganic fractions), 2 or 3% of soluble solids (residual sucrose molecules, not extracted during the process) and 50% of water (ICIDCA 1990). The chemical composition of the insoluble organic solid fibrous material depends on the sugar cane variety. It consists of polymers made by 15 to 35% of lignin, 25 to 35% of hemicellulose and 30 to 50% of cellulose (ICIDCA 1990; Cuba9 1990; Dinu 2006; Berndt and Hodzic 2007).

Sand

The sand used is an alluvial sand taken along the Congo River. Its particle size is presented in Table 1:

Table 1: Granulometric distribution of the Congo River sand.

>650 µm	>500 µm	>300 µm	>250 µm	>150 µm	>75 µm	>63 µm	>53 µm	< 53 µm
0%	4.1 %	19.1 %	32.6 %	76.8 %	93.8 %	95.6 %	97.3 %	2.7 %

Fine aggregate

It is a fine aggregate of the Inkisi sandstone locally called "dust". Its particle size distribution is shown in Table 2.

Table 2: Particle size distribution of fine aggregate.

>4.5mm	>4mm	>2mm	>1mm	>500 µm	>250 µm	>150 µm	>75 µm	>6 3 µm	<53 µm
0%	1%	23.5%	42.4%	59.2%	76.6%	85.4%	95.1%	97, 4 %	1.5%

Cement

There are different types of cement that differ in composition, strength, setting and hardening speed. The cement used in this study is a composite Portland cement EN - 197-1 CEM II 32.5 R.

2.0 RESULTS AND DISCUSSION

2.1. Properties of raw clays

The two clays were characterized by determining their chemical compositions by X-ray Fluorescence (XRF), mineralogical composition by X-Ray Diffraction (XRD), their Atterberg limits and their particle size distribution by laser diffraction. The results are shown in Table 3.

Table 3: Properties of samples A and B.

Properties	A	B
Chemical analysis (%)		
SiO_2	69.18	72.16
TiO_2	1.3	0.79
Al_2O_3	17.5	14.89
Fe_2O_3	3.54	4.03
MnO	0.01	0.01
MgO	0.01	0.19
CaO	0.07	0.03
K_2O	0.59	0.57

P_2O_5	0.05	0
LOI	7.75	7.33
Mineralogy (%)		
Quartz	53	55
Orthoclase	2	1
Goethite	7	11
Magnetite	2	0
Anatase	1	1
Kaolinite	31	28
Illite	4	4
Atterberg limits		
Liquid Limil LL (%)	34	32
Plastic Limit PL (%)	26	22
Plasticity Index PI	8	10
Particle size distribution		
Sand (2 - 0.063 mm) (%)	15	20
Silt (0.063 - 0.002 mm) (%)	75	68
Clay (<0.002 mm) (%)	10	12

The two clays have very similar properties even they derive from the alteration of different geological substrate. (carbonates for sample A, sandstone for sample B).

2.2. Mechanical tests

We performed flexural and compression tests on raw earth mixtures. Sample A was mixed with 1%, 2.5, %; 5% or 7.5% by weight of bagasse. Sample B was stabilized either by sand (with 35 or 50% by weight) or by fine aggregate (with 20 or 35% by weight)
The manufactured test pieces correspond to the standard dimensions for hydraulic mortar tests: 4x4x16 cm³. The test pieces were stored for 28 days in a controlled atmosphere. The room temperature was continuously maintained at 21°C (± 2°C) and the relative humidity at 60% (± 10%). The mechanical properties are estimated by flexural and compression tests on test pieces of 28 days in accordance with standard NF EN 196-1.

The flexural strength is determined by the 3-point bending test. The specimen is loaded at its center by a force centered and supported by two supports spaced 100 mm apart. The flexural strength is then defined at break. The loading speed during the bending test is 300 N/min. After rupture of the test piece by bending, the two pieces are submitted separately to compression. The compressive strength is determined at break. The loading speed during the compression test is 14.4 kN/min. The results obtained are shown in Table 4.

Table 4: Twenty-eight days flexural and compressive strengths on earth-bagasse, earth-sand and earth-agrregate mixtures.

Stabilizers	Flexural strength at 28 days (MPa)	Compressive str ength at 28 days (MPa)
Bagasse		
0%	0.66	2.54
1%	0.84	2.80
2.5%	0.91	2.92
5%	0.93	2.95
7.5%	0.99	3.14
Sand		
0%	0.56	2.28
35%	0.59	2.59
50%	0.71	3.09
Fine aggregate		
0%	0.56	2.28
20%	0.54	2.54
35%	0.56	3.10

Resistance to flexural and compression increases with the addition of bagasse. Flexural strength evolves from 0.66MPa without any additive to 0.99 MPa with 7.5% of vegetal fibers into the mixing. The compressive strength increases from an initial value of 2.54 MPa to 2.80 to 3.14 MPa with an addition of vegetal fiber ranging from 1 to 7.5%. The flexural strength also increases with the addition of sand from 0.56 to 0.71MPa for a 50 % weight mixture. The compressive strength from 2.28 with no sand to 3.09 MPa with 50 wt. % of sand. The addition of aggregate has little effect on the measured flexural strength. However, the compressive strength increases significantly, from 2.28 to 3.10 MPa with an addition of 35 wt. % of aggregate to the raw clay. For all the additives, the best mechanical results are obtained with the highest amount of vegetal (7.5%) or mineral additives (50% sand or 35% aggregates) to the raw clays.

Depending on the standard used and the country of reference, the compressive strength required for BTC differs, ranging from 1.5 to 3.5 MPa (Figure 2). The tested compressed raw clays display compressive strength values higher than 2.2: those values overpass the minimum requirements, except for the New Zeland standard (NZS). The different additives allow to improve their compressive strength above 3 MPa but still lower than the minimum requirement of 3.5 MPa for NZS standards.

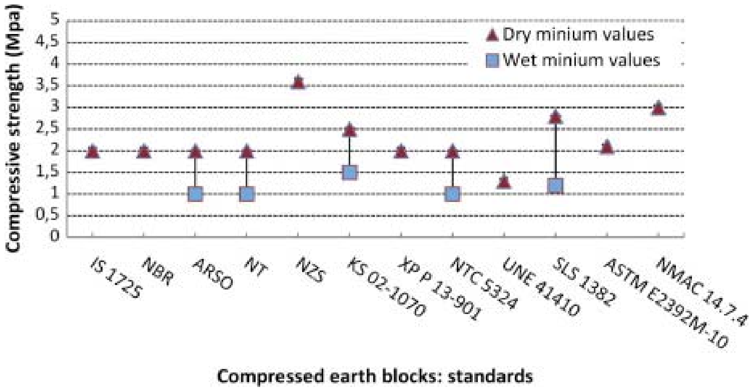

Figure 2: CEB minimum values of dry and wet compressive strength according to different standards: IS 1725 (India), NBR (Brazil), ARSO (Africa), NT (Tunisia), NZS (New Zealand), KS 02-1070 (Kenya), XP P13- 901 (France), NTC 5324 (Colombia), UNE 41410 (Spain), SLS 1382 (Sri Lanka), ASTM E2392M-10 (America), NMAC 147.4 (New Mexico). Source: (Jaime et al. 2012).

Flexural strength is less important than compressive strength in construction. Indeed raw earth constructions are generally dimensioned so that the material is only stressed in compression (Moevus et al. 2012). Therefore there are few requirements concerning the flexural strength of raw earth: it ranges from 0.1 to 0.5 MPa in the few available studies (Moevus et al. 2012). For instance, the New Zealand standard NZS 4298: 1998 recommends a minimum flexural strength of 0.25 MPa (Moevus et al. 2012). The tested compressed earth bricks all reach this minimum value.

2.3. Durability tests

The main disadvantage of the earth construction is its lower resistance to the action of water. To overcome this, we tested the addition of 6% cement on the 3 mixtures that gave the mechanical best results (7,5% bagasse, 50% sand and 35% aggregate). The 3 new mixtures were then subjected to a durability test. This was done by the humidification-drying test or alternating wetting drying cycle. The samples are subjected to six cycles of wetting - drying. They are immersed 25 minutes and then dried at 70°C, 40% humidity for 36 hours. At the last cycle, the compressive strengths of the "aged" samples are measured and compared to "healthy" sample. The humidity resistance coefficient (C_{rh}) is defined by the ratio between the compressive strength after 6 alternating wetting-dry cycles (R_{msa}) on the dry compressive strength R_{dry} ($C_{rh} = R_{msa} / R_{dry}$). The results are shown in Table 3.

Table 3: Values of dry compressive strengths (R_{dry}), compressive strength after wetting - drying (R_{msa}) and humidity resistance coefficient (C_{rh}).

	7,5% bagasse	50% sand	35% aggregate
R_{dry} (MPa)	4.73	3.19	3.71
R_{msa} (MPa)	3.54	3.00	3.64
C_{rh}	0.75	0.94	0.98

This test shows that there is an improvement in compressive strength with the addition of 6% cement. However, durability is not sufficiently improved: The treatment with 7.5% bagasse and 6% cement has a very satisfactory dry strength, however the resistance after wetting drying is altered by 25%. The treatment with 35% fine aggregate and 6% cement has satisfactory dry strength. The resistance after wetting drying decreases by 6%, but remains higher than the previous mixture. Finally the treatment with 50% sand and 6% cement give satisfactory dry strength. The resistance decreases by 2% after 6 cycles of wetting drying, but remains higher than the other two mixtures.

CONCLUSION

On average an earth material with a compressive strength of 2 MPa can be used in masonry. But the minimum value of compressive strength desired is 2.5 MPa. For flexural strength the desired value of the earth bricks for use in masonry is 0.4 MPa. We note that the addition of the different stabilizers (bagasse, dust and sand) allows to reach these values. The best values are obtained with the addition of 7.5% bagasse, 35% dust and 50% sand.

Stabilization with vegetal fiber of sugar cane (bagasse), fine aggregate or sand is therefore an interesting prospect. However, it is essential to do other tests of durability on these materials. The compressive strength decreases by 2 to 25% on the mixing containing 6% cement after 6 cycles of wetting drying. An increase of the percentage of added cement above 6% would lead to maintain the compressive strength values after wetting drying.

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Rodrigo Garcia-Alvarado

Initial Developments and Projections of 3D-Printed Construction

Initial Developments and Projections of 3D Construction Printing

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ABSTRACT: 3D Construction Printing is a novel technology to elaborate building parts by material deposition. This technique is emerging through several university and entrepreneurial initiatives, mostly in developed countries. Some exploratory buildings and/or pieces have been created and diverse companies plan to execute large constructions. This article aims to review architectural and urban projections of this technology based on these experiences and initial tests and developments in Concepción, Chile. Supplies and equipment has been collected and a number of concrete printing trials has been carried out. Additionally, parametric programming of 3D-printed walls is being developed in a BIM platform in order to generate and evaluate architectural models. Also, a robotic installation is being set-up with the support of a national program on building productivity, research centers and industrial companies. The material tests have demonstrated the feasibility of construction printing with local materials, in addition to an important reduction in the time and resources needed to produce pieces with different shapes, although this process does require automation, structural verification and large-scale execution. The parametric programming in BIM shows the integration of the design-to-construction process, in addition to versatility and optimization of architectural designs. The planning of an industrial installation expresses the convergence of different stakeholders in this technology and a particular interest in to develop local supplies and machines. These activities and other experiences suggest the impact of 3D construction printing on the emergence of new manufacturing systems for buildings, that impels an architecture of curved profiles and appealing spaces that can become part of the real-estate market as experimental neighborhoods and/or iconic buildings, related to new social trends.

KEYWORDS: 3D Construction Printing, Digital Fabrication, Parametric Design, Building Technology.

INTRODUCTION

Several initiatives around the world, usually in industrialized nations, are testing the digitally-controlled three-dimensional deposition of fast solidifying fluid material to produce building parts (Fig.1), which has been called "3D Construction Printing" (Perkins and Skitmore 2015; Labonotte et al 2016; Wei et al 2017, Panda et al 2018). In most of these experiences, cementitious mixtures are expelled from a nozzle hung from gantries or robotic arms to apply successive layers as additive manufacturing without formwork (Bos et al 2016, Duballet et al 2017). Certain initiatives have managed to execute small buildings, and some companies have promised to build large constructions, with shorter terms and lower costs than conventional processes (Perkins and Skitmore 2015; Labonotte et al 2016). Although equipment, materials and benefits are still being tested, it has been asserted that this technology will transform the construction industry, architectural design and the building of cities (Hager et al, 2016). This research aims to discuss the projections of 3D construction printing in architecture and towns, based on these experiences and initial developments of this technology in Chile. It includes tests of the mechanical deposition of cementitious compounds, parametric programming of architectural designs in BIM systems, and the preparation of a robotic installation.

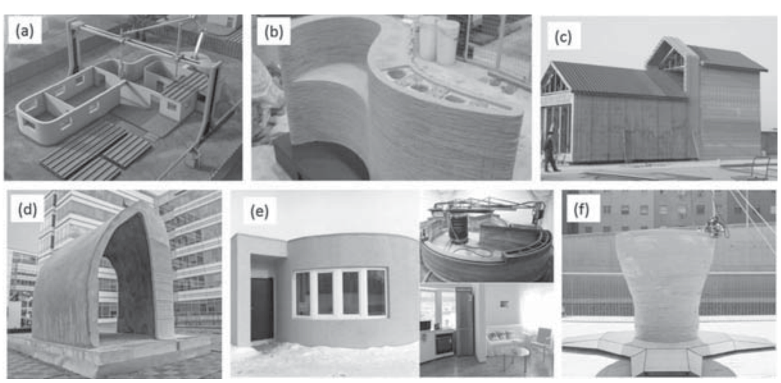

Figure 1: Experimental works created with 3D construction printing around the world: (a) USA, (b) UK, (c) China, (d) France, (e) Russia, (f) Spain. Source: (Panda et al 2018)

1.0 INITIAL DEVELOPMENTS IN CHILE

1.1. Tests of 3D-Deposition of Cementitious Composites

To review the elaboration of building elements through the three-dimensional deposition of cementitious compounds available from local industries, first a mechanical system was developed. Subsequently, diverse supplies were collected to make mixtures, basic trials were conducted, and several concrete machines were used. The tests focused on determining composites with the proper fluidity and early solidification required to lay down a horizontal cord by vertical extrusion in motion, and sufficiently fast hardening to support the next cord in a short period of time and maintain the stability of the sequence (like Malaeb, 2015; Torres, 2016, and Bos et al, 2016). Different mixing and pumping machines has been also tested, as well as the preparation of nozzles, clamping and control, for a large automated installation.

A load elevator, which provided adjustable vertical displacement, is used as the base of the test system, together with a small trolley mounted on rails, with a 1/8 HP electric motor for horizontal displacement, and hydraulic pistons with lateral axes to achieve rotation (with fixed support). The deposition system is made of a 60cm long, 110 mm diameter PVC tube that ended in a reduced 45 mm diameter, with a valve for air intake under pressure from a 2 HP compressor (Fig. 2). In addition, a mechanical mixer and integrated controls for the motors are used to synchronize operation. The tube is filled with the prepared mixture (approximately 5 liters), then the compressor and motor are turned on simultaneously to deposit a cord approximately 8 cm wide and 5 cm high, in a one-meter-long horizontal movement. After each horizontal deposition, the tube must be reloaded, the trolley moved to the initial position and the motor restarted for the following cord, which can be executed in a curve with lateral pistons. In the initials tests, the prepared mixtures were reviewed, and times, speed of deposition, hardening, and dimensions of the results executed were measured.

In the tests, different combinations of aggregates, cement, water and additives were used, in addition to compounds prepared. Currently, tests are also being carried out with micro-aggregates and sieving to achieve proper rheology and review fiber aggregates. Furthermore, standardized tests of viscosity, creep, compression and resistance are being conducted on the compounds, and normalizing a measurement of deposition by video recording, sizing and hardening by Vicat needle. Deposition is also being tested with another set of equipment in which mixtures are projected through a hose using pressurized air (shotcrete), while the nozzle is supported by rails.

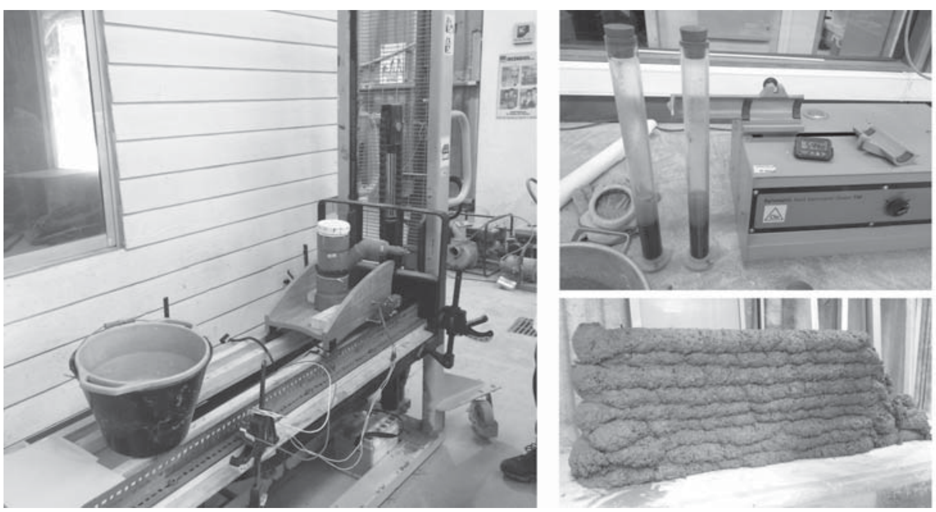

Figure 2: Left: equipment to test material deposition; Upper-right: evaluation of sands; Lower-right: sample of material deposition. Source: (Author 2018)

1.2. Parametric Design of Walls with 3D Construction Printing

In order to plan the architectural composition of walls created with 3D construction printing, a parametric programming is being developed in a BIM platform (with Dynamo language in Revit), based on similar works in the field (Raspall, 2015; Kasperzyk et al, 2017; Craveiro et al, 2017; Sacks et al, 2004; Davtalab et al, 2018). The programming assumes a machine-work space of 10 x 3 meters and 3 meters in height, with a capacity for three-dimensional deposition of self-supporting reinforced cementitious mixtures of 10 to 40 cm. in thickness. Thickness may be smaller depending on the curve, height and lateral support required to maintain structural stability. This can be reviewed by exporting the model to a finite element software, with point loads and minimal deformation. This production capacity is achievable both with the planned installation of a robotic arm with an automated rail and with mechanical equipment with rails for three-dimensional displacement of concrete delivery hoses. That is, it is estimated that this type of wall can be executed on site using specific equipment at lower costs than robots. Based on the workspaces to execute the walls, the architectural project is divided into magnitudes equivalent to or smaller than the workspaces, to establish the consecutive locations of the machinery. This operative subdivision also makes it possible to plan the equipment installation sequence according to the progress of execution to ensure clear transportation routes. If necessary, some modules or openings are postponed, in order to remove equipment when closing walls.

In the parametric programming, the main sizes of the configuration must be indicated at the beginning. Therefore, a linear or rectangular arrangement can be initially chosen, which can be applied consecutively in the same horizontal plane or successive vertical levels for larger configurations. The subdivision of parts is then carried out according to the maximum dimensions of operation (with splice margins). Options make it possible to ensure the regularity of parts of the greatest possible length, or a combination of sections, as well as to develop stretches that match at the corners. Afterwards, the sections are traced with random curvatures or those defined by the designer, in a similar way in all the sections or randomly within ranges, and on the same side or sequentially on opposite sides (which gives greater stability, but reduces the internal area). The criterion of structural optimization defines thicknesses according to height, curvatures and continuity, thus establishing parametric families of walls in the BIM environment (Fig.3). Random generation can develop a number of sequentially named alternative BIM models, thereby giving the designer different configuration possibilities.

The various models generated in the BIM environment can be quantified, thereby obtaining the total material required, according to the amount, length and thickness of walls. The number of sections can also be determined, as well as the total length of sections, which in turn can be used to calculate the total operating time (multiplied by the number of cords in height and speed of execution, plus the machine´s transfer time). Then, models can then be compared in terms of material or processing costs, which are normally different depending on the curvatures, in addition to their spatial configurations, from interior or exterior perspectives. The process can also be planned based on steps, according to work schedules, by defining the work route and machinery installation positions, and anticipating the requirements involved. Likewise, this plan can be integrated with the rest of the BIM model to combine with other elements, such as floors or covers (which can also be executed with construction printing), including doors, windows, services, and terminations, among others. Furthermore, climate, structural, or infrastructure management can be incorporated into analyses. The programming developed is currently being completed with the ability to generate variable height configurations and combined splices to ensure continuity, parallel, cross-linked or embedded layouts for structural performance and material reduction or combination with different performance requirements (i.e. resistance, thermic, acoustic, chromatic). Finally, the model generated is exported with the elements of parametric families, in solid production (STL) and/or the format for machine control (KRL).

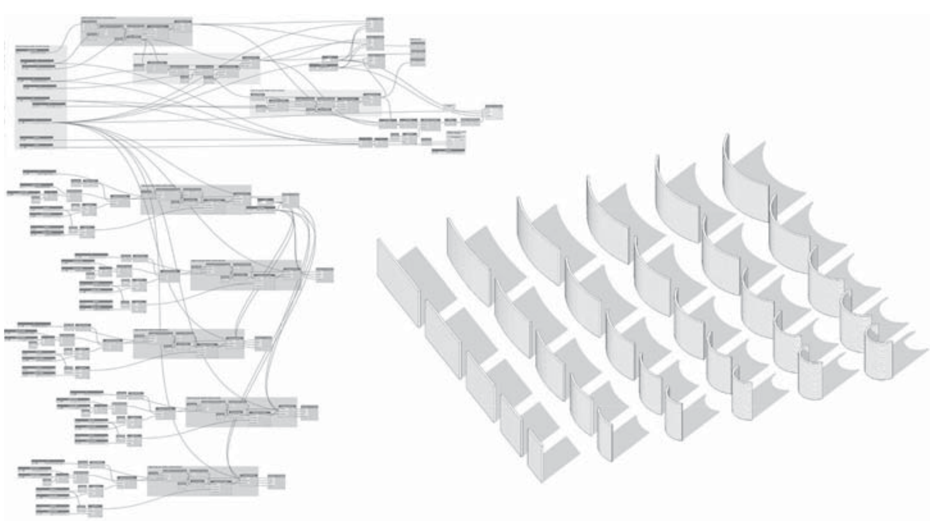

Figure 3: Parametric programming and examples of walls generated. Source: (DGNL Studio 2018)

1.3. The Implementation of a Robotic System for 3D Construction Printing

To boost the productivity and sustainability of construction, the Chilean government established a national development strategy (Corfo, 2014; Gutierrez, 2016) that included the creation of technology centers adjudicated by a consortium of local universities, with public financing and private collaboration. At the Universidad del Bío-Bío, located in Concepción, the main city in the south of Chile, which is characterized by its regional services and forestry resources, a large workshop is planned. This facility is targeted to elaborate prototypes in two areas of development: elements made of concrete, the primary construction material in the country; and prefabricated components made of wood, a material with environmental quality and local production. Both areas will be related through a mounting crane and integrated with a robotic system.

In order to experience 3D construction with concretes, polymers and/or biomaterials, the installation of an industrial robotic arm (Kuka KR120R2500) on a 10-meter rail with a concrete pump for a 120-liter pond with a 30 meter hose was approved through additional state funding. This installation will have a 140 m^3 workspace (Fig. 5) in which the arm and pump nozzle are able to make continuous walls of up to 15 meters in length and 3 meters in height, with six degrees of freedom. This will be the first 3D construction printing installation in the country and the most versatile and largest in Latin America. It will be managed by Universidad del Bío-Bío with the support of Universidad Santa María of Valparaíso; as well as the Research Center for Advanced Polymers and the Center for Nanotechnology and Bio-materials of Concepción; the PRODINTEC Foundation of Spain, which has been conducting research in 3D construction printing for five years; and Cementos Bío-Bío, Ready Mix and Bottai, the largest companies in the country devoted to cement production, concrete manufacturing and prefabrication, respectively. Financing has also been approved for additional research with a small-scale installation of robots with cars and 3D plastic filament printers that reproduce construction printing processes to experiment with multi-robot coordination in the execution of buildings.

2.0. PRELIMINARY RESULTS

2.1. Preparation and Samples of 3D-Deposition

To date, the equipment to test 3D-deposition has been used to carry out partial and complete elements, as well as review different compounds, machineries and procedures. In the test facility, 18 deposition samples have been completed with supplies available on the local market. The first twelve produced continuous cords, and the following six resulted in overlapping cords. In addition, other partial tests conducted with different mixtures were not able to produce continuous cords or regular finishing. In this way, the compound that was able achieve adequate flow and early hardening was determined to be a mix for quick concrete called "Topex”. In the first samples completed, adjustments were made in the configuration of the equipment in terms of operational control, working speeds, video recording and measurements. The average horizontal deposition speed of the initial samples was 22 seconds/meter, for cords 10 to 15 cm. wide and 4 cm. high. With additional time of around two minutes to load and reposition the trolley and by mixing in parallel, a production speed of 0.4 meter/min was obtained. Small linear and curved walls of up to 9 cords in height were formed, during a total production time of 24 minutes, with 3 minutes of deposition, which corresponds to an execution speed of 0.8 m^2/hour. Hence, a two-meter high wall could be made in 2.5 hours per meter of length, or in a more continuous process, without intermediate tasks, in 20 minutes per meter. This means that a wall of several meters can be completed in a few hours. Although production speed has not yet been verified for large pieces, it should be similar to other experiences reported (Malaeb et al, 2015; Torres, 2016; Ma and Wang, 2017), and is reduced in comparison with the various days required for the traditional execution of a similar wall, which involves formwork, reinforcement, pouring, curing, removing formwork, and repair of failures. Also, conventional construction of these elements entails more materials, personnel, accidents, quality control, administration, waste, transport and environmental impact.

Additionally, different inputs, mixers and pressure pumps has been tested. Therefore, mixtures with improved rheology (regular distribution of particle sizes of materials) were prepared to get pasty compounds. Seven samples of fine aggregate from local producers were collected, sieved and combined with cements and accelerators to develop preliminary tests. The expulsion nozzle was mounted on a longer-range horizontal rail (2 meters), with a larger capacity motor, and the vertical lift and transverse displacement system was designed to achieve a working space for samples up to 1.8 meters long and 1.2 meters high. In the future, these capacities must be industrialized, by means of mechanical or automated equipment, regular supplies and specialized staff. However, these experiences demonstrate the initial feasibility of creating building elements through construction printing with products available in the country, and their adaptability to different circumstances or local conditions, resulting in a significant reduction in time and resources in relation to conventional construction.

2.2. Generation and Assessment of Parametric Models

The programming developed to generate models of walls according to 3D construction printing features made it possible to implement a procedure for the design and evaluation of architectural alternatives in a BIM environment. A number of production assumptions are taken into consideration and used in a planning method with computational support to determine more effective and meaningful compositions. The design process is then integrated in a BIM platform, with parametric families of building elements determined by specific construction printing equipment, and the capability to generate and assess models, as well as to export information for analysis, quantification and visualization, and later, plan the execution and control of the machinery (such as Davtalab et al, 2018).

A building framework is first established by proposing a sequence of work spaces with fitting ranges to ensure continuity of production, in addition to equipment operating conditions such as thickness, deposition speed, and the resistance capacity of the material, among others. With these properties, geometric rules are programmed by means of graphic components and relationships through Dynamo in Revit software, with some instructions in Python to determine conditional recursive sequences and families of walls. The procedure then generates a set of models and also a schedule of quantities that can be exported. Furthermore, a macro is created in Excel to examine the data extracted in the analysis of models.

After several preliminary tests with different generation values, the programming was tested with an exercise to create an enclosure of 20 x 40 meters, with wall segments of a maximum of 10 meters, which may have a regular curvature, like an arc. It assumes that curvature implies different structural capacities (Martens et al, 2018), and therefore diverse thicknesses in different wall families. The programming makes it possible to develop 30 simultaneous models with different amounts of wall segments and curvatures (Fig. 4). Each model is assigned a code of variables, and subsequently elements are tabulated and exported to the spreadsheet. Thus, models are used to quantify the project, considering the total length proportional to the execution times, and the volume of material equivalent to the cost. Then the fastest and the cheapest models are identified and also the appropriate combination of both. From these three models, interior and exterior views are generated. In this way, the models are quantitatively and qualitatively evaluated. The process must be validated with the operational capabilities of the equipment, as well as in actual design activities. However, it facilitates the systematization of the design and execution processes with construction printing through digital integration targeted at developing the versatility and optimization of the building.

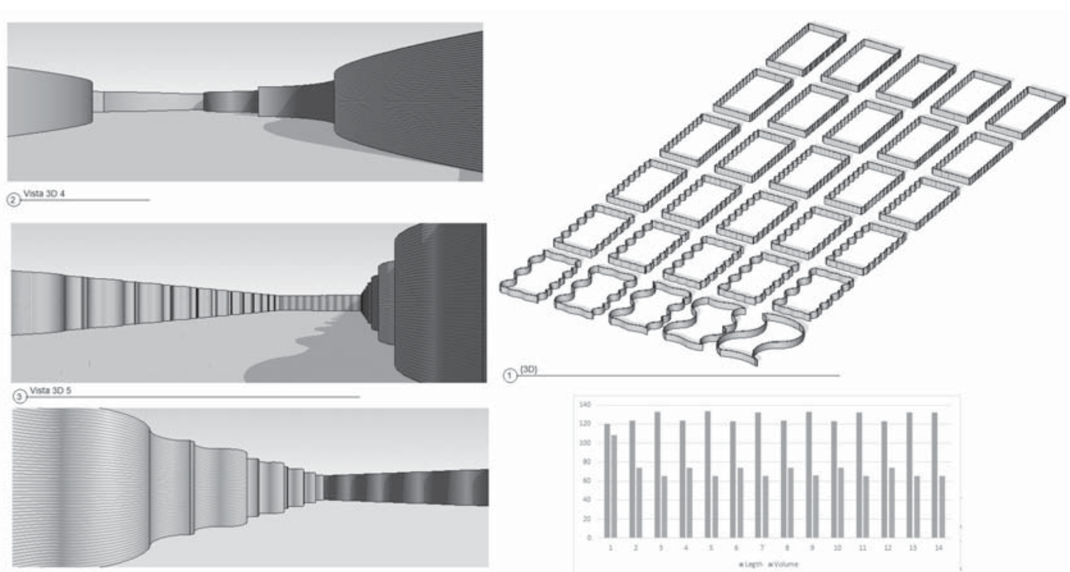

Figure 4: Models generated, visualizations and quantitative assessments. Source: (DGNL Studio 2018)

2.3. Agreements on and Plans for a Large-scale Robotic Installation

State, industrial and academic stakeholders have converged in a plan to install a large-scale robotic system for construction printing in Chile in order to move towards more efficient building with less environmental impact (Bogue 2018). The provision of state funds oriented towards the productive and sustainable development of the country; university interests in professional training with a perspective on the future; and the motivation of private companies aimed at maintaining or increasing their participation in the construction market, express trends that come together in the planned installation and which have been consolidated through financing approval and specific work agreements.

A technical board has been formed with representatives from the participating institutions and companies, collaborative developments have been prospected and joint tests are being carried out. Cement companies have provided concrete injection equipment and various materials to conduct pumping tests. The Research Center for Advanced Polymers has supplied samples of polymer blends and injected polyurethane to test printed elements. The Center for Bio-materials and Nanotechnology is preparing cementitious compounds with nanocellulose fibers for testing, to develop local products with low environmental impact, and better resistance and thermal performance for construction.

The agreed installation expresses a joint development perspective in the building sector. It involves the production of cementitious mixtures for deposition in: a plant for prefabricated elements, the site-work for the execution of the main parts of buildings, as well as the manufacturing of products and equipment, and large-scale construction in medium and larger dimensions, with the participation of local companies, state programs and national standardization. It also represents a motivation to promote new compounds with polymer blends and bio-materials, in search of lower execution costs and greater constructive and environmental functions. The agreements and plans developed should materialize in the installation and joint experimentation, with the adequate provision of resources and coordination of activities. They are evidence of the relevance of this technological innovation and its potential to have a productive impact on the local construction industry and to link stakeholders and society.

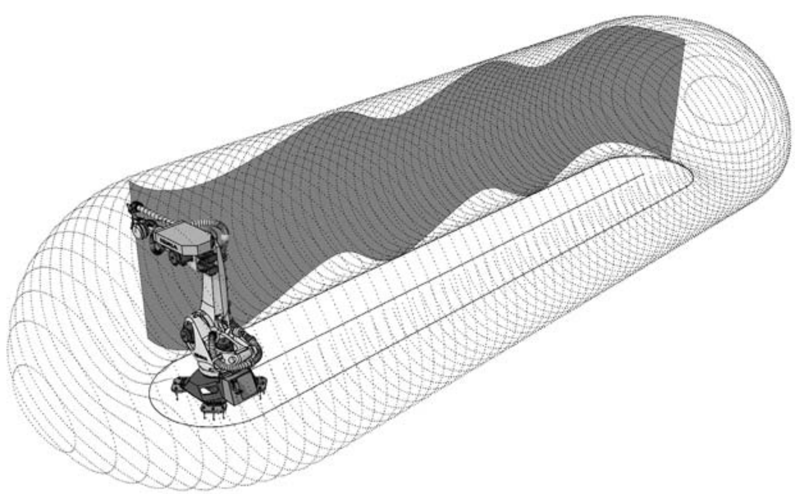

Figure 5: Working space of the installation. Source: (DGNL Studio 2018)

3.0 ARCHITECTURAL AND URBAN PROJECTIONS

3.1. Architectural Compositions

According to the experiences detailed previously and reports of diverse initiatives around the world (Perkins and Skitmore 2015; Labonotte et al 2016; Wei et al 2017, Panda et al 2018), the developments in 3D construction printing have mainly focused on the main vertical elements of buildings. Some cases have involved inclined or vaulted coverings, or prefabricated pieces or sections that are later moved and mounted on the ground (Yuan et al, 2018). The vertical printed elements are self-supporting planes and diverse in form, usually with rounded corners and/or curved parts; so that the first printed constructions have mostly been horizontal buildings, low in height with sinuous shapes, and integrated with conventional products for roofing, fenestration, services and/or terminations. There is great interest in increasing the insulation, finishing and resistance of these vertical compounds, as well as in curved fabrication, which together provide more stability, better performance and novel spatial experiences and meanings associated with new technologies, environmental requirements and/or cultural attributes. Most stakeholders and entrepreneurs of 3D construction printing are motivated to develop large-scale housing projects with short construction terms and innovative features, but it is also possible to construct buildings for commercial exhibition use, industrial workshop or public services. Due to the incipient conditions of 3D-printing technology, which depends on new and large equipment, in addition to unique supplies and specialized personnel, the buildings could be concentrated in new urban complexes promoted by local developers.

3.2. Building Processes

The planning and design of buildings with 3D construction printing should integrate this technology early on in the process, thereby taking advantage of its technical and expressive features (Delgado et al, 2018). The available local suppliers must be taken into consideration, together with the formal, constructive and economic condition of the architectural configuration. Previous experiences should be used to determine the specific attributes of the buildings, while also testing some parts or characteristics that have not previously been developed. Hence, traditional design documents, construction management and experienced personnel must be combined to progressively integrate these new technical capabilities. The digital management of the process should motivate an increasing exchange of documents, and agreement on formats, tasks, protocols and analysis potential, especially related to visualization, planning, structural, environmental and/or economic features. This implies the need to normalize and regulate some constructive conditions, systems and commercial products in relation to the scope of elements and buildings that can possibly be executed, for example in functional properties, articulated with their commercial and social projections. Development will most likely concentrate on specific products (buildings, elements or applications), which call for commercial and constructive advantages, in sufficient magnitudes and with a permanent demand to sustain them. This can impel productive synergies, or perhaps also financial bubbles, which will enable new close linkage between the market, society and the construction industry, along with flexible and intense professional developments with promising capabilities.

3.3. Urban Perspectives

3D construction printing has been promoted to reduce work time and resources, which was confirmed in the first experiences with deposition and digital integration capabilities, although they do require industrial development. These conditions are crucial in construction due to the large costs and duration of planning and execution that involve previous expenses in materials and personnel with late exploitation, and require high amounts of financing and management efforts. Consequently, decreases in time and resources should result in lower costs and enable the participation of smaller companies and stakeholders than in conventional construction. However, initial actions depend on advanced capabilities and equipment, which require greater technical and financial support, waiting for dispersion through entrepreneurship. It should also be considered that the lower costs of printed construction should be linked to lower value lots, usually located in the peripheries of cities, which may be close to production sites, thus encouraging experimental neighborhoods or exceptional buildings in these sectors. The versatility of technology and digital processes enables local adaptation that must be oriented towards the relevance and effectiveness of buildings and reducing social and economic gaps. In the long term, the development of 3D construction printing should motivate real estate decompression, the acceleration of the industry and social initiatives, and connection with new cultural trends and environmental commitments, thereby promoting the achievement of a collective well-being.

CONCLUSIONS

This work presents initial works with 3D construction printing in Chile to explore its architectural and urban possibilities. The results of material tests, design programming and the planning of a large installation demonstrate local feasibility, architectural features and sectorial interests related in particular with biomaterials and large-scale construction, which would enable the production of singular buildings and urban complexes. Like also others initiatives around the world are showing. Nevertheless, there are also important challenges in the development and industrialization of this technology. These experiences demonstrate the capability for fast execution and process integration, and the potentialities of curved patterns, performance and novel constructions based on natural resources and infrastructure needs. This technology can promote projects for new city sectors and exemplary buildings associated with commercial, environmental and/or cultural motivations. Through experimentation in developing countries such as Chile, local adaptations and specific initiatives can be achieved that complement the global emergence of this technology, thus establishing a more varied horizon of architectural and urban evolution.

ACKNOWLEDGEMENTS

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Dahlia Jamila Nduom

Housing and Culture In 21st Century Ghana: A Model for Research and Evidence-Based Design

Housing and culture in Ghana: A model for research and evidence-based design.

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ABSTRACT: This research paper investigates the relationship between history, culture and housing and proposes design solutions which begin to address the notion of home for Akan residents of Accra. The research analyzes work done by historians who documented how Akan people in Ghana traditionally used space. The paper uses Amos Rapoport's model of the dismantling of 'culture' as a framework for this analysis. It juxtaposes this historical notion of space against current urban issues in housing such as resident satisfaction, multi-habitation and density and over-crowding within the city. The analysis of these texts is supplemented by primary investigations conducted in Ghana.

The paper concludes by showing how this cultural research can be used as a design strategy to develop new ways of looking at qualities of space, materials and sustainability principles for housing in Accra by describing case studies which have attempted to bridge this gap between research and evidence-based design. The examples presented in the paper show that it is possible to use this material to develop housing that is at once modern but also steeped in traditional and cultural notions of the home. The hope is that this approach can lead to innovative ways of thinking about affordable housing with increased resident satisfaction. The research presented in this paper also provides material for those architects aiming to utilize similar methods to translate cultural and historical research into a design strategy for housing.

KEYWORDS: Ghana, Housing, Culture, Evidence-Based Design

INTRODUCTION

Many rapidly urbanizing cities grapple with the challenges of housing provision. Ghana experienced rapid population growth resulting in a severe housing deficit. The majority of Ghana's new housing is unable to meet the needs of the masses. Due to this lack of affordable housing choices, many people live in crowded informal communities marked by compound homes and multi-habitation. The development of the housing typology in Ghana has shifted from the traditional dwellings of the various ethnic groups to single-family homes and townhouses in gated communities to multi-story apartment complexes with luxury finishes and amenities catering to the expanding middle class. This shift in housing typology is inspired by western forms and meaning with many local architects struggling with how to negotiate between tradition, culture and global influences in the definition of what it means to dwell.

While much has been written about the relationship between housing and culture (Low, Rapoport) and resident satisfaction in Ghana's capital city, Accra, little has been written about the correlation between culture, traditional spatial delineation and methods of construction and their impact on the development of the housing typology in Ghana. This historical and cultural research is essential as it can be used as an evidence-based design strategy for implementing housing solutions which respond to residents' perception of what the home means in contemporary non-western society.

1.0 CULTURE, HOUSING AND DESIGN

1.1 Culture and Housing

Numerous academics have held the belief that a study of culture is important to how we view, inhabit and mold our spaces. Edward Hall argues that different cultures will have different experiences upon viewing and inhabiting the same environment (Hall 1966). Sven Hesselgren argues that a building has the function of giving expression to attitudes towards living (Hesselgren 1975). This relationship between the built environment and culture is further explored by Neil Leach who advocated for a more in-depth analysis of architecture and culture to understand how identity and meaning are inscribed on architectural forms by the users (Leach, 2002). Housing plays a key role in this relationship between culture, identity and the built environment as Setha M Low states, "Dwellings can be conceptualized as meaningful social and cultural objects (Low and Chambers 1989, 209)."

Missing from these earlier writings is a clear method for systematic analysis of this crucial relationship between culture and housing. Culture as defined above is difficult to measure, analyze and make substantive relationships to the built environment. Amos Rapoport shares the view that the close relation of housing and culture implies that housing can communicate identity. However, he believes that to thoroughly analyze the relationship between housing and culture one must first 'dismantle' the notion of culture and study individual components and their relationships that lead to a definition of culture (Rapoport 1998). His model makes tangible the intangible aspects of culture.

> Important among these are potentially observable, social expressions of culture such as family and kinship structures, social networks, roles, statuses, social institutions, and the like. These can feasibly be related to the built environments, whereas 'culture' cannot (Rapoport 1998, 8).

Rapoport's model for analyzing culture is outlined in Figure. 1 and is used as a framework for analyzing texts on Ghanaian culture and housing. Specifically, the analysis focuses on the definition of housing as a *system of activities*, the fixed, semi-fixed and non-fixed elements related to housing and the influence of the following dismantled cultural aspects: family structure, social networks, identity, lifestyle and activity systems. The paper will investigate how these elements of culture are manifested in traditional notions of housing. The subsequent sections will also demonstrate how this model can be used to frame evidence-based research on the topic and propose strategies or how to translate this research into design criteria for the development of solutions to affordable housing in Ghana.

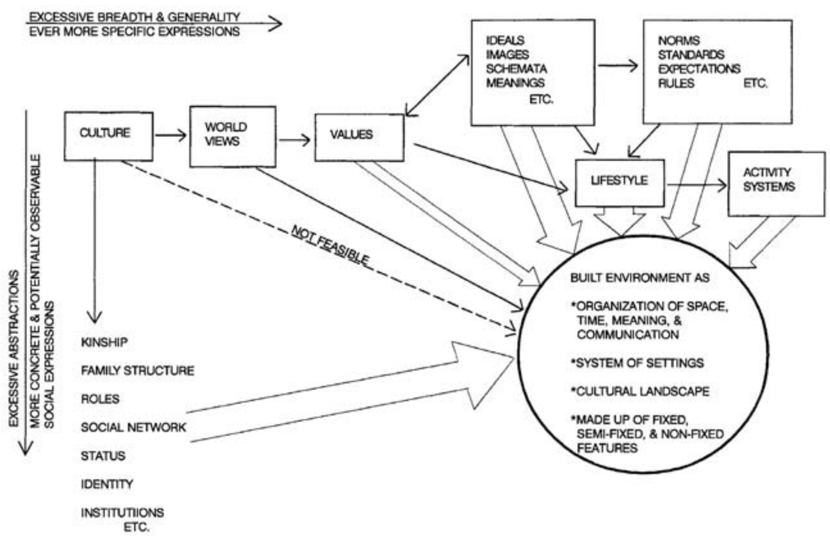

Figure 1: Dismantling of 'culture' and relating its expressions to the built environment. Source: (Rapoport 2001)

1.2. Culture and Housing in Ghana

As outlined in the previous section, the relationship between housing and culture is intrinsically linked. This is true in Ghana where culture and cultural practices are linked to the identity of Ghanaians even amidst global influences. This is outlined in the extensive study Culture and Customs of Ghana by Steven J Salm and Toyin Falola. Salm and Falola describe Ghanaian culture as:

> a dynamic culture that reflects the "duality" inherent in the attempt to blend rich cultural institutions and customs with continuing adaptations to the political, economic, and social exigencies of the modern world (Salm and Falola 2002, 1).

This duality of past and present is seen in many facets of everyday Ghanaian life. While political, economic, social and urban systems have been heavily influenced by colonization and globalization, there remains a strong cultural Ghanaian essence permeating through these institutions. Privately, the everyday citizen maintains this cultural identity through the practice of traditional festivals and ceremonies, while publicly the government and the private sector are conscious about supporting artistic expression and lending support to local cultural institutions (Salm and Falola 2002).

However, unlike other aspects of culture, where there is a clear duality and co-existing of tradition and modern ideals, the architecture of Ghana is often deficient in terms of understanding and referencing tradition and culture in the creation of modern edifices. This is especially true in the case of housing where the flurry of modern luxury high-rise and middle-income apartment dwellings are constructed in the form of Western ideals of dwelling often without reference to traditional practices and ways of living.

These traditional ways of using dwelling spaces can be seen throughout Akan culture and reflect how family structure, social networks, lifestyle and activity systems have shaped the vernacular architecture.

The Akan are the largest ethnic group in Ghana making up about 48% of the population (Salm and Falola 2002). The Akan share many cultural traits including traditional ideals of the home. The traditional Akan dwelling is marked by the courtyard as a central focus of the dwelling. Similar to Frank Lloyd Wright's notion of the hearth as the center of the home, the courtyard is the center of the Akan home. Rooms are typically arranged in a rectilinear fashion around the open courtyard (Figure 2). These rooms consist primarily of spaces for sleeping but otherwise have restrooms, bathrooms and living areas. However, the courtyard is the center of domestic activities where, cooking, socializing and family events take place.

Figure 2: Typical Compound Home. Source: (Afram 2007).

This arrangement reflects the activity systems and family and social structure which impacted the dwelling's form and arrangement. In addition to the formal arrangement, the Akan often added ornamentation to their homes in the form of Adinkra symbols. These symbols were painted or constructed as a relief on the wall surface. These symbols portrayed status in the neighborhood as well as conveyed a message about the family (Salm and Falola 2002). The incorporation of these symbols is an example of Rapoport's ideals and images and how they relate to values and the built environment. The use of symbols is often seen on more contemporary architecture, but its deployment is often superficial, losing some of the original meanings behind their use.

In terms of materiality, the nature of the traditional dwelling shifted based on its geographic location within the country. Those situated in the Southern coastal area of the country were typically constructed using more lightweight materials such as timber posts with walls of bamboo infill or woven palm fixed to the frame. These houses were topped with thatched roofs made of palm (*Traditional Forms of Architecture in Ghana* 1978). These lightweight materials were suited to the climate and allowed for ventilation through the building envelope. In addition, the building envelope was very open allowing for capturing of sea breezes. The Fante (an Akan sub-group) veered from this construction technique, utilizing rammed-earth construction instead of timber frame construction.

The Fante are an interesting Akan sub-group to study in terms of the development of their housing. They were one of the first to encounter Europeans when the Portuguese made contact in 1471. It has been documented that even within the face of European influences, cultural traditions and ways of living have maintained. For example, archaeologists studied the remnants of Fante buildings and found that in the face of European influence Elminians "exhibited strong continuity with an African, largely Akan, cultural tradition" (Decorse 1992, 175). These dwellings typically evolved in form and material use taking advantage of the new technology imported from the Europeans (e.g. use of stone). However, the Fante people occupying these homes largely carried on cultural traditions such as burial rites, festivals and ritualistic offerings and most importantly the traditional relationships to dwelling spaces. A structure excavated in Elmina showed:

> the linear arrangement of rooms around a central courtyard is comparable to traditional house construction throughout the Akan and Guan area. Many modern houses in Elmina retain a similar functional arrangement. The courtyard is of particular importance, serving as a semi-private area for cooking, eating and a variety of other activities. It may even be used as a sleeping area on hot nights. In function it seems to have changed little between the early seventeenth century and the present (Decorse 1992, 185-186).

Another sub-group, the Ashanti constructed a variation on the courtyard home also using mud or wattle and daub walls. They opted for a rectilinear layout around one or more courtyards with floors elevated on a plinth (*Traditional Forms of Architecture in Ghana* 1978). The traditional Ashanti architecture also utilized symbols in their dwellings to denote prestigious houses and to portray a message related to the family. This use of symbols is also an example of denoting status and identity in Rapoport's model.

Despite the various ethnic groups making up the country of Ghana, the numerous forms of traditional dwellings in Ghana are primarily compound/courtyard homes. These traditional ways of building and inhabiting spaces have evolved over the years, significantly influenced by Europeans during colonization. Over the years, global influences have also played a role in the development of the architectural language of the country. The infiltration of modernist ideals in a post–independence climate and more recently images disseminated through mass media have all played a role in the evolution of architecture, specifically the housing typology in Ghana. These influences and imagery have informed the design of luxury and middle-class housing in Ghana. Examples include multi-story apartment buildings with high-end finishes, grand gated communities with luxurious townhouses and single-family dwellings on huge plots of land.

Nevertheless, modern iterations of the compound house are still dominant in urban Ghana. As outlined in the following section, the social networks, family structures and activity systems that were traditionally experienced in the vernacular dwellings still proliferate in modern Ghana. As a result, it is important to understand these relationships and resulting architectural form and understand how it can translate into new ways of thinking about housing architecture.

1.3. Culture and Housing in 21st Century Urban Ghana

Like many developing countries, Ghana and its capital Accra have had to face the challenges of rapid urbanization including congestion in the city center, inadequate infrastructure, sprawl and of course lack of housing. Over 50 % of the population (24.2 million) live in urban areas (UN Habitat 2011). The capital, Accra is the largest urban area in terms of population, with an estimated population of approximately 2 million people and a projected population of 4 million people by 2020 (Grant and Yankson 2003). The population has steadily increased over the years as people from the rural areas flock to the urban areas in search of jobs and better opportunities. In addition to the influx of people, land tenure issues, cost of living and access to financing have resulted in a severe housing deficit which government policy has been struggling to address. UN Habitat estimates that 5.7 million new *rooms* are required by 2020 at a rate of 3.8 rooms to be completed in every minute of the working day for ten years to meet this target. The situation for self-contained dwellings is not any less drastic with two million houses (one per household) needing to be supplied by 2020 to meet the demand (UN Habitat 2011).

Housing in Ghana is primarily made up of self-contained dwellings (detached or semi-detached), and multi-occupied housing (compounds or villas). Multi-habitation is by far the most common means of dwelling with 55 % of people occupying compounds and 24 % occupying other forms of multi-occupied residential buildings (UN Habitat 2011). These compounds consist typically of rooms around a courtyard with shared facilities and are reminiscent of the traditional dwellings occupying this structure and social system. Today traditional compound homes have negative connotations and association with poverty, but their importance in the informal sector should not be denied. About 90% of the housing in urban Ghana is built within the informal sector, using local knowledge and systems. While they have historical and cultural roots, compound homes and multi-habitation dwelling also provide a solution to alleviate some of the housing deficit. UN HABITAT's housing report outlines this in their analysis stating:

> If the new rooms were to be provided in compounds (or their modern equivalent) on the same sized plots, with a mean of ten rooms, they would require 574,000 houses covering 67,000 HA (96,000 football pitches), less than one third of the land required for the self-contained bungalow option and a considerable saving. (UN HABITAT 2011, 25)

Attention needs to be paid to this form of dwelling, not only from a historical, social and cultural perspective but also from a practical way to meet the housing needs of the nation. This requires not only a change of policy within the government but at times a change of perception. In addition to these practical benefits, the compound home also exhibits the social and cultural way of living of most Ghanaians. Social benefits include security and access to childcare within the compound as well as providing a structure to prevent homelessness. It is not uncommon to see families housing relatives who can't afford or are unable to fend for themselves (UN Habitat 2011).

Studies have investigated the relationship between these compounds and residents' perceptions of these dwelling spaces. Two notable studies conducted by UN Habitat and Irene Appeaning Addo show residents' view of the compound home and the perceived advantages and disadvantages of this spatial organization.

Both studies outline that while residents see the benefit from a social and security perspective (as traditionally envisioned), they also find that the lack of privacy and shared facilities are detrimental to their satisfaction of their dwelling spaces (UN Habitat 2011, Addo 2013).

The degree of resident satisfaction is also affected by some residents' shifting values in the face of globalization and new housing forms. The imagery of multi-story luxury apartments or gated communities have permeated the ideals of many. Considering this shift in values some have viewed the traditional compound home and its multi-habitation arrangement as outdated and not modern. However, most housing options currently being constructed are not available to the lower income masses. The spatial arrangement of the compound home has value in terms of responding to the climate (providing ventilation), lighting, passive security, easily adaptable and easily constructed. These advantages should not be ignored and could provide a solution for affordable housing (Afram, 2007).

It is clear that cultural research as it relates to social networks, family structure and activity systems is important to the development of housing in Ghana. However, due to shifting images and policy by the government, this cultural research has not often been applied to housing policy. Local architects also neglect to do this research and apply it to the development of housing. When research is conducted, it is often used superficially, with new architectural developments relying on adding decorative elements such as traditional forms and symbols as opposed to thoroughly investigating the way space is traditionally versus currently used. A response to housing that is culturally based requires a deeper analysis using Rapoport's model as a guideline. The resulting research can then be translated into a set of design criteria for development into architectural form. The subsequent sections outline case studies where this cultural research has been translated into clear strategies for housing design.

2.0. CASE STUDIES

As outlined in previous sections, Rapoport's framework allowed for an analysis between housing and culture in Ghana, focusing on the family structure, social networks, activity systems and the resulting architectural form of the compound home. This analysis can be translated to useful criteria for evidence-based design to tackle the issue of affordable housing in Ghana.

Evidence-based design has been gaining popularity throughout the design field. However, it has seldom been used in the affordable housing field due to a disconnect between designers and researchers (Ahrentzen 2008). There is a need to bridge this gap and provide guidance on how to translate research findings into design criteria that can be implemented by architects and designers. As previously expressed, research in design (especially this type of cultural research), is crucial for the development of structures that speak to one's notion of the home.

Caren Martin and Denise Guerin created Informe Design to bridge this divide between designers and researchers offering synopses of research papers and translating these into evidence-based design criteria that can be accessed by architects easily through their online database (Martin and Guerin 2006). However, this website lacks concrete examples or case studies of how this information was used in a design project. Furthermore, a search of the database revealed no research summaries on Ghana, traditional housing, culture or current housing issues facing the nation. The below case-studies begin to fill that gap and allow for an understanding of how to translate the above evidence-based research into tangible design criteria.

2.1. Multi-story Compound Housing in Kumasi

This evidence-based research is exemplified in the work of S.O Afram and S.E. Owusu, two faculty members in the Department of Architecture at the Kwame Nkrumah University of Science and Technology in Kumasi in Ghana. They studied traditional and modern interpretations of housing in Kumasi in the Ashanti Region, noting that in this urban condition a large number of low-income households in the Ashanti Region live in compound houses. They studied the formal relationships between the single-story compound homes versus the multi-story compound homes, analyzing the advantages and disadvantages of this typology.

The multi-story compound house developed in Kumasi in response to the rising land values and congestion in the city. It consists of typically 2 – 4 stories similar in layout to a single-story compound house, i.e. emphasis around a central courtyard (Figure 3). Upper story access is usually via a staircase which ascends from the courtyard to the upper levels and circulation is provided via an exterior balcony which wraps around the courtyard. While, the multi-story compound home is similar in concept (central courtyard as primary element), to a single-story compound home, a study of activity systems and lifestyle reveals that this verticality shifts the way social interactions occur and how numerous activities that would normally inhabit the ground floor courtyard could be exercised. Examples include entertaining in the courtyard, play, cooking and preparation of food and washing and drying of clothes (Afram and Owusu 2006).

Figure 3: A Multi-Story Compound House. Source: (Afram and Owusu 2006)

Afram and Owusu's work outlines how their evidence-based research can be used to set a series of design criteria to be used in the development of these future multi-story developments by studying specifically the implication of lifestyle and activity systems. They summarized these as creating a design response to need for fufu preparation (especially pounding), washing and drying of clothes, refuse disposal and a utility space (for cooking, storage and relaxing). They summarized these criteria stating:

> Since the compound house principle is more towards communal living and the sharing of facilities, these would be harnessed to achieve these four activities mentioned above, thereby strengthening the cultural and family ties which, as it were, are trademarks of the typical Ghanaian and more especially the residents of the Ashanti Region (Afram and Owusu 2006, 76)

Furthermore, Afram and Owusu's work found advantages in the veranda in front of rooms overlooking the courtyard that were often co-opted for a wide variety of uses such as cooking and sleeping on hot and humid nights. They also highlighted the security advantage of multi-habitation and the cheap and simple construction known locally. Rooms in the compound home could also easily be translated to commercial use to serve the numerous people who have home-based enterprises in these urban areas. Lastly, they note the sustainable advantages of the compound home with the layout and courtyard allowing for cross ventilation. Their research also understood the disadvantages including shared facilities such as toilets, shared utilities such as electricity and water, and public/private boundaries being blurred and aimed to find solutions to these deficiencies (Afram and Owusu 2006).

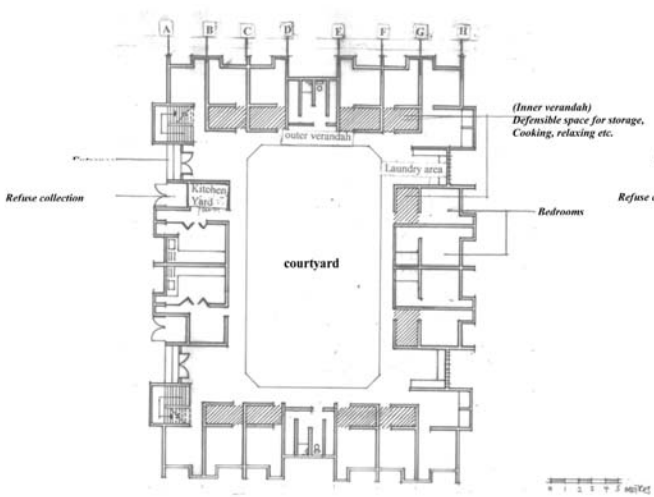

Figure 4a: Proposed Ground Floor
Source (Afram and Owusu 2006)

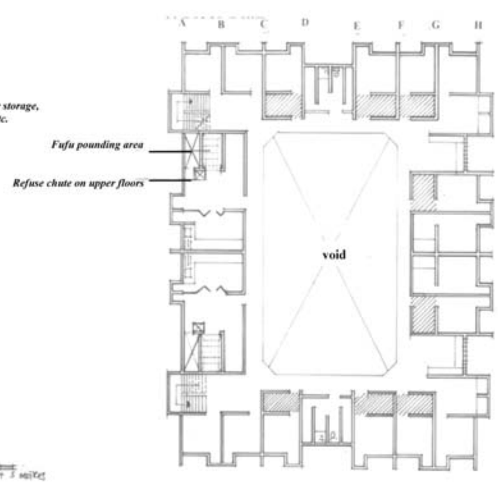

Figure 4b: Proposed First Floor
Source (Afram and Owusu 2006)

Their design innovations translated from this evidence-based research included developing a system whereby the compound home could be realized as a module and allowed to grow by accretion similar to the single-story traditional compound homes. They also developed systems for enhancing the multi-story compound house allowing for activities that would typically take place on the ground floor to be allowed to take place on upper levels while maintaining the importance and central nucleus of the courtyard. These include allowing for refuse disposal and utility space that can be used for various activities by the residents (Figure 4).

2.2. Multi-story Compound Housing in Accra

This theme of researching culture through family structure, social networks, identity, lifestyle and activity systems can also be seen in one of my ongoing research projects which aimed to use an evidence-based approach in the development of the architectural product.

This project uses Rapoport's framework to analyze family structure, social networks, lifestyle and activity systems to develop a set of criteria to translate traditional modes of dwelling to a multi-story housing complex. This research uncovered key statistics already mentioned above including, the relationship between traditional modes of dwelling and modern housing developments in the capital city of Accra. The proposed project is sited on the border of two areas of the capital of Accra, Asylum Down and Adabraka. As in other parts of Accra, access to home ownership is difficult, resulting in 60.5 % of residents in Asylum Down living in rented accommodation with 57.4% of residents living in a compound (Baiden, Arku, Luginaah, Asiedu 2011). Cramped facilities and lack of infrastructure led to numerous residents expressing dissatisfaction with their current housing situation in Asylum Down. An interview with a resident of a compound home in Asylum Down revealed some of the advantages previously outlined in the literature. She enjoyed the social aspects of people sitting in the courtyard and conversing and the occasional party and other social events in the outdoor courtyard space. On weekends children play in the courtyard while the women wash and dry laundry and cook. She also reflected on having easy access to childcare via her neighbors and the social network established through communal living. She appreciates the sense of security gained from living with others stating "We are never worried. There is always someone around." However, privacy is an issue which needs to be addressed in the compound home.

This traditional and modern cultural research was used to inform the following design criteria for the building:

1. Provide sustainable concepts based on traditional forms of dwelling (ventilation, shading, thermal performance and use of local materials).
2. Highlight the advantages of the compound home and understand how its activities and formal translations could apply vertically
    a. Maintain the communal aspect of the courtyard vertically
    b. Allow for privacy while maintaining a sense of a security
    c. Provision of 'flex' spaces for various activities

These design criteria were translated into a concept for weaving different aspects of the program together, allowing for pockets of shared spaces within the building that reference the courtyard and providing outdoor spaces which are more private. The proposed concept allowed for density while subverting the typical apartment floor plan consisting of numerous apartments around a hallway, primarily serving as circulation and a way to enter and exit people's apartments (Figure 5).

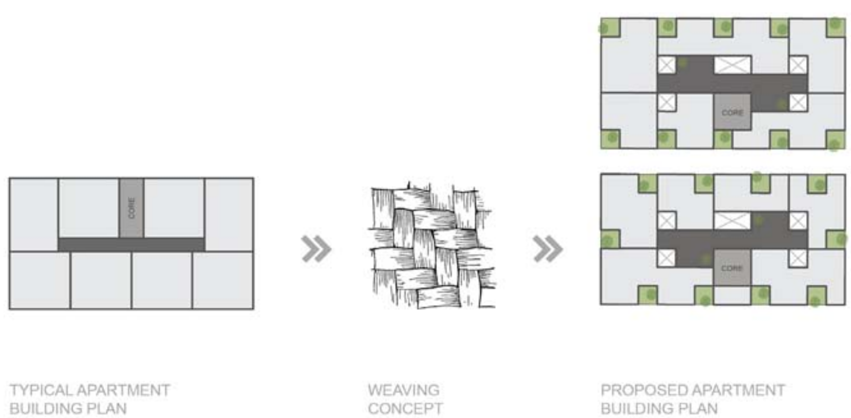

Figure 5: Conceptual Diagram. Source: (Dahlia Nduom 2017)

These pockets of space weave in plan and section and provide common spaces where various activities could take place. They become the heart of the building (similar to the courtyard) with additional voids allowing light and air to reach these interior common spaces. This conceptual plan for an affordable housing solution is heavily based on research and cultural analysis and provides a solution for understanding and negotiating between traditional and modern ideals of what it means to dwell.

CONCLUSION

This paper has outlined the importance of cultural research in understanding housing in Ghana in the 21st century and a framework for analyzing this research. Two case studies have been presented outlining how this evidence-based research can produce architecture that is culturally specific.

This paper presents the beginning of a series of ongoing primary research. This research is investigating residents' reactions to these housing proposals and elaborating on how ideals, images and meanings relate to the built environment through the fixed, semi-fixed and non-fixed features outlined by Rapoport. Further analysis of what this means for the rented room in a compound home (how do people make these rooms theirs through implementation of these features and spatial transformation) could shed further light on the design and manifestation of these spaces.

This ongoing cultural research and the resultant architectural form will continue to serve as an example of the importance of bridging the gap between cultural research, evidence-based design criteria and architectural design as it relates to housing in Ghana.

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Apostolos Kyriazis, Ayesha Zahid, Shafaq Qamar

A Cultural Paradox and the Double Shift of the Housing Typologies in the Arabic Gulf Area: Undergraduate Research Case Studies in Abu Dhabi

A cultural paradox and the double shift of the housing typologies in the Arabic Gulf area: Undergraduate research case studies in Abu Dhabi.

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Abu Dhabi's transition from a fishing village to a contemporary capital city in less than 50 years is more than remarkable. Its rapid growth, fueled by oil revenues and combined with a real estate frenzy is reflected into its urban morphology. The origin and evolution of Abu Dhabi's urban grid has swung between political pragmatism and modernist influences of Doxiadis' master plans in the region.
However, its architecture is highly diverse in terms of stylistic approaches, with little influence from the rich Arabic vernacular heritage. Especially when it comes to housing, Abu Dhabi and most of the neighboring cities in the GCC area have been monopolized by the presence of the "western villa" typology. This phenomenon is poorly analyzed in related literature.
This paper will present the preliminary results of two ongoing parallel undergraduate research programs with regards to the cultural clash that perseveres in forging the urban scape: the western villa, its properties manifesting an absolute contrast to the prevailing Islamic values and daily patterns. It will also attempt to identify the underlying resonate.
In addition to that, there will be an analysis with regards to an attempt from the urban planning authorities towards a second shift back to the neglected principles of the Arabic urbanism and traditional architecture, for achieving sustainable targets. Indeed, Culture was recently introduced as the fourth pillar to the local sustainability accreditation system (called "Estidama"), in a parallel attempt to reinstitute a national identity. To that direction, both research and academic studios' work have already started producing a promising outcome that would definitely affect the urban environment and improve its spatial and social parameters.

KEYWORDS: Abu Dhabi, typologies, housing, culture, Arabic

INTRODUCTION

Abu Dhabi's growth during these fifty years of oil-driven history may be comparable to biological rates. That pace leaves little room for the creation of a palimpsest, a historic layering that would build upon, protect and exploit the properties of this sequence that are vital to a city's success as a social capacitor. The so-called collective memory and eventually the creation of an urban identity, in parallel with a national one are forged within such environments and in return they operate as an added value to the direction of time.
Given the eradication of its pre-oil core, Abu Dhabi's architecture and urban planning have become a key factor on introducing a novel, modern identity for both the newly-born federal state of the UAE and its Capital city. Doxiadis' superblocks influenced the iron grid plan that also fitted the political priorities for equity, uniformity and flexibility enough to rapidly channel the anticipated oil revenues into the production of urban space (Kyriazis, 2017).
That rapid growth doesn't come without consequences, since two of the main urban elements are considered as temporary or even ephemeral. Buildings are set to live in a "laisser faire" mode guided only by real estate market rules and are replaced in pre-arranged time periods regardless of their aesthetic value and their overall contribution to the context. So apart from the loss of all pre-oil structures, many neglected modernist and post-modernist specimens are replaced by shining towers and heavily decorated villas. It is only recently that initiatives with regards to preserving that last-remaining heritage through retrofitting have emerged (Menoret, 2014b).
In an oddly similar way, the citizens themselves are also considered highly expendable. The expatriate communities of the city that make the vast majority of the population mix arrive, work and live under the knowledge of temporality, as this being the philosophy of the visa-providing system in the UAE (sponsor-based). So on one hand, the multicultural set of architects and designers have – together with the ever-broadening imagery of the local clients – produced a highly diverse international architectural vocabulary that seems to be far more associated with the display of superficiality than with context-driven needs. However, on the other hand, even being part of the temporal population they fail to connect to the collective values of

the city, thus reinforcing that superficiality and failing to forge a modern national architectural identity (as the political leadership has been aspiring to since the ‘70s).

Supporting that statement, Islamic patterns of everyday life that dominate the urban condition – even as defined by the city’s urban planner, Abdelrahman Makhlouf (Reisz, 2013) – seem to come in direct contradiction with many of the selected urban morphologies and architectural vocabulary. This paradox is the subject of the ongoing research presented here. Its documentation could resolve fundamental issues regarding architectural education in terms of the need to address issues related to contextuality, locality and a synthesis-driven design.

1.0 RESEARCHING ABU DHABI’S SUPERBLOCKS

1.1. Research identity

This paper presents findings from two ongoing undergraduate research programs conducted by the authors. The programs enjoyed internal funding, in an effort to stimulate critical thinking and architectural research even from junior years. The primary target was to identify, document and register the variety of morphologies, typologies and special architectural elements used on the façades, the plot or the sidewalk. Since literature directly connected to Abu Dhabi is quite poor, such an endeavor alone would be extremely useful in creating an index of the architectural vocabulary used in the city. Later on, those quantified data could be cross-compared for the extraction of some more qualitative results.

The initial question of the research itself was to analyze the architectural vocabulary of the prevailing urban housing scheme in Abu Dhabi and to report incompatibilities with regards to climatic conditions. However, the outcome of this study soon passed beyond climate and reached a social, cultural and religious agenda.

1.2. The urban setting

All land and buildings on the main Abu Dhabi Island belong exclusively to Emirati nationals. In the early 60s, Sheikh Zayed distributed to each Emirati three plots on the island, allocated for residential, commercial and industrial use, in an unprecedented gesture of generosity (Al Fahim, 2013). Together with the iron-grid plan of Makhlouf (that was based on the Islamic neighborhood pattern of the superblocks), it took less than two decades for the city to spread throughout the whole island (ADM, 2003). Later on, in terms of construction loads, the “Khalifa Committee” assisted Emirati owners to construct and manage buildings on their plots in big numbers through repetition of typical plans (Elsheshtawy, 2011) and popular post-modern ornamental approaches seemingly referencing Islamic geometries. Much of Abu Dhabi’s existing building stock belongs to this act, forging today’s superblocks and a critique regarding the aesthetically bland and banal urban morphology (Samarrai, 2016). Today, the urban space is regulated and managed by a set of exhaustively detailed standards and a sustainability accreditation system similar to LEED, called “Estidama”.

The uniqueness of the Abu Dhabi superblocks is not because of its street network but of its binary morphology that resembles the “watermelon” structure (with a high-rise “peel” and a less dense inner part). This pattern is highly evident on the main island, especially on its northern half. Makhlouf’s grid and the “watermelon” morphology were highly influenced by Doxiadis’ work (Kyriazis, 2017) in nearby cities (Baghdad, Islamabad and Riyadh) together with one of Makhlouf’s tutors, Hassan Fathi. His theoretical work on Ekistics, the science of human settlements, a dynamic interpretation of the modernist urban planning approaches (Doxiadis, 1968) was spatially manifested in these three examples by two distinct elements: the dynamic growth axis and the neighborhood modules or Superblocks. The automobile was the indisputable means of transportation and growth. However, Doxiadis provided a far more flexible approach compared to other modernist urban planners. A fractal approach on the modules’ scale, the watermelon pattern and linear parks connecting the public space cores displayed a will to tame the urban mega-scale to human scale transition (Kyriazis, 2017). Makhlouf adjusted those ideas to create an Islamic capital with a new national identity. He proposed a neighborhood unit with low-rise residential use and all necessary community facilities (Figure 1): “I made a social plan for how we would fill Abu Dhabi’s grid with housing. Each unit had seven houses. The plan was made so that neighbors from the same block could sit together after evening prayers. My plan reflects their traditions. You don’t have to walk far to visit your family, and you had all your services, including the mosque and school, nearby” (Reisz, 2013).

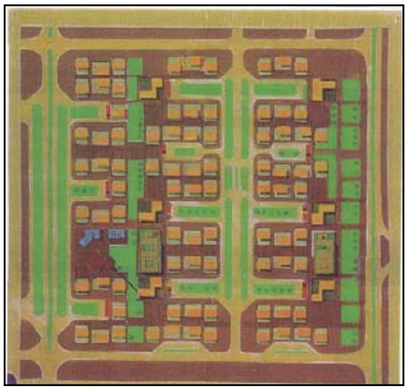

Figure 1: Layout of a "social neighborhood unit", by Dr. Makhlouf (Reisz, 2013).

1.3. The first typology shift: The western Villa takeover

The Sha'abiyat (the typical Emirati housing unit) was introduced by Makhlouf as a reinterpretation of the traditional Arabic courtyard house (Menoret, 2014b). However, the transition to the western villa was fast and complete as all traces of the traditional houses soon became obsolete. His original blocks now survive on a small part of the city, with inflated volumetrics, altered morphologies and a more diverse set of land uses on the ground floor level[i].

Although there is efficient amount of literature regarding housing in the GCC countries, there are almost no references dedicated to the shift from the courtyard house to the setback villa in terms of process, resonate and motivation. A shift with paramount implications on the production of urban space, sprawl, the human scale and the sociocultural daily patterns and behavior.

Menoret argues that the first villas were implemented to host the western expatriate officials of ARAMCO in Saudi Arabia, soon after the beginning of the oil boom. Their design then passed to shape the newly regenerated Al Malaz neighborhood in Riyadh as an attempt to modernize the city. Original suspicions were soon replaced by what would become a bourgeois dream, a way for the emerging urban classes to imitate the princes and isolate themselves from annoying rurals, a symbol of social distinction (Menoret, 2014a: 110). The detached villa, regardless of the social, cultural and religious paradoxes that was creating (windows' blocking and plot wall extending) and the climatic incompatibility, became a trend, an icon, a means of splurge and a tool for social segregation and gentrification from within.

In the UAE, Sheikh Zayed's political perseverance allowed for a swift start of the Emirati national housing program, through the "sha'bi" – the "people's house" and the incorporation of vernacular elements and Islamic architecture (Elsheshtawy, 2016). The modular courtyard house – made to fit the everchanging needs of the Bedouin people, proved far from rigid. Its adaptable and flexible typology allowed for a wide range of customizations and transformations that addressed both functionality and urban aesthetics through the direct involvement of the end-user in an unlikely participatory process.

The western villa transition in Abu Dhabi and Dubai took place within the early 80's, due to the oil and – consequently – automobile boom and an urban sprawl that covered almost the entire Abu Dhabi Island and parts of the mainland. All developments including the national housing program were increasing plot sizes and automobile dependency to the expense of community facilities (Alawadi, 2016). The impact of the western villa to Riyadh's upcoming middle class was easily transferred to the other Gulf States. Combined with new sets of standards by authorities and the need of the land-owning nationals to distinguish themselves, the villa typology prevailed and monopolized all low-rise areas of Abu Dhabi.

Furthermore, the overwhelming growth rates and the complete absence of a pre-oil traditional housing architecture seem to have created a new stereotype for the form of the single housing unit. A stereotype that would be reinforced by the suburban explosion in the last three decades, the ongoing automobile domination and the common practices approved and implemented in the vast majority of housing developments in the country. Its presence is easily detected in the work of early years architecture studios, where students are still anchored to perspective. Practically, one of the underlying objectives of the research programs presented here was to identify, analyze and question that particular stereotype in terms of its adherence to the social, cultural and climatic context.

2.0. FIRST CASE STUDY: A SUPERBLOCK

The first case study to be presented was the subject of the first of the two research programs mentioned. The study team made a first round of superblock selection within the island of Abu Dhabi (Figure 2). These three blocks would have to be approximately on the average size of all city blocks and present a basic variety of land uses and morphology, in order for the following analysis to be representative enough and to be able to produce essential comparisons.

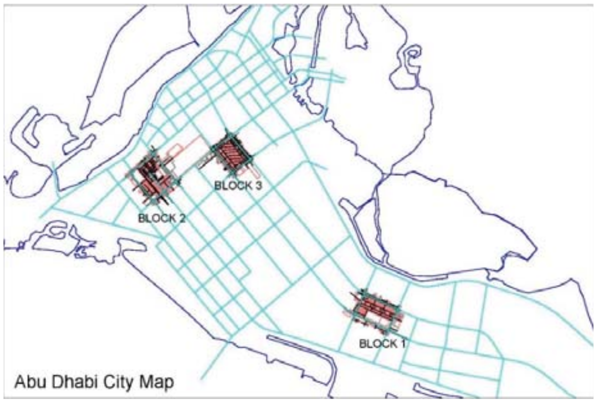

Figure 2: Abu Dhabi City map showing the selected blocks.

2.1. Selection of superblock

- Block No1 is rectangular and contains a shopping mall that faces a large park. One side of it has midrise buildings (G+5) along the main road. The rest of the superblock holds low rise villas (G+1 floors). It has a residential density of 60-80 units/gross hectares and 5-10 units/gross hectares. Some retail shops exist on the ground floor of the midrise buildings.
- Block No2 is also known as the Khalidya Village. Mid-to-high rise buildings (from G+5 on the interior to G_25 on the perimeter) cover half the block and the rest is just low rise (residential townhouses). It has a residential density of 10-20 units/gross hectares.
- Block No3 displays a rather striking design. Its rectangular shape is dominated by high rise buildings on all four sides (G+25 floors) that enclose a group of low rise villas. This is what a "watermelon" block is characterized by. In numbers, a high density of 80-100 units/gross hectares exterior surrounds a residential density of 5-10 units/gross hectares. Furthermore, apart from the peel or the block's outline, the low interior follows a rotated axis system, aligned to north-south direction.

After analysing the three superblocks, the third one was chosen for possessing most of the features desired for the conduction of the rest of the study.
Block No3 has the highest density in its building units compared to the other two blocks. Higher density housing ensures that the inhabitants have everything in walking distance and live in a dynamic neighbourhood. It also has the highest number of high rise buildings in all three superblocks with the rest of the building units being 2-3 story villas (figure 4). The block has a variety of land uses from retail, medium density residential to educational units. This sharp variation in building heights and land uses makes it a very intriguing site for further architectural analysis (Figure 5). Block No3 also exhibits rather unique features in comparison to the other two blocks in terms of layout alignment that makes it stand out from the rest of its neighbouring blocks in a very pronounced manner. Actually, it is the only one in the entire urban fabric with a rotated interior that doesn't align to the external edges (figure 3). A first assumption regarding the resonate hidden behind this gesture could be the alignment of all internal plots (and consequently buildings) to the North-South axis, in an attempt to harvest the most of the sunlight on the streets, the best of the housing orientation, the best for aligning the Mosques to the grid (the Qibla line in Abu Dhabi is almost parallel to the North) and the optimum for catching the prevailing northern winds.

Figure 3: The chosen Superblock, showing its typical properties both in a Google Earth image and in plan (produced by the Authors).

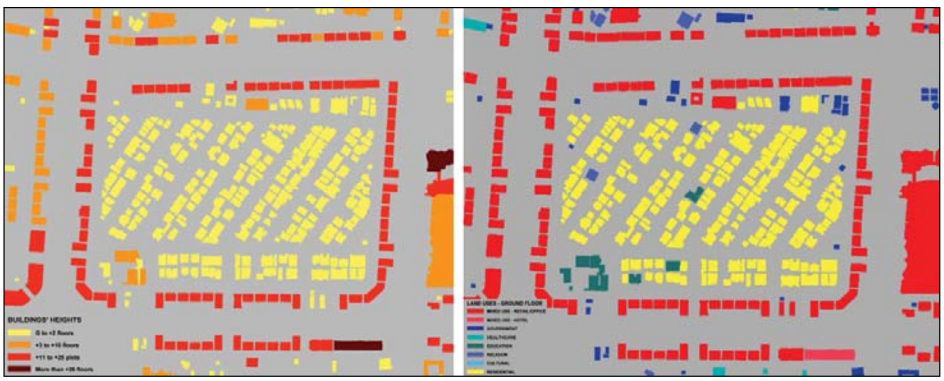

Figure 4: Maps showing the existing buildings' heights and the ground-floor land uses within the selected superblock (produced by the Authors).

Figure 5: The selected Superblock as seen from an angle. The "watermelon" feature with the outlining high-structure envelope and the low interiors is easily recognizable (photo credit: principal author).

2.2. Quantitative Analysis

An in-depth study of the chosen block was conducted to analyse the morphology of the housing units. That study was conducted by a thorough site visit that included notes, photographs and a quantitative documentation of urban morphology features and architectural elements, both combined with land uses. All elements were chosen for the clarity and importance in describing and defining all necessary spatial attributes. Unfortunately, due to extra sensitivity with regards to privacy issues, the research team was unable to access areas within plots and document these elements mentioned. So all observations were restricted to a street-view, in combination with satellite imagery (Google Earth).

Table 1: Urban morphology elements on plots/buildings per land use (source: authors).

Urban Morphology	Elements	Retail+ Residential	Retail+ Office	Retail (Hotel)	Residential	Government	Religion	Education
	1 to 3	0	0	0	103	4	4	1

Heights (G+ floors)	4 to 10	6	0	0	0	0	0	2
	10 to 25	54	1	4	0	0	0	0
Plot Coverage	Up to 70%	0	0	0	8	1	2	0
	70% - 100%	60	1	4	95	3	2	3
Setbacks	Yes	60	1	4	78	2	3	2
	No	0	0	0	25	2	1	1
Condition	Old	25	0	0	57	3	3	1
	New	35	1	4	46	1	1	2
Plot Wall	Yes	0	0	0	101	3	2	3
	No	60	1	4	2	1	2	0
Garden	Inside	0	0	0	47	1	0	2
	Outside	1	0	0	49	0	0	0
Parking	Inside	0	1	1	56	1	0	0
	Outside	60	0	3	76	3	4	3
Sidewalk	Yes	60	1	4	103	4	4	3
	No	0	0	0	0	0	0	0
Side Elevation	Open	22	1	2	53	1	4	2
	Blind	38	0	2	50	3	0	1
Total Building Units		60	1	4	103	4	4	3

The most remarkable points demonstrated through Table 1 are:

- The majority of the buildings have a plot coverage of 70% to 100% (total absence of open/uncovered plot area). This surprisingly includes the low-rise villas, thus highlighting the failure of the setback rule as a regulator of urban density, natural light, natural ventilation and privacy.
- All the retail buildings and apartments have a setback whereas a few residential villas and service buildings lack them. Compared to the previous point, most villas seem to have illegally occupied the side setback spaces, leaving little space only in front and back elevations. This phenomenon has significant implications on the forged urban morphology, since the "float-in-the-plot" villa has been transformed into a form of attached housing.
- An opaque plot wall is only present in most of the residential villas and service buildings, reinforcing the absolute boundary between public and private space.
- Side elevations have an equal distribution of being either blind or open in both the high-rise and low-rise buildings. With regards to the villas, this finding agrees with the two first points of this table in terms of the usage of architecture solutions that turn side setbacks to obsolete. Regarding the surrounding high-rise buildings, the presence of sikkak (the narrow pedestrian openings) is justifying this point.

Table 2: Architectural elements on buildings per land use (source: authors).

Architecture	Elements	Retail+ Residential	Retail+ Offices	Retail (Hotel)	Residential	Government	Religion	Education
Roof	Flat	60	1	4	88	4	4	3
	Multiple	0	0	0	15	0	0	0
	Metal Cladded	0	0	0	0	0	2	0
	Cornices	3	0	0	30	0	0	0
Façade	Recessed Ground Floors	50	1	4	0	0	0	0

	Projecting facades	30	0	2	71	2	4	3
	Glass	25	1	4	20	0	0	1
	Tiling	25	1	4	15	1	0	0
	Plaster	36	0	0	88	3	4	3
	Brick	1	0	0	30	0	1	1
Windows	Pivoting	30	1	4	8	1	1	1
	Sliding	35	0	0	87	3	4	3
	Arched	5	0	0	70	0	2	1
	Louvered	0	0	0	23	2	3	1
	Metal frame	60	1	4	103	4	4	3
	Balcony	25	0	1	60	0	0	1
Entrance	Porched	5	0	1	50	3	3	0
	Stepped	19	0	3	68	2	2	0
	Levelled	41	1	1	35	2	2	3
	Shaded	31	0	4	16	1	1	3
	Wooden Door	0	0	0	37	0	3	1
	Glass Door	60	1	3	1	2	0	0
	Metal Door	0	0	1	65	2	1	2
Ornaments	Windows	7	0	0	40	1	1	2
	Entrance	13	0	1	76	0	3	2
	Roof	31	0	2	43	2	4	2
	Plotwall	0	0	0	52	1	1	2
	Balcony	7	0	0	30	0	0	1
	Handrail	2	0	0	36	0	0	0
	Recessed filling	25	0	1	0	0	0	0

Amongst other findings, table 2 shows that:

- Apart from the high-rise buildings, even residential units have big glass facades. These glass facades were a result of adopting western villa styles. However, most of these glass facades were covered by curtains, restricting indoor-outdoor connectivity. This controversy is a result of the conflict between the western villa style and the Emirati culture. Throughout the block, the choice of façade finishes does not correspond to a certain architecture style but rather on personal preference.
- A plethora of ornaments were found on the buildings of this block, which was a result of fusing various architectural styles. Ornaments were found from entrances to roof and facades to even the plot walls. Often the choice of ornaments for a building did not respond to a specific architectural style. Hence, it is often that buildings have ornaments inspired by different eras/cultures (i.e. neoclassic together with modern or post-modern styles). Such a display of design elements results in an architecture that lacks a specific language.
- Furthermore, lots of ornaments are also found on the high-rise buildings' elevations, in evidence of the lack of deeper understanding their role in the architectural vocabulary and of the sense of scale, thus emphasizing the paradox aforementioned.

2.3. Interpreting the findings

The results of this analysis focused on the quantification and consequently the demonstration of the contradictions originated on a sociocultural and spatial level by the swift and total transition of the housing typology from the Arabic courtyard model to the western villa. A first reading identifies this paradox at two levels: The urban one where public space is wasted (i.e. unnecessary sikkak) but individualism and privacy are empowered through arbitrary interventions to the detached villa model, and the architectural one where the misuse of the "western" housing vocabulary contradicts with the prevailing cultural context; the Islamic daily patterns. In an effort to soften the controversy, the use of ornamentation with Islamic/Arabic inspiration is often exaggerated and misinterpreted, since it only serves superficiality and has long neglected any practicality that could pursue sustainability.

2.4. The second shift; Back to the values of Arabic architecture

The Abu Dhabi Urban Planning Council, the major regulating authority in the Emirate with regards to architecture and planning guidelines and development control, in acknowledgement of this paradox (Elsheshtawy, 2016 and Kyriazis, 2017) have recently proposed a set of alternative guidelines to housing developments (especially the ones associated with the national housing program). After importing a cultural pillar into the local sustainability accreditation system ("Estidama"), they called designers and developers to openly consider returning their housing projects back to the courtyard house model and the multiple virtues of the organic and compact Arabic urbanism (UPC, 2017). The "Fareej" would be an opportunity to reuse traditional ideas under contemporary technologies. However, this shift would now need a lot more than a mere authority broschure to make an equal impact.

CONCLUSION

The presented research project has focused on the visualization and documentation of the obvious: A paradox that is experienced on a daily basis and has become so fundamental and natural that has turned into a young but solid stereotype. The prevalence of an imported housing typology that stands against any national and cultural identity, any religious custom and any climatic condition, only to serve as a social imaginary. What was a choice for modernity has turned a fundamental right into a display of financial wellbeing and a spatial segregation tool.

Part of this undergraduate research initiative and architecture studio work conducted by the author aim exactly at the analysis, demystification and deconstruction of this stereotype, and its replacement by the values of locality, synthesis and openness.

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i A quantitative and qualitative analysis of this transition is the main subject of the second ongoing undergraduate research aforementioned.

Lyndsey Deaton

Creating Community: Housing Insecurity & the Tiny-House Village Model

Creating community: housing insecurity & the tiny-house village model

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ABSTRACT: This paper describes resident's perspectives on social capital in the context of tiny-house villages intended to mitigate housing insecurity. Three development models (one grassroots, one hybrid, and one traditional) are compared to understand how the architecture supports each village's resocialization goal. Using an inductive framework, this study is founded on 21 interviews with residents and staff at each community as well as my observations as an Architect. I found common themes of stability, cleanliness, belonging, leadership, and community politics across all communities, which highlight key social dynamics that inform the resocialization process.

KEYWORDS: tiny-house villages, total institutions, cohesion, urban morphology, and sustainability

INTRODUCTION

Once a design statement advocating minimalist living, tiny-houses are now the building blocks of villages for people with nowhere else to go. Yet, little is known about the village model that advocates for social cohesion through micro-dwellings, shared amenities, and sweat-equity. A few of these villages are stark representations of the development spectrum that advocates are replicating across the United States. Dignity Village in Portland, Oregon was once a tent city that rose to legitimacy and land rights through purely organic means. Opportunity Village in Eugene, Oregon is a hybrid model of grassroots management with municipal intervention that evolved following the Occupy Movement. Community First! Village in Austin, Texas is a private development founded through a religious organization. These villages represent the spectrum of bottoms-up to top-down development methods, which influence the perceived identity and community formations within each village.

All three villages respond to the American social crises of escalating rent and lower employment, which is frequently cited as a trigger for rising housing insecurity. Dominated by a temporal nature, the built environment for those facing chronic housing insecurity flickers between fleeting moments of relief followed by long stretches of instability. In response, all three villages are built on the promise of stability through social capital. Amenities ranging from common kitchens to gardens to training centers are prescribed as architecture that will support social cohesion in a way that evokes Erving Goffman's *total institution* - imbibing villagers with a new, common identity. How do the three development models shape the village identity? Do the villages resocialize residents? And, how does the architecture and urban design support these goals? These questions emphasize the originality and friction of the tiny house village model – where residents are encouraged to reinvest their notions of independence, autonomy, and freedom for the new values of agency, security, and social capital.

1.0 HOUSING INSECURITY IN AMERICA

The spectrum of housing insecurity is wide covering those without shelter to those occupying informal shelters to those residing in temporary shelters to those with unreliable shelter. The description for individuals struggling with housing insecurity as *homeless* is subjective (and derogatory) capturing a narrow but shifting slice of their daily experience. Thus, I will not use the term *homeless* unless speaking to a reference and I will use the phrase *people with housing insecurity*. For the purposes of this paper, tracking the scale at which people with housing insecurity are present in America and the nationally recognized categorizations of homelessness will support a better understanding of the tiny-house village mission and the potential of this morphology to mitigate housing insecurity.

Controversy surrounds the actual number of homeless people in America on a given day but the most accepted estimate is the national Point-in-Time (PIT) count conducted by the United States Housing and Urbanization Department (HUD). Each year, one-night counts are conducted during the last 10 days in

January across the nation through 399 Continuums of Care (CoC). In January 2017, 553,742 people were homeless on the given night in the United States; from last year, this is a 1% increase in the total number of homeless people but an 8.5% increase in the number of unsheltered people (Henry 2017). In contrast, the National Law Center for Homeless People (NLCHP) criticizes HUD's methodology citing inconsistent methods and training used across CoCs, narrow definitions in types of homelessness, failure to account for the transitory nature of homelessness, and severe structural issues (Stanley 2017).[1] Using annual data, NLCHP endorses a study which found that the "actual number of homeless individuals is 2.5 to 10.2 times greater than those obtained using a point in time count" (Metraux 2001, 334). Both HUD and the NLCHP agree that the population of homeless people is on the rise in the United States.

The increase in housing insecurity in America is attributed to a recent decline in wages and a shortage of affordable housing. However, drastic cuts to the federal affordable housing program combined with political foot-dragging, municipal agency delays, and the painstaking process of raising money means that building affordable housing takes too long. Socially, housing insecurity is not a priority in America because it competes with cultural norms regarding property rights and the neoliberal ideology fortified by class reproduction. Ultimately, housing insecurity is a socially reproduced inequality relying on forms of capital transfer to fortify class disparities.[2] The modern capitalist concept of individual property rights is founded on property as capital transfer; property is owned and inherited. In today's neoliberal context even public space is literally and culturally privatized.[3] Support for housing security is thus relegated to the periphery of the social agenda as a *local issue* with decreasing national interest.

As America shifts the responsibility to local organizations, Putnam's (2000) research shows that social institutions are nationally in decline and thus weaken the traditional forms of relationships (face-to-face encounters) that fortify community cohesion. These tiny-house villages attempt to use architecture to create a cohesive community through interactions as a form of total institution. Total institutions are places with high levels of control such that residents drastically change their values, beliefs, and behavior and are considered *resocialized*. Generally, these places have considerable control over resident's lives. Goffman (1961) first revealed this social phenomenon through his work on mental asylums but other researchers have extended the theory to concentration camps, military boot camps, convents, cults, and tangentially to non-residential places such as Alcoholics Anonymous. Total institutions have both positive and negative social consequences but all feature important characteristics: control over resident's lives, intention to weaken resident's former self-identity, and strict treatment (Barkan 2011).

2.0 METHODOLOGY

Community is a personal experience unique to each member. Therefore, I sought to form my understanding on resident's voices - their opinions and perceptions of community - rather than on observations of how the community may actually function. In addition to reviewing site plans, field notes, and spending time working in each community, I interviewed residents and staff to ascertain their views on how residents identify, participate, and belong in their community. These villages were selected to represent the spectrum of bottoms-up to top-down development methods once the basic criteria was met. The basic criteria included a minimum duration of occupancy (>1 year); the colocation of support services, similar populations, and a high diversity of dwelling typologies. At the time of the interviews, the three communities were considered mid-sized with approximately 27 to 60 residents each albeit Community First Village has ambitions to expand to over 200 residents.

I conducted each interview at the participant's village in a common space with auditory but not visual privacy using a semi-structured interview as described by Weiss (1994). I interviewed a total of 21 participants – 5 residents and 1 staff in Dignity Village, 6 residents and 2 staff in Community First, and 6 residents and 1 staff in Opportunity Village – about their use of the village environment in social activities. To increase the credibility of the interview data, I member checked significant themes, triangulated findings by reviewing secondary sources (such as former media interviews and community governing documents), and used thick descriptions in the findings section. While participants were not demographically controlled, I sought multiple perspectives across ethnicity, gender, and cohabitation status as my previous work with tiny-house villages revealed these factors to be especially important in representing the spectrum of resident experiences. Each interview lasted 20 to 80 minutes and was audio-recorded and transcribed. I took field notes after working at each village as well as after each interview to document important visual and sensory cues not captured by the audiotape. The focus is on the resident's daily experiences and on their personal perspective of how the community cleaves and coalesces within the village environment.

I carried out the analysis in several iterative stages based on recognized qualitative data analysis steps with a grounded theory perspective. Using a constant comparative method, I moved between the interviews, transcripts, and field notes early in the analytical process to identify categories. My categories were community relations, architecture, and resident values. Further distillation of key themes resulted in a second level of analysis using axial codes (ex: belonging, participation, sources of conflict, sources of cohesion) and memos. I assigned the interviews demographic characteristics (gender, ethnicity, and cohabitant status) as well as attributed them to their village and the village location (industrial or rural). Finally, I established theoretical codes and transferrable themes based on a systematic, empirical-based analysis of the transcripts and field notes by reading and re-reading the text and then looking for regularities (Bryant & Charmaz 2007). I also identified and attached the theoretical codes to existing theory (Goffman's total institution) as a foundation for understanding and describing my interpretation of the results. I used computer software (Dedoose) to synthesize my codes and then to analyze the data. I looked for anomalies and trends in the frequency of codes combined with demographic and locational factors. To analyze the data, I normalized the results and attributed a percentage (out of 100). I only focused on codes that had a disparity of more than 50% and appear more than 30 times (I consider this high frequency). This analytic information was used only as a lead to investigate themes; the real findings came from a close reading of the data and my experiences.

3.0 URBAN MORPHOLOGY

All village plans show a clear delineation, within the community, of public and private. There is a strong need in the communities for territorial security which is expressed through the construction of a perimeter fence and at Dignity Village and Opportunity Village there is also a guard shack. All communities are located on low-value property; Opportunity Village is located on an excess lot adjacent to the railroad in an industrial complex, Dignity Village is located on a paved lot adjacent to the city's leaf-composting yard and the Portland International Airport, Community First is located on the urban periphery in a rural area. The remote location was a strong theme across villages. The residents are challenged with varying degrees of noise pollution, air pollution, and accessibility to services. Dignity Village and Opportunity Village, per city lease, are not allowed to dig on-site and all utility services (such as water) are placed in aboveground pipes. Community First Village has traditional belowground services.

All villages have allocated public space for gardening, but feature degrees of residential investment; at Dignity Village and Opportunity Village these activities are seasonal and engage only a few residents while at Community First financial incentives for participating in gardening combine with professional leadership equate to year-round crops and consistent participation. All communities also value DIY (do it yourself) maintenance practices and include a separate structure to house home-maintenance equipment. Again, their development model exposes slight variation. At Dignity Village and Opportunity Village the DIY aspect is used mostly for small home and bike repairs by those residents who know how to use the tools while at Community First Village professional volunteers hold journeyman training, showing residents how to service the infrastructure. The largest indoor space in both communities is the community-gathering hall, which signifies the importance of social capital. This space is used to foster in-person interactions and strengthen community cohesion. Amenities of the community-gathering hall typically include Internet access, climate control, lounge furniture, and a notification board for local events. These spaces are also used to hold village meetings. Each community features a form of food storage/access. At Dignity Village and Opportunity Village this is a single building functioning as the receptacle of centralized donations while at Community First Village there are multiple locations for food access: a mini-mart, a free farmer's market, and pop-up food trucks.

All villages have arranged their houses in smaller clusters around green space, either a quad or a raised garden bed. These clusters, according to residents, give the villages a neighborhood-like feel and support resident interaction. Architecturally, the houses range in size and form: Dignity Village houses are 60-120sf and single-story with some lofts, Opportunity Village houses are >60sf and single-story, Community First 120-350sf and single-story. The effect of a range of typologies is a perception of diversity and personal expression as revealed in the interviews – no house is identical and each has the opportunity to represent the resident's personality and display ownership. Overall, all communities prioritize security, have similar urban planning priorities, and represent community through orientation, typology, and construction methodology.

Yet, the communities have evolved diverging narratives based on external pressures and internal dynamics. While their spatial forms and architecture feature strong similarities, mitigating housing insecurity is about more than shelter. How do these villages mitigate the social patterns of chronic housing insecurity, which is heavily reliant on personal outlook, habits, and agency? The spatial arrangement of these villages – small personal spaces and large social spaces are part of a type of re-socialization process.

4.0 SOCIAL THEMES

> It is such a blessing to wake up - to go to sleep every night not having to worry if the cops are going to walk-up or some random drug addict is going to come up and be, like, trying to take your stuff or anything like that. I mean you just rest better. -Charlotte, Opportunity Village resident[4]

Stability entails both security and reliability; it is a critical issue for people with housing insecurity. The village model intends to provide residents with more stability through increased social capital than they would typically receive through municipal and charity programs. Many residents had utilized the charity programs but were expelled or felt it was a burden to their identity (ex. no pets allowed) and thus it was not a stable alternative to residing on the street.

> I just started staying away because when you're there, you're basically a prisoner from 7 p.m. to 7 a.m. and then you get kicked out for whatever. -Chuck, Community First Village resident

Yet, a main concern with all residents was the instability of the street lifestyle because possessions were at risk and municipal codes required constant relocation. One resident from Opportunity Village, Ike, rented a storage stall for approximately $85 a month plus $15 insurance for stability. Ike maintained a high concern that when camping on “the street, his possessions (and himself) were always under threat of seizure by either the police or others. Maintaining his identity was another reason as he was a trade welder. By retaining a storage unit, his possessions (and hope to revitalize his identity as a trade welder) were secure, he was more mobile, and he felt he had more locational freedom. For some residents, a stable place provided the opportunity for personalization and identity, which improved their quality of life.

To expand upon the high frequency of cleanliness voiced, residents specifically described behaviors of disorderliness, hording, and hygiene in Opportunity Village and Dignity Village while at Community First Village a resident noted that the “cleanliness” made the village seem “pleasant” and ultimately attracted him to apply for residency (Matthew). The main concern for uncleanliness was the sanitation of the restrooms and kitchen.

> Yeah, people just go into the kitchen and make oatmeal and just leave the pan on the stove to rot forever. It’s disgusting. -Doug, Dignity Village resident

Beyond the kitchen, residents of both Opportunity Village and Dignity Village believed that about a tenth of residents hoarded materials and possessions in a way that was detrimental to the community’s health. Many residents expressed frustration at how many residents lack personal responsibility and hygiene. Additionally, Ike described how he was concerned that disorderliness and hording would affect the greater community’s perception of the village model as a solution for housing insecurity.

> People just don't know how to clean up after themselves at all. So, you basically have to babysit them - you have to go around and get rid of their crap… It looks bad and if you try and get donations it messes with the look of our community. Ugh, it's like walking around looking at a bunch of trash. -Ike, Opportunity Village resident.

I found that cleanliness could be attributed to three factors: how the village manages cleaning programs, the age of the village, and the resident’s hygiene habits. While Community First Village pays residents to perform janitorial services (which not only keeps the village clean but also trains residents on how to clean), it is also the newest community (one year in service). At Dignity Village and Opportunity Village residents are required to clean in shifts as part of their community service and these communities have been in service for 17 and 5 years respectively.

> That [cleaning] is not something I’m typically good at and I think that is probably a common problem here, most people – I mean you have to be really meticulous in order to live in a small environment like that and a tiny house and have it feel like there is some order to it you know and because every time I walk in I’m just like it’s – you know what I mean? It’s kind of – it’s not like oh I’m home, I can relax now. It’s like damn I still got to deal with this. -Peter, Opportunity Village resident.

Residents voiced concerns that larger units would support habits of hording and uncleanliness. From this perspective, most residents preferred the tiny-homes to the possibility of larger units. By having smaller houses without kitchens, begrudgingly, neighbors were willing to keep the main facilities picked up – sort of. In this way, the tiny home becomes a vehicle for resocialization to discourage hording and make it easier for residents to clean up after themselves.

> To live here you have to detach yourself from stuff because if you are about to go into a small space you can’t bring a whole bunch of stuff [with you]. -Anna, Community First resident

Another theme that was strong throughout the interviews was the sense of belonging stemming from the village model. When asked, “what makes this community unique” one villager responded:

> Personally, I think it’s more of a connection. Because, on the streets, there are a lot of people – so many homeless people don’t want help. You know, so many people want to stick in their ways… and they just want to be able to pass out where they want and they don’t really care. But when you come and you actually have to apply to a community like this… like, a mission you can just walk in and stay the night. Here, you apply, you go thru an interview, and there are rules. So, the people that come here really want to do something. Whether its to have an established place to stay or /and to get on their feet. And, so, I think it does kind of bring us more together. We don’t argue like people would on the street... And, we talk so that we can get things accomplished more… Yeah, people take pride in it and we talk a lot about cleaning the bathrooms and cleaning the kitchen and I was just talking yesterday to some people about doing a gardening committee. -Charlotte, Opportunity Village resident

Community cohesion involves interdependence and shared loyalties between members of a community. Holdsworth and Hartman found that “a sense of belonging has a reciprocal relationship to engagement: engagement helps to foster a sense of belonging, whilst belonging motivates engagement behaviors” (2009, 12). Many residents used the metaphor that their village was a large (and sometimes dysfunctional) family because while residents bicker and argue they also unconditionally support each other in crucial moments. One resident of Dignity Village, Doug, described the unofficial tradition of answering the community phone as if the village were your house and not disclosing any information about residents. According to Doug, if an employer finds out that you are living in the village it is usually grounds for termination, thus whoever answers the phone pretends to be family. He went on to add that “if someone needs help, they get it here” giving examples of residents supporting each other through rides to the hospital and meals when crucial. Further, when asked about the factors that led to a sense of belonging all residents referenced the community spaces and interactions in those spaces with their neighbors. They catch up on good deals at the smoking tent, they find out about a residents social security status while waiting for the bathroom, they argue about the upcoming election during the weekly meetings and they gossip about the latest ‘guest’ at the guard shack. The urban plan of the village contains nodes (such as the clusters) and dominant public spaces (such as the yurt at Opportunity Village) that both encourage interactions. Further, the limited amenities within the tiny houses motivate residents to utilize these public spaces. The balance of public-private space works in tandem to offer opportunities for community interaction while respecting their need for privacy and seclusion as desired. Interactions alone do not create belonging; interactions between people that are motivated, with similar life-opportunities and socially invested *do* manifest a familial sentiment. This is another way in which the village model re-socializes residents to positively view social relations through belonging and participation.

CONCLUSION

Tiny-house villages are places with high levels of social control and require, to varying degrees, that residents to change their former values, beliefs, and behavior to match the village values. Each village in this study promotes a different set of values reflected in their ideology.[5] Dignity Village promotes security, resilience, and self-sufficiency. Opportunity Village promotes self-governance, village cohesion, and stability. Community First promotes self-esteem, work-ethic, and community empowerment. Yet, they all use similar means to indoctrinate residents. Strict treatment starts with the exclusivity of the communities. Each potential resident must apply, be screened (mostly through background checks), and be interviewed before being added to the wait list. All communities have wait lists. This process is significant because it describes the exclusivity and privilege of participating in the community. Further, the process is an implied warning that the supply for new residents is high. During interviews, some residents expressed anxiety knowing they could be so easily replaced and this has manifested as a reluctance to socially engage in the community. Exclusivity alone motivates new residents to follow rules and attempt behaviors and habits contrary to their former identity.

All villages use a governance system of rules to prescribe appropriate village behavior. After reviewing the bi-laws for each community, I found the rules for all communities to be relatively standard to social organizations. However, the idea of compliance was contrary to many resident’s personal values and they voiced frustration with *having* to comply. Further, many residents felt that their peers used the rules to threaten and criticize; the rules became a source of soft power with an implied threat of tattling. Whether explicit or implied, rules are part of every society. What is interesting with this population is the aversion to explicit rules as an ideological principle. Almost every resident voiced some degree of discomfort with what was perceived to be an acquiescence of the transient lifestyle by complying with rules. The second piece to control is surveillance and privacy. Dignity Village uses peer surveillance in which issues are raised to an elected board of residents for consideration. Opportunity Village uses peer surveillance and staff intervention to raise issues to a composite board (elected residents and non-resident staff) for consideration. Community First uses peer and volunteer surveillance (middle class residents that volunteer to uphold community values) as well as numerous security cameras to raise issues to the staff for consideration. As most tiny-houses are single rooms tightly spaced next to one another, privacy was limited in all communities. Most residents expressed frustration due to a lack of privacy (both visual and auditory). I want to specify the type of privacy described by residents in the interviews: privacy from people that knew you, that could hold you accountable, that were aware of your habits. This is distinct from privacy from all people. Most people living with chronic housing insecurity are subjected to very public lives (camping in public parks, sleeping in dormitories, daily life on busy streets) and come to define privacy as an intimacy with personal habits and attribution. Thus, discomfort was not with being in the social situations but being in social situations in which people knew your habits and could attribute your actions to negative consequences. Yet, reflecting on the ideologies of each community these types of control are part of the resocialization processes used to make residents comfortable with rules and improve community cohesion while navigating away from their former “I’m on my own/no one cares” identity. Staff describe this system as the social reintegration process.

Certainly there is much to be learned from the tiny-house village model as a response to housing insecurity. However, the common themes of stability, cleanliness, belonging, leadership, and community politics begin to unravel the complex social dynamics at work. These themes have a mutual current of self-empowerment that unites villagers, increasing community cohesion and social capital. Each village resocializes residents, echoing Goffman’s total institution, but in different ways that reflect their development models. Community First Village, a traditional development model promotes self-esteem, work ethic, and community empowerment through top-down leadership and integration with middle and upper classes. Opportunity Village, a hybrid development model promotes self-governance, village cohesion, and stability through mentorship and integration of community resources. Dignity Village, a grassroots development model, promotes security, resilience, and self-sufficiency through an organic process of internal leadership. All residents expressed pride in the village model and their communities.

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ENDNOTES

[1] PIC counts mobilize volunteers to count the number of homeless people seen in public, yet most municipalities criminalize the activities of homelessness encouraging homeless people to hide from authorities.
[2] See Karl Marx, reproduction; Pierre Bourdieu, four types of capital for social reproduction in society.
[3] Cultural privatization describes the social restrictions placed on public spaces – hours of use, occupancy limitations, rules and regulations – that typically interpret them as middle class spaces.
[4] All names have been changed for the protection of the residents in accordance with the University of Oregon Institutional Review Board.
[5] "Village values" refer to values promoted by each village through signage, by-laws, and/or cultural significance. However, they may have been established through democratic means, taken from a parent organization, or included for another reason altogether.

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Understanding the Impact of the Residential Built Environment Design on Inhabitants' Wellbeing

Understanding the impact of the residential built environment design on inhabitants' wellbeing

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ABSTRACT: An increasing body of evidence suggests that some of the contemporary forms of the physical environment have a negative influence on the wellbeing of its inhabitants. This paper presents a literature review on the impact of the built environment on the inhabitants' wellbeing in the residential context. The paper reviews recent literature from various interconnected fields such as psychology, physiology, and sociology in the built environment context. Previous research has shown that the characteristics of the built environment can influence all aspects of human life. The effect of the built environment on the physical and psychological wellbeing is extensively investigated. However, there is limited research on the relationship between the residential built environment and social wellbeing, as measured by social integration and cohesion which suggests the need for more exploration, particularly in the context of the Middle-East. The lack of understanding results in a disconnection between the local communities' socio-cultural needs and actual design and supply of housing.
The broader aim of this research is to identify indicators that evaluate wellbeing, dwellings, and neighborhoods. These indicators can be used by researchers, architects, urban planner and policymakers to study and design neighborhoods.
KEYWORDS: Wellbeing, Residential built environment, Indicators.

INTRODUCTION

Human beings spend a considerable amount of time in and around the built environment, and they form an essential aspect of an individuals' daily life consequently they act as an influence to the wellbeing of people (Brasche and Bischof 2005; Davies-Cooper, Burton, and Cooper 2014). Wellbeing broadly has been a focus for many countries; moreover, governments have invested in measuring and quantifying their nations' wellbeing. It is believed that the origin of this research interest traces back to ancient Greek philosophers. Like wellbeing, many other terminologies such as quality of life, life satisfaction, and happiness are found in the ancient philosopher's writings (Stoll and Laura 2014; Wadi and Furlan 2017). However, the literature shows an obvious overlap in meaning, indicators, and measures of these concepts. The relationship between housing and wellbeing is complex and multidimensional. Moreover, behavioral, biological, cultural, social, physical and political factors are variables that affect this relationship. Quality of life, happiness, life satisfaction, sustainability and wellbeing are some theories and concepts that study the relationship between physical environments and users. A review of previous methods and indicators used to measure and evaluate wellbeing and the quality of the residential built environment, organized to aid architects and planners to predict the impact of their designs on the wellbeing of users.
The paper begins with a brief background and describing the research gap. The next sections focus on definitions of wellbeing, introducing theories and concepts of wellbeing. Later, current research on built environment and wellbeing, in addition to methods of assessment is included in this paper.

1.0 DEFINITION OF WELLBEING

Wellbeing was developed throughout history in different phases; each was characterized by a different theme. Starting with Ancient Greece, philosophers described wellbeing as happiness and pleasure. Later, it was the Enlightenment era, philosophical happiness turned into scientific wellbeing that could be measured. During the next couple of centuries, the sociologists, psychologists, and political philosophers entered this research area. The subjective wellbeing measurement was improved later in the second half of the twentieth century (Stoll and Laura 2014).
The World Health Organization (WHO) identified wellbeing as "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." Hartig and Lawrence (2003) agreed that health has several facets, involving personal characteristics, behavioural aspects, and socio-physical environment features. On the other hand, sociologists defined social wellbeing as a combination of five dimensions includes coherence, integration, actualization, contribution, and acceptance. Social cohesion and integration were discussed in an urban context (Keyes 2016). Keyes (2016) argues that social wellbeing

correlates with other indicators of life satisfaction, happiness, and dysphoria. However, residents describe community wellbeing as availability of attractive setting, social offering, and different cultures acceptance (Kruger 2011). Kostas (2017) believes that social wellbeing in the residential context can be influenced by the social capital, sense of community, neighbours ties, and the social interaction. His literature suggests that subjective wellbeing is affected by good relationship like having friends, spending time with family members, and marriages and romantic relationships.

2.0 THEORIES AND CONCEPTS OVERLAP

There have been numerous people interested in studying the built environment, users health and behaviour, and other issue caused by the manmade environments. Therefore, concepts like quality of life, quality of space, liveability, residential evaluation, satisfaction, and sustainability have emerged and usually are used as synonyms since their meanings overlap (Kamp et al. 2003). Furthermore, some of these terminologies are used to define each other. In this context, it is claimed that these notions are not original as anything can fit. The origin of these notions can be traced in multiple research studies into health, safety, wellbeing, residential satisfaction, and urban physical environment (Kamp et al. 2003). Kostas (2017) argue that these concepts come from subjective wellbeing perspectives including; hedonic, eudemonic, and life satisfaction. Moreover, his literature shows a confirmed distinction between different terms by many researchers as; hedonic wellbeing (psychological wellbeing), life satisfaction (prudential happiness), and eudemonic (perfectionist happiness).

3.0 Current research on the built environment and wellbeing

There are multiple dimensions for wellbeing in the built environment context: some have looked at social wellbeing and the built environment (Ellaway 2014; Brown and Lombard 2014; Miles, Coutts, and Mohamadi 2011; Allin 2014). Others looked at psychological wellbeing influenced by the built environment (R. Mitchell 2012; Evans 2003; R. J. Mitchell et al. 2015; White et al. 2013; Miles, Coutts, and Mohamadi 2011). While a large volume of research were found to focus on the health and the lifestyle association to the design of the built environment (Coombes, Jones, and Hillsdon 2010; Thompson Coon et al. 2011; Fraser and Lock 2011; Klepeis et al. 2001; Townshend 2014). The built environment relationship to wellbeing was explored on the national scale as well (R. J. Mitchell et al. 2015; Hartig and Lawrence 2003; Wiedmann, Salama, Ibrahim 2016).
The literature on wellbeing and the physical built environment can be narrowed down into two ways; category of wellbeing, and typology of the built environment. Yet, wellbeing perspectives overlap and influence each other (Helliwell and Putnam 2004), thus all types of wellbeing were considered in the initial phase of this research. As for the built environment, this research explore the residential context which includes the dwelling and the neighbourhood scales.

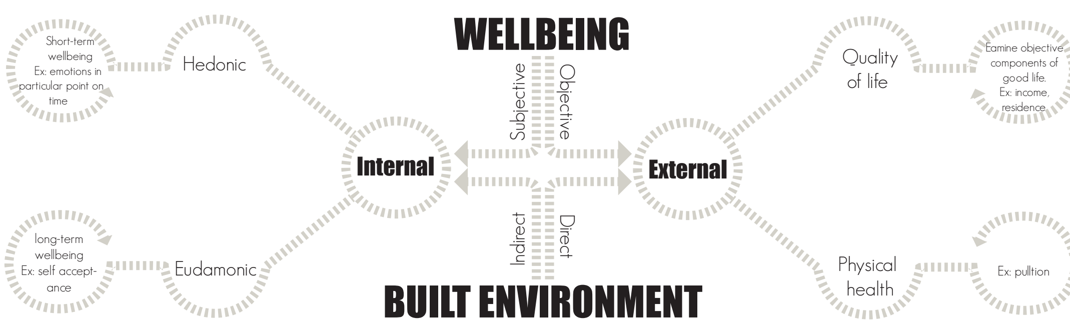

Figure 1: Illustration of wellbeing and built environment relation. Source: (Author 2018)

While studying wellbeing in the built environment, researchers defined their relation differently (Figure) It has been proven that buildings have an enormous influence on many aspects of peoples' wellbeing in direct and indirect ways (Evans 2003). Similarly, it is believed that there are two approaches to wellbeing; objective and subjective wellbeing (Western and Tomaszewski 2016). The direct impact of built environment affect the objective wellbeing of the inhabitants, for example the physical wellbeing is influenced by the toxic building materials (Lawrence, 2012). This kind of relation can be measured through the quality of life or actual physical wellbeing measurements as external, tangible indicators. On the other hand, the indirect influence of the built environment on the inhabitants impact their subjective wellbeing which includes two types of internal wellbeing. The first is long-term wellbeing which is functioning well (eudemonic wellbeing) to do with purposeful, meaning in life and self-realization. The second is short-term wellbeing seen in feeling good (hedonic wellbeing)(Steemers 2015).

3.1 The dwelling scale of the residential built environment

The section on the dwelling will discuss research undertaken to study three types of wellbeing: social, physical, and psychological. The purpose of the work is to identify the connections between quality of dwelling and wellbeing found in the literature.

3.1.1. Social impact of the dwelling

In the social wellbeing research, Cooper (2014) proved that children's wellbeing is influenced by many aspects of the built environment such as density, lack of privacy, lack of green and play areas. Moreover, he assigned safety, availability of public areas, and the condition of house maintenance as major indicators of adults' social wellbeing. It is believed that different housing typologies have unlike effects on the inhabitants' wellbeing. Professor Burton (2014) explains that the local characteristics of buildings and neighbourhood better assist wellbeing as they increase the sense of belonging and attachment, especially in children. It has been found that apartment buildings reduce social networking, which accordingly results in more loneliness for women as well as restricting children from playing outside the residential unit (Evans 2003). Further studies have identified spatial arrangement as a variable which can influence the inhabitants' wellbeing. Professor Elizabeth believes that the gradual transition between public and private through buffer zones helps to maintain the privacy of the household and reflect on the wellbeing of people. Additionally, the house's capacity to control the space of contact with others sustains a positive social psychological process (Lawrence 2012). As some behaviours require privacy, controlling the interaction between the people inside and outside the house is essential. Failing to do this may influence the psychological and social wellbeing of the inhabitants (Hartig and Lawrence 2003). Another issue while studying spatial arrangement and wellbeing is overcrowding. This influences social wellbeing since it increases the tension between adults and children (Cooper 2014).

3.1.2. Physiological impact of the dwelling

As for the research on physiological wellbeing, it has been found that high population density increase the chance of infection which influences pregnant women and the unborn children (Cooper 2014). Due to design problems and peoples' behaviour, wellbeing and health states of inhabitants is affected. Smoke from tobacco or wood-fire for heating or cooking, emissions from gas, and exposure to pollutants have very harmful effects on the health (Lawrence 2012 ; Hartig & Lawrence 2003 ; Cooper 2014). A significant volume of research evidences the influence of noise, light levels, access to natural views, air quality, and crowded spaces on the physical and psychological wellbeing of adults (Coombes, Jones, and Hillsdon 2010; Thompson Coon et al. 2011; Fuller et al. 1993a). Cooper (2014) investigated seniors' wellbeing in the built environment and found that the sleep patterns and agitation are influenced by the ability to see nature , as well as noise and light levels. In another dimension, maintenance is one of the most significant issues when looking into physical conditions of the house. It has been proved by Lawrence (2012) that mould growing in the house poses risks to the inhabitants' health. It can cause many problems such as asthma, chronic bronchitis, nasal allergies, and eczema. Maintenance include sewage and solid waste disposal as it can cause infectious diseases (Lawrence, 2012). Another danger on occupants' wellbeing is the safety of the physical conditions of the house. In the European region, more deaths are recorded from accidents inside or around the house than on the roads.

3.1.3. Psychological impacts of the dwelling

Evan (2003) claims that some genetic features make some people more likely to be affected mentally by the built environment. Also, he argued that high-rise housing units negatively impact the mental health of both housewives and children. Crowding - the number of people per room - in the home reduces privacy which results in psychological distress which is more common in some demographic groups like young women (Cooper 2014). Others argue that crowding affects people psychologically which consequently results in physical health problems (Fuller et al. 1993b). The indoor environmental quality is another concern for many researchers. Air quality, for example, is essential for good health, and it is associated with toxic building materials, heating or cooking. Cooper (2014) related psychological distress to air pollution, and the rates increase among people who have adverse life events. Noise prevents inhabitants from using their houses as an emotional retreat: if they suffer from noise, they will spend their leisure time outside the house (Hartig & Lawrence, 2003). Even more- ten percent of adults in Europe suffer from chronic sleep disturbance and need treatment (Lawrence, 2012). Although different age groups respond to lighting levels differently, poor daylight in the house causes poor mental health for the human being (Lawrence, 2012). Beside this, learning in early life can be affected by light quality and quantity (Cooper, 2014).

3.2 Neighbourhood scale of the residential built environment

3.2.1. Social impact of the neighbourhood

The larger context of housing is the city and urban planning impacts on how well the people are. It is advised to integrate different public gathering spaces into the street fabric; it could be parks, squares or public buildings. It has been found that such places impact different aspects of social wellbeing of various age groups (Brown and Lombard 2014; Cooper 2014; Qawasmeh 2014). Independence and accessibility of the neighbourhood are crucial specially for seniors' social wellbeing (Oswald et al. 2007). Ismail (1993 p 582) concluded in his socio-anthropological research that the change in the urban form of the neighbourhoods in Doha has resulted in a superficial and shallow relationship between inhabitants. Relationships of interest, and caution replace relations of affection, trust, and social solidarity. Furlan (2016) concluded that modern planning in Doha's built environment had neglected the liveability aspect. Bertha (2011) investigated the effect of the social network in neighborhoods on the wellbeing. The findings confirmed that living near to extended family members or with an ethnic group helped in reducing stress, encouraged people to interact, avoided isolation and loneliness. Although the research did not quantify proximity, people in this circumstances reported receiving emotional support, material support, household maintenance, and child welfare (Ochieng 2011). Judith (2013) proofed that by having good social life, mental wellbeing is improved consequently. Schoolers debated neighborhoods density. However in the western context, higher densities seems to be best for social interaction, personal relationships, widen the network and enable frequent socializing which considered as social support components (Mouratidis 2017; Montford 2013) Judith (2013) suggest that some characteristics in the building scale increase the interaction between neighbors such as the spatial arrangement, function and physical distance, multi-user and multi-purpose spaces.

3.2.3. Physical impact of the neighbourhood

No one can deny that walking in the neighbourhood promotes social as well as physical wellbeing. Researchers claim that a good mixture of uses within walkable distance promotes physical activity (Handy et al. 2002; Cooper 2014). It has been noticed that some design features of the neighbourhood may influence people's activity routines such as distances to destinations, direct routes, sidewalk situation, and availability of attractions along the roads (Townshend 2014). The design and location of facilities such as shops, leisure facilities, and residential areas impact not only peoples' general wellbeing or physical behaviours, but also diet and health (Cooper, 2014). A robust body of evidence supports the positive relationship between health, physical activity and, sequentially, the built environment. Research shows that insufficient physical activity causes death (1 in 6 deaths) and long-term diseases which increases the cost on the government (Lee et al. 2017). Research reported a positive relationship between the amount, proximity, of natural environment around the house and physical activities (Fraser and Lock 2011; Coombes, Jones, and Hillsdon 2010; Thompson Coon et al. 2011; Saeed and Furlan 2017).

3.2.4. Psychological impact of the neighbourhood

Alternatively, psychological wellbeing is linked to the design of the neighbourhood. Numerous surveys support better mental health as a result of exposure to greenery. The results vary according to socio-economic status, age, and gender (White et al. 2013). Further research was conducted to study the quantity and quality of the urban parks and its effect to the mental health of residence (Mitchell 2013; McEachan et al. 2016; Van Dillen et al. 2012; Cooper, 2014). As for the density, it was proved that higher housing density reduces depression symptoms among inhabitants. However, this result is not the same when the ratio of car usage to the land area increases, as noise exposure effect mental wellbeing (Miles et al. 2011).

4.0 Methods of assessing wellbeing and the built environment

4.1. Built environment assessment

To assess housing quality Hartig and Lawrence (2003) suggested mapping different layers that influence wellbeing. Measurements can be structured as: physical features of the house, location of the housing, landscape features and other land uses, distance to services, support for social contact, access to the house etc. To measure design or construction of the house and its impact on the health of residents, Hartig and Lawrence (2003) advise following the housing standards that describe the minimum qualities of the home required to satisfy physical and psychological wellbeing. Other researchers used computational tools to do the assessment of the built environment such as space syntax (Al-Jokhadar and Jabi 2017). Table 1 show indicators and tools used to assess the built environment.

Table 1: Built environment indicators used in previous research. Source: (Author 2018)

Physical environment factor	Indicators	Assessment of the evidence	Source
Hierarchy of spaces	Spatial arrangement	AGraph	(Al-Jokhadar and Jabi 2017)
Social interaction	Spatial arrangement, Amount of living spaces	AGraph , VGA	
Visual privacy	Spatial arrangement	Syntax2D, VGA	
View to the exterior	Openings location	VGA	
Greenery	Quality and quantity of greenery	GIS analysis: greenery per dwelling. Quantity and quality of greenery was assessed by observations.	(van Dillen et al. 2011)
Natural environment	Type of environment: natural, other type of environments.	Estimate the proportion of land cover in a respondent's area of residence that is green space.	(Mitchell 2012)
Green urban areas	Percentage of LSOA land cover	Data were derived from the Generalised Land Use Database	(White et al. 2013)
Common areas	Interaction in green areas	Site observation and analysis In-depth interviews	(Saeed and Furlan 2017)
Quality of Urban Life	residents' perception of the physical environment, the social and perceptual factor	Site visits, observation Walk through assessments In-depth interviews with residents	(Wadi and Furlan 2017)
Quality of Urban Life	Residents real interaction and relationship with their living built environment	Interaction and urban activity Residential satisfaction and attachment	(Qawasmeh 2014)
Crowding	Subjective housing quality measures Objective crowding measures	Interviews Satisfaction surveys	(Fuller et al. 1993b)(Qawasmeh 2014)(Qawasmeh 2014)(Qawasmeh 2014)
Housing density	Data were provided by the ABS	Dwelling density per hectare	(Badland et al. 2017)
Housing quality	Structural quality, clutter and cleanliness, hazards, indoor climate, and privacy/crowding	Walk-through rating	(Rollings et al. 2017; Poortinga et al. 2017)

4.2. Wellbeing assessment

Modern governments and policymakers were interested in wellbeing. The level of happiness of countries are evaluated by the United Nations (UN) using six different indicators; freedom, generosity, health, social support, income and trustworthy governance (Helliwell, Layard, and Sachs 2017). Some research was found to use the gross domestic product (GDP) as an indicator of happiness and wellbeing of people. Paul argues that the GDP is a less reliable indicator since it gives a partial picture of social progress, quality of life, and the environment states. Growth matters but we cannot ignore other factors such as our families, relationships, and community in which we live. The social indicators movement was initiated against one-sided focus on economic security (Kamp et al. 2003). Table 2 show methods used to assess different types of wellbeing.

Table 2: Indicators of wellbeing used in previous research. Source: (Author 2018)

Wellbeing perspective	Indicators	Assessment method	Source
Social	Social interaction	Content analysis, site observations, walking tour assessments	(Eissa et al. 2015)
Social	Affordable housing, density, and tenure.	Review urban planning documents Neighbourhood spatial measures. VicHealth Indicators Survey Survey community satisfaction	(Badland et al. 2017)
General health	General health. General mental health status	Self-reported health questionnaire (N.1641), Short-Form 36, (MHI-5).	(van Dillen et al. 2011)
Mental	Internal environment control Design, maintenance, noise, density and escape	Postal survey: SF36 subscales for mental health (MH) and vitality (V).	(Guite, Clark, and Ackrill 2006)

Mental	Urban form : housing density, green spaces, density of auto commuters Social environment	Validated measure of depressive symptoms	(Miles, Coutts, and Mohamadi 2011)
Mental	Environments grouped as natural or non-natural	General Health Questionnaire (GHQ) Warwick Edinburgh Mental health and Wellbeing Score (WEMWBS)	(R. Mitchell 2012)
Mental	Distance to urban green spaces	Short-form, 12-item GHQ Global life satisfaction survay	(White et al. 2013)
Mental	Neighbourhood characteristics or services	WHO-5 scale Interviews 2012 European Quality of Life Survey (EQOLS)	(R. J. Mitchell et al. 2015)
Psychological	Household crowding	Survey on depression and anxiety	(Fuller et al. 1993b)
Psychological	Dwelling quality Neighborhood quality and stability	Rutter Child Behaviour Questionnaire Youth and Adult Self Report Scales	(Rollings et al. 2017)

CONCLUSION

It is not surprising that wellbeing research is getting more attention, as many of the residential built environments are prototyped and pre-fabricated, yet norms and cultures are marginalized. This literature review shows some dimensions of residential built environment impact on inhabitants' wellbeing. Furthermore, it forms a starting point for future investigation in this subject. The paper attempt to clarify briefly and distinguish overlapped terminologies used in wellbeing and built environment research. The lack of knowledge in this matter has resulted in miss-use and mixture of parameters. It is important to clarify these terms by comparing their definitions and their measures. It has been noticed that some of the objective wellbeing indicators like the quality of life are influencing the subjective wellbeing dimensions. This paper shows a great need for expansion of exploration on the impact of residential built environment on inhabitants' wellbeing beyond the Western region.

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Clifton Fordham

Solar Design for Wellbeing and Expression: Louis Kahn's Psychiatric Hospital Addition

Solar design For Wellbeing and Expression: Louis Kahn's Psychiatric Hospital Addition

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ABSTRACT: Immediately before completing the Yale Art Gallery, Kahn built a psychiatric hospital in Philadelphia which is a relative footnote in accounts of his institutional work. Although the subject of the building is burdened by stigma and access limited, the Radbill addition to the Philadelphia Psychiatric Hospital warrants renewed attention in light of a sophisticated design that introduced architectural order and deft detailing to a demanding building type. The hospital is organized so that spaces warranting more privacy are at higher levels, corresponding with glazing that is proportionally shorter than at the lower levels. Horizontal shading devices of three different depths are shallower at the upper levels in acknowledgement of a reduced shading burden when windows are shallower.

The psychiatric hospital was built at a time when the effects of post-war material rationing was still resonant in the planning of buildings, and institutional buildings were still designed for natural ventilation and conditioning. In this context, passive strategies to counter excessive solar heat gain when daylighting was desirable, since thermal discomfort could not be completely offset by mechanically. As mechanical conditioning became standard in the United States, passives solar control strategies receded and building facades flattened. Despite a scientific basis for shading devices provided by academics including the Olgyay brothers, solar design remains largely an intuitive process.

With the advent of digital modeling and analysis, predictability of solar device performance renews cause for exploiting their potential and maximizing daylight while minimizing corresponding liabilities of glazing. Digital analysis also permits better understanding of solar impact on existing buildings allowing for expanded methods of historical analysis and understanding of architectural significance. It advances a position where unseen characteristics of building design are given standing alongside visible characteristics. Central to this is the use academic study of the health benefits of daylighting.

KEYWORDS: Daylighting, Shading, Glazing

1.0 INTRODUCTION

The program of a psychological hospital has seldom been recognized in architectural histories and professional journals. Compared to general hospitals, psychological hospitals are typically sequestered from the public, and the individuals and conditions treated shrouded in stigma. Hospitals are also subject to demanding programmatic requirements that typically result in standard configurations that resist formal play and flexibility of silhouette. It is against this backdrop that Louis Kahn designed an addition to a psychological hospital in Philadelphia which is relatively unknown and was opened in 1953 when design and construction for the Yale Art Gallery was ongoing.

Kahn's buildings after, and including the Yale Art Gallery, were comprised of fundamental shapes, and had relatively flat and materially rich facades. Design of the hospital addition occurred when overt solar shading devices were in vogue, although it was the last time Kahn used projecting devices. Two aspects of the hospital project are unique. First, the horizontal shading devices are stepped so that they get progressively deeper toward the bottom of the building. Second, the resulting formality correlates with the vertical height of window opening, and to the nature of program on each level. Admittance of daylight to buildings in this climate is achieved at the cost of lost heat during the cooling season, and overheating in the summer due to solar radiation. Low insulation value of windows compared to solid walls during winter and summer is a liability, then as now. Shading devices help compensate by increasing the thermal performance of buildings, and greater justification of glazing.

The goal of this paper is to demonstrate that the use of solar shading in this building fulfills three design objectives that are intertwined, criteria for integrated design. As described in the prior paragraph, the first criterion mentioned is the effective management of thermal heat. The visual reading resulting from shape of objectives which is treatment of patients in a hospital setting. Kahn's building is better appreciated when artistry is evaluated along with performance.

1.1 Methodology

This paper utilizes three approaches to analysis. First is a normative historical approach and includes a programmatic and formal analysis necessary for understanding the significance of the building and its context. The second part of the paper accounts for digital analysis of the building performed by the author which sheds light into the effectiveness of the shading devices. In the latter part of the paper characteristics of the building are related to science based research in order to support techniques used in the building when most concepts of the value of natural light were understood more intuitively. At stake for this program is the connection between daylight, mental health, and healing.

2.0 BACKGROUND

Louis Kahn and his partner Oscar Stonorov gained a commission to design an addition to the Philadelphia Psychological Hospital which is located to the west of downtown near the city border. An initial unrealized scheme, different than the final, was developed in 1946. When the partnership disbanded, Kahn set up his own practice in 1947 which would survive until his death in 1974. Kahn continued to work for the hospital and develop the scheme which was realized. The plan of the four story annex called the Radbill Building can be described as a bent bar with a narrow extension at the knuckle.

The period in which the building was designed and built was transitionary, between periods in which early experiments in minimal modernism were premised on ideals of transforming society to one in which the social and political agency of architecture was no longer paramount. Paul Overy dedicates a book called *Light, Air and Openness* toward the connection between cleanliness, light, air and healing in modern architecture between the great wars when it embodied a utopian inclination. The buildings he chronicles, health and non-health care structures, combined clear form, connections to nature, and openness; qualities that carried over into later periods. (Overy 2007)

Hospital design was transformed by modernity even earlier than office buildings which adopted glass curtain wall construction. Before the first war hospitals were typified by punched windows and large amounts of clutter including furniture, artwork and piping infrastructure resembling residential architecture. The post-war period, when Radbill was build, streamlined rooms with precise geometries and large amounts of light were accepted, largely due to the efforts of earlier architects to promote a connection between form, surface and health.

Figure 1: Photograph of Radbill addition to the Philadelphia Psychiatric Hospital circa 1953 (Source: The Louis I. Kahn Collection, University of Pennsylvania and the Pennsylvania Historical and Museum Commission).

2.1 Plan and Program Distribution

Kahn's Radbill Building (Fig. 1) is set into a sloping site to the north of the existing main building. Both the connection to the main building and main entry are on the southwest side which is effectively the second level of the building. The lowest level has an exterior exposure on north side so that four floors are visible rather than three at the entry elevation. Floor areas totals 30,000 feet, which is distributed evenly on all levels. The plan form of the building is best described as a thirty-eight foot wide bent bar with a 40 degree shift off-center. A deviation is the stair tower which juts out at the north end of the bar and the connector passage to the main building. As a result of the cant, none of the elevation faces are of equal extent although the building incorporates regular column spacing with an exception of a half bay at the end of the building which is legible at the façade.

The main level building function is primarily administrative and includes a reception area, offices, a meeting room, a library and a records room. Service functions, including receiving and kitchen are the primary spaces at the basement, with a cafeteria at the short wing. A mechanical room is located under the connector. The long side of the second floor (Fig. 2) houses patient rooms on both sides of a double loaded corridor. At the short side of the same floor are doctor's offices. Located on the third, and top level, are two large open treatment rooms separated by a central service core, and operating rooms located at the short end.

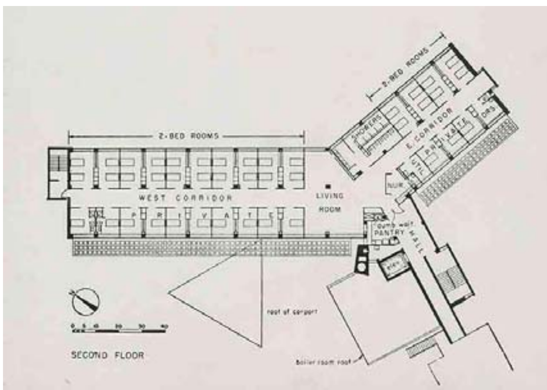

Figure 2: Plan drawing of second floor of Radbill addition to the Philadelphia Psychiatric Hospital, circa 1953. (Source: The Louis I. Kahn Collection, University of Pennsylvania and the Pennsylvania Historical and Museum Commission).

2.3 Elevation and Sections

The openings on the long facades are strip windows with an opaque panel below. At the main level and at the cafeteria glazing is a storefront that spans from the floor slab to the underside of the concrete slab. At the north side the opaque panels were originally comprised of thin slate. At the ends the building surface is brick which covers the columns. The concrete columns are exposed and the windows between the columns are evenly spaced so that there are four sections of glass for the standard column spacing and two sections at the last bay.

The floors structure is comprised of flat concrete slab supported by concrete columns organized on a twenty foot increment running the length of the building at the perimeter. Another series of columns is located slightly off-center so that they fall to the side of the central corridor. The building floors are all spaced similarly which is visible on the elevations. Structural floor slabs extend outward of the building enclosure at the southerly faces of the building (Fig. 3) to form the shading canopies, which are perforated.

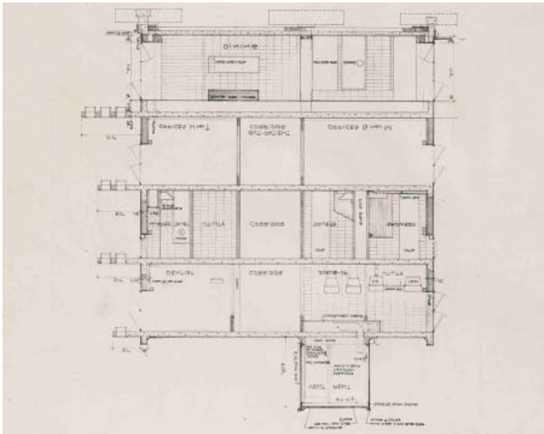

Figure 3: Section of the Radbill addition to the Philadelphia Psychiatric Hospital. (Source: The Louis I. Kahn Collection, University of Pennsylvania and the Pennsylvania Historical and Museum Commission).

Perforations in the concrete awnings are formed with terracotta tubes that are appropriate for forming a chimney flue. This results in canopies with one, two, and three tiles (Fig. 4) per corresponding depths. The tiles are deeper than the concrete slab so that they are visible in elevation and section. An effect that is visible in photos is stippled reflections of the sun on the façade of the building and ground that change during the day under different environmental conditions heightening a sense of dynamism.

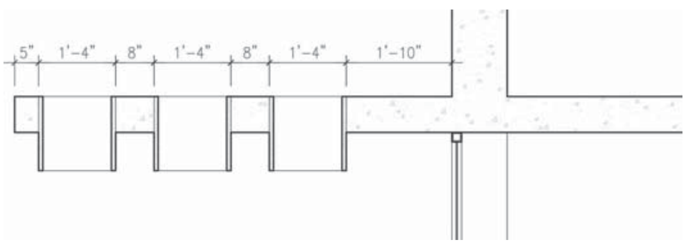

Figure 4: Detail Section at Lower Level Shading Device (Drawing by author).

2.4 Geometry and Style

Kahn's design for the hospital anticipates features that appear regularly in future buildings considered his masterworks including regular structural dimensions and infill between bays. Another central characteristic of his work is monumental, a quality that relates to timelessness through form and material. In later works, nuanced program elements are fit into fundamental shapes such as squares and perfect rectangles, something the mid-century moderns seldom considered. Similarly, Kahn's designs are fundamental in elevation and section, with legible repetitions of squares and triangles.

Radbill deviates from later projects in that the regular rectangular plan is bent at an odd angle, and met by the connector at an angle that does not have precedent as a classical geometry. The structural grid in plan is also close to regular but changes at the building ends. The result is a nod to function versus purity of form rendering the building less monumental that fluid. Besides the repetitive grid, and regular floor-to-floor dimensions, the building incorporates geometrical discipline and strong geometry when the regularly stepped awnings, which are triangular in silhouette, are factored (Fig.5).

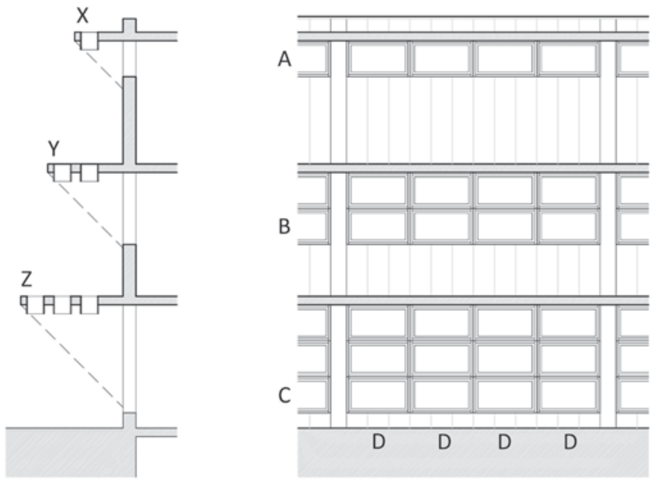

Figure 4: Diagram Section and Elevation (Drawings by author).

2.5 Digital Analysis

The hospital was designed at a time when it was difficult to calculate and verify performance characteristics of a building largely due to time constraints and available tools. As a result, many decisions were made by rule-of-thumb, not verified, or verified on a limited basis. Contemporary tools allow for greater understanding of performance, particularly thermal and lighting which would have escaped earlier analysis. A digital model was constructed of the building from archival drawings by the author with the aim of determining if the solar shades functioned effectively. Energy analysis was conducted with the existing geometry, with no shades, and with shades on one of the two major facades, and not the other. Results confirmed the overall efficacy of the shading devices, with the devices on the shorter façade, which faces more directly south being more effective that the entry facade.

If the shading devices at the entry façade are not as effective, and served a more decorative function, other justifications are needed beyond objective performance. The devices could have been conceived of differently, responding to the western sun with different extents or geometry such as vertical fins. After, tweaking the devices, the author determined that aesthetic benefits of the awnings also have to be considered, particularly at the main elevation which provides the public image of the building (Fordham 2016). In this case, the effects of light passing through perforations in the awnings activate the facades adding value to the projections. Removing the projections from the main façade would also result in a less dynamic and flatter façade making the building susceptible to the critic that architecture from the era was inevitably boring.

3.0 PSYCHOLOGICAL EFFECTS OF LIGHT

Architecture has traditionally been subject to a visual assessment with non-visual features addressed with a criticism grounded in philosophy and post-modern theory. Science when applied to architecture is largely relegated to the functioning and expression of building systems, with the exception of lenses used to comprehend sustainability. Relating science and scientific methods of research to architecture has been more difficult largely tied to different notions of what is valuable considering resource limits and the prime skills of the architectural profession. Limiting architectural analysis to familiar content and relying on intuition extensively belies findings in other fields that when brought to architecture help bolster design decisions including the relationship between light and human health.

An early example of a study to link the suns ray to health and rehabilitation can be found in William Atkinson's 1912 book, *Orientation of Buildings or Planning for Sunlight*. As an architect, Atkinson was mainly interest in the shape of buildings and the implication of those shapes with respect to the sun. In support of his study Atkinson refers to medical scholars and sanitarians that attribute daylight to better physical health. Although he mention thermal heat gain as a resultant of admittance of light into buildings, the majority of text and diagrams a concerned with access to daylight and avoiding shadows on building surfaces with openings to important building spaces. In the case of his book, hospital spaces were the subject of an entire chapter of his study. Interestingly, along with hospital planning, Atkinson dedicates a chapter of his book to urban design and the implications of building height in relation to street widths (Atkinson 1912).

An early twentieth-century example of the medical profession weighing the benefits of natural light from the sun can be found in an article published in the British Medical Journal in 1938 titled *Daylight in Relation to Climate and Health*. The article utilizes environmental data including daylight factor seasonally adjusted, comparing natural light to illumination qualities that can be expected from artificial light. This data is related to the healing potentials of sunlight for different afflictions and mental conditions. The positive conclusions can be related to the general sentiment of the age adopted by architects and chronicled by Paul Overy.

Another article in the British Medical Journal six years later called *Brightness, Wellbeing, and Work,* presaged the contemporary workplace improvement movement, relating suitable light levels to the workplace. Illumination is not just about being able to do work, something that can be reduced to productivity, but rather about comfort and health of the worker, a result that carries beyond the environment that affects the individual. Most importantly, eye strain, and body strain are correlated to mental effects of working in an under-illuminated environment (Weston 1944). This analysis equates artificial lighting as an adequate substitute for natural lighting but provides a good window into the awareness of how lighting conditions affect the performance of people in spaces.

Contemporary scientific research continues to relate lighting to human performance and the built environment. Mental health is widely believed to be affected by exposure to light and seasonal affective disorder is widely accepted and treated. Suicide rates have been recorded as higher in locations which receive little light during the day such as Finland and parts of Russia. In their article *Residential Light and Risk for Depression and Falls: Results from the LARES Study of Eight European Cities* authors Mary Jean Brown and David E. Jacobs support the correlation between light levels, building design, and depression, and that light levels are impactful regardless if medication is used as treatment (Brown and Jacobs 1974).

3.1 Evidence Based Design

The burgeoning field of evidence based design (EBD) unites results found in rigorous studies to outcomes in physical infrastructure, chiefly healthcare facilities. An important figure in the movement is Robert Ulrich who established a link between views from hospital windows healing after surgery (Ulrich, 1984, 420-421). He has taken part in studies which have found that pain can be reduced when patients are exposed to higher levels of daylight and nature (Malenbaum et al, 2008). This echoes recent evidence presented in a New York Times article which featured a recent study in a New Jersey Hospital where pain levels were reduced up to 30% through testing or a redesigned room (Kimmelman, 2004). Of particular relevance to a psychological hospital is evidence pointing to improved mood and reduced hospital stays in depressed patients as a result of differences in the built environment including exposure to natural light. Similar results have been found for patients with unipolar and bi-polar conditions (Ulrich, 2008)

Patients are not the only individuals in treatment settings to suffer from stress and compromised performance due to environmental conditions. In their article *Windows, views, and health status in hospital therapeutic environments*, Stephen Verderber and David Reuman find that patients and staff react differently to windowless environments in hospitals. They studied six hospitals comparing plans and other physical building characteristics, factoring questionnaire, induvial characteristics such as affliction and occupations, exterior lighting levels and views. (Verderber 1987)

Although the older study determined that patients and staff do not benefit equally from light in hospitals, nurses are found benefit from access to light as a complement to artificial light due to the stressful nature of their work. A 2012 study in HERD focused on hospitals with intensive care units (ICU's) confirming similar results with staff and patients. They studied windows, daylight, and stress finding that any amount of natural light helps by the quality of light and geometries of the window are important. Windows should not be too far and not too high, but more specifically, horizontal windows are preferable (coincidently consistent with mid-century design). Good views also factored into the analysis (Shipley et at, 2012).

A cautionary note is that actions of the architectural profession, other building interests, and the heath community to shape healing environments have not always resulted in solutions found to satisfy patient needs. In the essay The *Natural History Of Windows: A Cautionary Tale* in the British Journal of Medicine, Lord Taylor makes an argument for windows in every room, operable windows, no room with all glass, and air-conditioning only when necessary. The argument coming from a physician might seem overly opinionated except that the study utilized scale drawings, comparative diagrams, and references from other medical journals. (Taylor 1974) If architects can relate non-architectural evidence to healing better, then blunt criticisms of characteristics of modern architecture can be tempered.

4.0 CONCLUSION

Louis Kahn designed during a period in which the science of light and its effects on building performance was generally understood intuitively with the architectural profession. Similarly, the impact of light on human health was less clearly understood and verified by scientists and health professionals. Today, relationships between light and health are better known, allowing for a fresh look at older structures in which light played a key role. Expanded perspective also provides a stronger link between aesthetic concerns and behavior outcomes since benefits of play between light and structure contribute to both facilitating a dependency which can be mutually beneficial if handled deliberately.

Lessons to be gained from the Radbill Addition to the Philadelphia Psychological Hospital include the use of shading devices to mediate thermal gains, form making, and activating a façade through the manipulation of indirect light. Kahn did not assume that equal amounts of transparency commonly associated with modern curtain walls was the appropriate response to the hospital program and rather correlated the amount and location of windows to the program. Anticipating later rigor, Kahn utilized three variations in window height and associated shading projections. Most importantly, linking studies to architectural outcomes can help recalibrate our appreciation of works of cannon in ways that can better serve cotemporary objectives of service to society.

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Ute Poerschke

Data-Driven Design in High Modernism: Ludwig Hilberseimer's Solar Orientation Studies

Data-Driven Design in High Modernism: Ludwig Hilberseimer's Solar Orientation Studies

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ABSTRACT: This paper presents High Modernism as a predecessor of today's discourse on evidence-based design. The 1920s and 1930s provide rich examples of promoting the relationship between research and design, as many modern protagonists claimed their designs resulted from analyzed data and expert input rather than historical reference or creative talent. Scientists, economists, engineers, and architects alike investigated problems such as hygiene conditions in housing and cities, human needs at work and home, construction mechanization, and traffic optimization as the basis and justification of spatial designs. As an example, this paper addresses the discourse on best solar orientation of housing, with the architect and urbanist Ludwig Hilberseimer as one of several proponents of this discourse, among them Walter Gropius, Ernst May, and Le Corbusier. Regarding solar studies, Hilberseimer's projects and writings can be divided into three phases. The first phase is marked by his famous 1920s renderings of the residential city and high-rise metropolis, which conform to the orientation recommendations by urban planners Richard Baumeister and Karl Hoepfner. The second phase spans Hilberseimer's teaching at the Bauhaus from 1929 to 1933, in which he contributed to the extensive solar studies for diverse housing types undertaken at the Bauhaus building department. A third phase, in which he applied the findings to "settlement units" in linear city patterns, came to full fruition after 1938 when Hilberseimer started teaching at the Armour Institute, later renamed the Illinois Institute of Technology in Chicago. The case of solar studies in High Modernism and Hilberseimer's work in particular illuminate the challenges of relating research, performance-driven design, and actual building projects.

KEYWORDS: evidence-based design, housing, hygiene, Durchsonnung, "Licht Luft Sonne"

INTRODUCTION

The 1920s and 1930s provide rich examples of promoting the relationship between design and research, for which today we use terms such as "evidence-based" and "performance-driven" design. Many modern protagonists claimed their designs resulted from collected and analyzed data and expert input rather than historical reference or creative talent. With respect to housing, scientists, physicians, economists, and architects alike investigated problems such as hygiene conditions in housing and cities, the definition of human needs, construction mechanization, and traffic optimization as the basis and justification of spatial designs. The following paper focuses on the investigations in solar orientation of housing during that time. Architects like Walter Gropius, Le Corbusier, Otto Haesler, Hannes Meyer, and many others,[1] investigated housing schemes and urban plans with respect to solar orientation. The paper attempts to illuminate this topic by focusing on the architect and urbanist Ludwig Hilberseimer (1885-1967), whose solar studies are reflected in his projects for buildings and settlements with high and low densities. Describing the topic of solar orientation as a central driver for his architecture and urban designs will allow contemplating on the relationships of research, evidence-based design, and actual building projects.

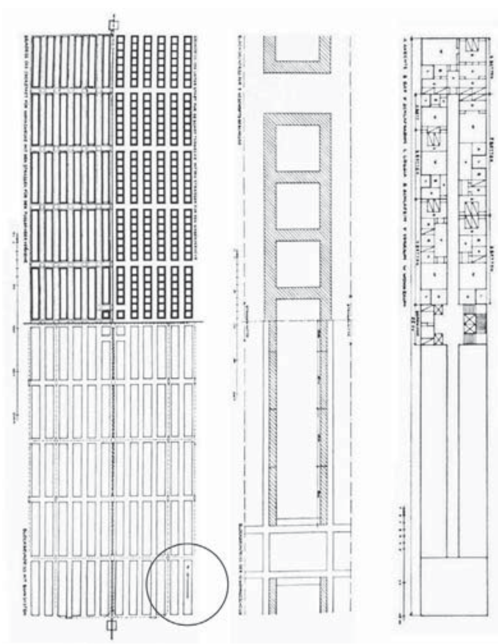
1.0. FIRST PHASE: ENGANGING IN MODERNISM

After studying at the Technische Hochschule in Karlsruhe, Germany, from 1906 to 1910, Hilberseimer worked in several architecture offices in Bremen and Berlin. In 1919 he engaged in the socialist artist groups *Arbeitsrat für Kunst, November Gruppe,* and *Die Kommune*, and around this time his architectural expression changed from more historical gestures to modernism (Pommer 1988, 26-28). Many of his early modern design schemes and writings reveal an interest in achieving optimal solar orientation—as defined at that time. Hilberseimer described topography, sun orientation, and "higher viewpoints, a sense for architectonics" as the major guidelines for designing urban settlements (Hilberseimer 1927, 5).

1.1. The "Hochhausstadt" (High-Rise Metropolis)

The wide interest in housing arose from the unhealthy conditions in large cities with dense, poorly lit and ventilated blocks. For the future metropolis, Hilberseimer demanded a well-ordered city layout, healthy and comfortable apartments, without closed courtyards, but instead with open blocks for good ventilation. For best solar exposure, he recommended that street and courtyard widths measured the same as the building heights (Hilberseimer 1927, 12-13). He exemplified these demands in the famous scheme of a metropolis for one million people on an area of 1,400 hectare (Fig. 1), that he developed from 1924 on.[2] The metropolis consisted of twelve by ten blocks, 120 blocks total. Each block, providing housing for 9,000 people and 90,000 square meters of business spaces, had a dimension of 100 by 600 meters. Both the courtyard and street were sixty meters wide. Split vertically in two areas, the block consisted of five-story office and manufacturing spaces at the lower level, and fifteen stories of apartments above that.[3] The actual building width of the business areas was eighteen meters, while the apartment bars were only ten meters wide. This had the effect that the apartment buildings stepped eight meters back on the street side to accommodate elevated pedestrian walkways. In addition, while the lower part had buildings on all four sides of the block, the apartments were arranged only at the long sides of a block, leading to north-south running housing bars with apartments facing either east or west. Hilberseimer justified this scheme in 1927 as follows:

> "The new city layout defines its street system with respect to solar orientation; its street and block sizes demand, with respect to light and air supply, a minimum distance between the buildings that is equivalent to their height; street width equals building height. This refers to street width and block depth since the building distance within the block must correspond to the building height, too." […] these apartments […] can be called entirely and hygienically unobjectionable, thereby a solution for the metropolitan housing problem was found." (Hilberseimer 1927, 18-20, German)



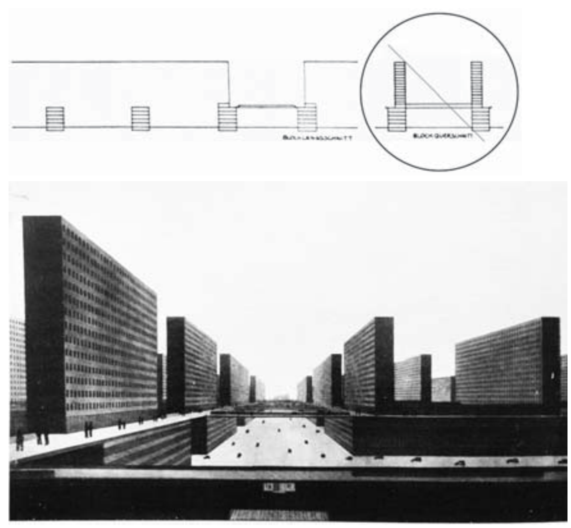
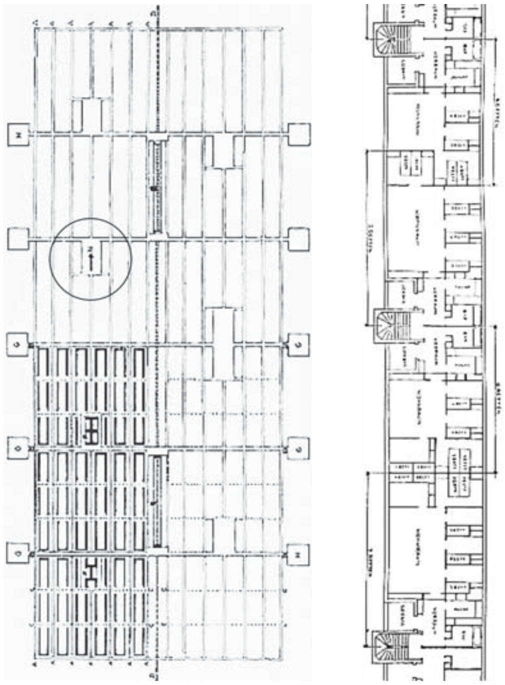


Figure 1: Ludwig Hilberseimer: High-Rise Metropolis; plans, section, rendering; emphasized are the north arrow and the ratio of building height to courtyard width being 1:1 (Hilberseimer 1927).

Hilberseimer achieved a high urban density comparable to Berlin's average density, but this came with a deliberate sacrifice for the apartments, which were arranged along a middle corridor, thus allowing only single-sided orientation of the apartments to either east or west. Cross ventilation and two-sided solar exposure were impossible. Later, Hilberseimer spoke extremely critically about his famous scheme, not only referring to its sterility, but particularly to its solar exposure: "The apartments did not have the right orientation. In order to reduce the city area, a higher residential density was necessary, which was achieved by arranging the apartments along a middle corridor. Consequently, the apartments could not be ventilated well. The residential density was higher than desirable." (Hilberseimer 1963, 22, German)

1.2. The "Wohnstadt" (Residential City)

In 1925, around the same time as the development of the metropolis scheme, Hilberseimer published his design of a "Wohnstadt" (Residential City), dating its development back to 1923 (Fig. 2).[4] Similar to the metropolis scheme, although different in scale, Hilberseimer was interested in the tenement building as the most common way of living in German cities. The residential city was meant for 125,000 inhabitants. It consisted of twelve by six blocks, seventy-two blocks total or about 1,750 people per block (Hilberseimer 1927). Each block, with an elongated north-south proportion, had an approximate size of 40 by 330 meters (a description of the exact size could not be found). The shorter block sides included shops and offices, and only the long, five-story tall sides contained apartments, all of them oriented to both east and west. Similar to the metropolis scheme, these apartment bars had consistently the same spacing, no matter if there was a street or courtyard in between, to allow an even solar orientation.[5]



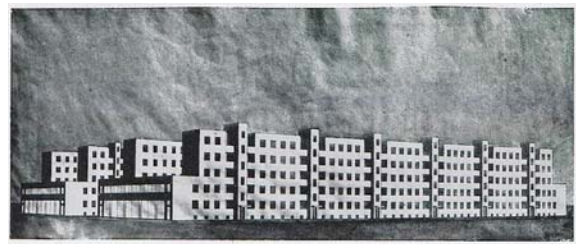


Figure 2: Ludwig Hilberseimer: Residential City; plan, floor plan, rendering; emphasized is the north arrow to show the north-south running building blocks (Hilberseimer 1926).

Sections or written statements verifying the exact ratio of building height to building distance could not be found. In the various published renderings, the distance of the housing bars seems to exceed the ratio 1:1. The floor plan reveals a narrow building width of only eight meters, with most bedrooms facing to the courtyard, and living room, loggia, and stairs facing to the street. Thus, the two apartment bars of a block were mirrored and did not follow the common orientation paradigm of the time that bedrooms should face east to the morning sun and living rooms west to the evening sun. The apartments allowed cross ventilation.

Similar to his critical evaluation of the “Hochhausstadt,” Hilberseimer’s later comments on the “Wohnstadt” were negative: “The orientation of the apartments is wrong. The rooms are arranged toward east and west. East orientation can be accepted, while the one toward west is to be rejected. Rejection of the orientation means at the same time rejection of the residential density. It was fundamentally wrong to assume the tenement building to be the only possible residential form.” (Hilberseimer 1963, 14, German)

1.3. Justification of East-West Orientation

Hilberseimer’s layouts for the high-rise metropolis and residential city were based on reviews of publications on city densities and solar calculations. A vast majority of authors around 1900 concluded that building blocks with a north-south running axis were the preferable scheme in dense cities.[6] One example is Reinhard Baumeister (1833-1917), professor of urbanism in Karlsruhe while Hilberseimer was a student.[7] Already in 1876, Baumeister complained about the unhealthy conditions of dense urban city blocks: “For the human being to prosper, sun light and pure air are necessary. […] light is removed by excessively dense positioning of buildings, limited courtyards, and small windows; air is spoiled by dense crowding in few small rooms.”[8] In addition, Baumeister criticized that most building codes, while only vaguely asking for the development of healthy living conditions, lacked clear regulations about distances, heights, and arrangements of buildings. He therefore recommended that “the most favorable and at the same time simplest ratio h=b should be adopted,” while “h” is the building height and “b” the distance between buildings (Baumeister 1876, 317, German). In other words, he recommended a 45° angle between the bottom of a building and the eaves of an opposite building to determine building height and distance. Baumeister further complained that building regulations existed mainly for the street side of buildings. Since courtyards commonly had much worse conditions—such as an approximate h=3b rule in Hamburg or h=5b in Paris—he asked for the same rule of a 45° angle for rear buildings and courtyards (Baumeister 1876, 323-325, and 1905, 277). However, with respect to scientific evidence, he added in 1905: “The ratio between height and distance of h=b cannot be theoretically justified, but only based on a feeling that tries to negotiate between considerations for health and for ground use.” He again summarized that “the hygienic ideal is h=b, that is a 45° incidence angle of light.” (Baumeister 1905, 275, German) This rule applied to all orientations; no difference was made if buildings had a north-south or east-west axis.

A more scientific approach was undertaken by Karl Hoepfner, professor of urbanism at the Technische Hochschule in Karlsruhe, in his book *Grundbegriffe des Städtebaus* (Basic Concepts of Urbanism) of 1921. Hoepfner became highly influential to Hilberseimer, particularly by coining the term "Durchsonnung" (sun shining through) that can be found in Hilberseimer a decade later.[9] In his book, Hoepfner extensively wrote about the necessary sun exposure of rooms, façades, and the ground surface around buildings. In the first step of the argumentation, Hoepfner acknowledged the superiority of south orientation, stating that in "fall and spring, and particularly in winter, that is in the most important times […] the sun can shine at midday for a long time fully and deeply into the south rooms. [...] but you cannot grant this advantage to a few inhabitants if in return the others, three to four times more of them, have to accept very health-damaging dwelling conditions" (Hoepfner 1921, 193-195, German). He added that north façades were inherently unhealthy, often dealing with mold, and therefore should be avoided, and also warned that the south façade could be overheated in summer (Hoepfner 1921, 173). In a second step, he then listed the advantages of apartments facing east and west, with his main argument being that east and west façades would be at least equal. Blocks should be designed in a way "that potentially all rooms receive in an equal amount a portion of the overall achievable amount of 'shining through'" (Hoepfner 1921, 173). In numerous diagrams, Hoepfner compared differently oriented blocks with respect to solar exposure and shading (Fig.3) and showed that, while for free-standing buildings the south orientation is superior, this orientation leads to excessive shading when used in dense urban areas: "The insolation of south rooms in free-standing buildings is good already in fall and spring, and exceptional in the winter months […]. However, dense urban areas have the disadvantage that the sunrays particularly in the winter months, in which they are the most valuable, are hold off by the buildings opposite the street." (Hoepfner 1921, 150) In other words, he claimed that best orientation differs for low-rise settlements with individually optimized buildings and dense urban areas where entire blocks and streets had to be optimized: When dealing with urban density, best orientation turns to east and west. Hilberseimer followed this recommendation, but, as will be shown below, came back to Hoepfner's analysis a few years later to arrive at opposite conclusions.

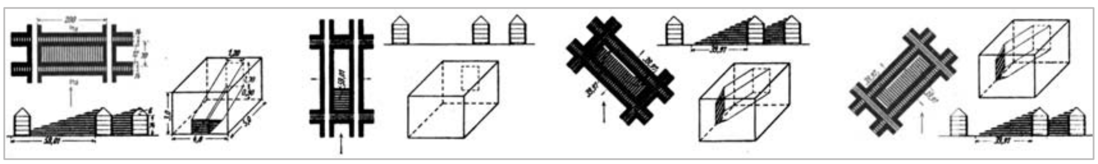


Figure 3: Karl Hoepfner: Study of sun exposure for differently oriented blocks for the winter solstice at 12 noon; altitude 17° 36'. Left to right: east-west block, north-south block, and diagonal blocks (Hoepfner 1921).

2.0. BAUHAUS INVESTIGATIONS: "MISCHBEBAUUNG"

In 1929, Hilberseimer was appointed as Bauhaus teacher, working first under director Hannes Meyer until 1930, then under Ludwig Mies van der Rohe until the closing of the Bauhaus in 1933. During the entire period, Hilberseimer's research and design work shifted away from studying dense blocks in residential cities or metropolises toward the design of mixed-used areas with high- and low-rise housing. Slowly, his understanding of best orientation for housing changed. Hilberseimer first experimented with schemes in which single- and multi-family buildings had diverse orientations to east, west, and south (avoiding north). At the end, he claimed that for all residential buildings south orientation should be achieved—thus abandoning the widely accepted argument that south orientation was ideal for single-family housing, but not practical for multi-family apartment blocks because of a lack of density. While in his earlier schemes he subordinated an ideal solar orientation under the requirements for density, now it was density that had to subordinate under the requirements for best orientation. Hilberseimer increasingly became a critic of high density, stating as early as 1930 that "a perfect solution is only possible by giving up today's population density of the metropolises and by extensive decentralization of the city area" (Hilberseimer 1930a, 520).

2.1. Mixed-Rise Multi-Family Blocks and Single-Family Units

In a 1929 article for the Bauhaus journal, Hilberseimer presented a scheme of five-story north-south running buildings for families alternating with ten-story buildings with apartments for singles and childless couples. Rooms were oriented to east, west, and some to south (Fig. 4). He stated that "the blocks were laid out in a way that they have the relative largest sun illumination when living rooms are allocated in both directions" (Hilberseimer 1929a, 4). A similar 1929 article presented different settlement layouts that show his interest in mixed heights, mixed building types, and apartments facing east, west, and/or south (Hilberseimer 1929b).

In the early 1930s, Hilberseimer became interested in the single-story, L-shaped single-family house, which, in his view, combined "the advantages of the townhouse with the ones of the free-standing house" (Hilberseimer 1931, 1, German). While the free-standing single-family house provided the highest flexibility of arrangement and expression, maximum solar exposure, and complete isolation from neighbors, and the townhouse allowed cheaper building with the disadvantages of limited east and west orientation and less isolation from neighbors, the L-shaped house benefitted from a direct garden access of all rooms while allowing a good isolation from neighbors and a perfect solar exposure with the main spaces oriented toward east, west, *and* south. Hilberseimer's investigation of the L-shaped single-family house became increasingly sophisticated and the type advanced to one of his preferred building types over the years, allowing "free arrangement and more intensive insolation of the rooms" (Hilberseimer 1931, 1, German) (Fig. 5).

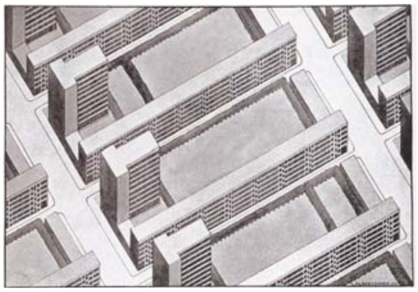


Figure 4: Ludwig Hilberseimer: Ten-story buildings alternating with five-story buildings (Hilberseimer 1929a).

Figure 5: Ludwig Hilberseimer: Proposals for L-shaped single-family houses (Hilberseimer 1931a and 1932, Wagner 1932).

2.2. Comparing Urban Density

Along with these investigations, Hilberseimer began comparing high-rise and low-rise housing units with regard to best orientation and population density. Through diagramming he showed that there was no great difference in density between both housing types if each targeted an equal standard for best solar exposure rather than reducing the standard for multi-family housing (Hilberseimer 1931a, 1931c). In addition, Hilberseimer compared the density of low-rise and high-rise types with the existing density of Berlin and other cities. He calculated, for example, that the high-rise type would allow 384 people per hectare and the low-rise one 324 people per hectare, while comparatively Berlin had a range of 300 to 383 people per hectare—all quite similar. However, at that point, he questioned "if the population density of today's metropolises should be the standard of the population density of a city at all" (Hilberseimer 1931c, 778) and promoted, for the sake of better solar exposure, to decrease the density of urban areas to below 300 people per hectare (Hilberseimer 1931b, 251). His guiding principle was that each room of an apartment should receive at least two hours of direct sun insolation every day—a number that he later increased to four hours. And he concluded that the development of mixed settlements ("Mischbebauung") would best acknowledge different user types without sacrificing density. Also in 1931, Hilberseimer arrived at a scheme in which he oriented both high-rise and low-rise buildings toward south allowing direct sunlight into rooms while avoiding shading of other plots (Fig. 6).

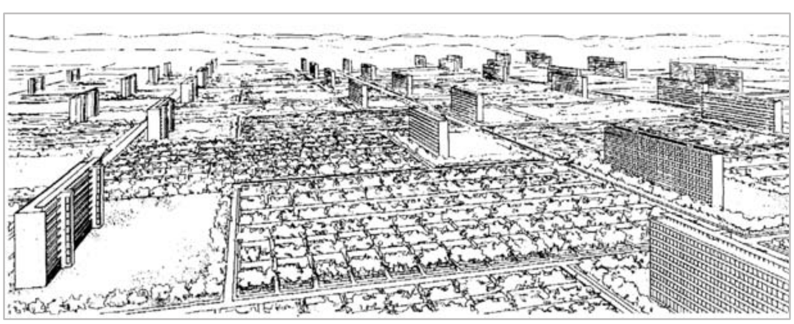
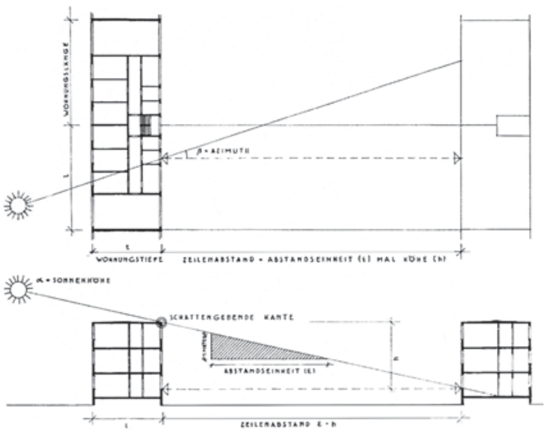


Figure 6: Ludwig Hilberseimer: Scheme for a "Misch-bebauung" with L-shaped single-family houses and high-rise buildings, all oriented toward south (Hilberseimer 1931c).

2.3. Justification of South Orientation

Hilberseimer's extensive sun studies culminated in two articles, published in 1935 and 1936 in the journal *Moderne Bauformen*, which can be seen as a summary of his Bauhaus investigations on solar orientation of dwellings. The first article focused on the housing unit, the second on the urban layout. In the first one, "Raumdurchsonnung," he showed in diagrams that in north-south running buildings, although the sun shines on east and west façades for quite a long time, little sun radiation actually comes *into* the room. Stating that insolation was not a matter of surface**,** but one of space—which he called "Durchsonnung" (shining through)—he concluded that buildings with south, south-east, and south-west orientation of all main rooms were the most preferable. He recommended that building codes should require minimum standards of

"Durchsonnung" of apartments, particularly for the winter conditions. This would result automatically in requirements for minimum distances between buildings and restrictions of allowable building heights (Hilberseimer 1935, 36). In the 1936 article, "Raumdurchsonnung und Siedlungsdichtigkeit," Hilberseimer came up with a table that presented the necessary distances between buildings for a four-hour insolation of rooms at the winter solstice (Fig. 7). South-facing buildings in Berlin (51.5° north latitude), according to this table, would need a distance of 4.73 times the building height for sun exposure between 10am and 2pm. With the same four-hour insolation, the distance would increase to 6.78 times the building height if the settlement was built in Moscow (55° north latitude) and decrease to 3.63 times the building height in Paris (48° north latitude) (Hilberseimer 1936, 69). In conclusion, for Hilberseimer, it was ultimately the sun angle which determined the density of a settlement. However, he also showed that a layout of three-story buildings with south orientation and four-hour insolation would achieve a density of 322 people per hectare, which he considered too high a density anyway.



Breitengrad	Zeit	α	β	ε Süd	ε Diag.	ε O-W
48	9	8,0	40,9	5,41	7,14	4,69
	9^{30}	11,0	34,7	4,22	5,05	2,92
etwa:	10	13,6	28,2	3,63	3,94	1,94
Wien	10^{30}	15,7	21,4	3,30	3,25	1,29
München	11	17,3	14,4	3,11	2,76	0,80
Paris	11^{30}	18,2	7,2	3,01	2,40	0,38
	12	18,6	0	2,98	2,11	0
51,5	9	5,3	40,7	8,18	10,75	7,02
	9^{30}	8,1	34,3	5,77	6,87	3,94
etwa:	10	10,6	27,8	4,73	5,10	2,54
Warschau	10^{30}	12,5	21,1	4,21	4,13	1,62
Berlin	11	13,9	14,2	3,92	3,47	0,99
London	11^{30}	14,7	7,1	3,77	3,02	0,50
	12	15,1	0	3,72	2,64	0
55	9	2,6	40,6	16,47	21,60	14,09
	9^{30}	5,2	34,1	9,00	10,69	6,10
etwa:	10	7,5	27,6	6,78	7,29	3,54
Moskau	10^{30}	9,2	20,8	5,76	5,62	2,19
Königsberg	11	10,5	14,0	5,23	4,62	1,30
Flensburg	11^{30}	11,3	7,0	4,97	3,95	0,61
	12	11,5	0	4,89	3,46	0

Figure 7: Diagram showing the spacing of buildings needed for sun exposure. The table columns include latitude, time, altitude, azimuth, and distance of buildings for south, diagonal and east-west orientation (Hilberseimer 1936).

3.0. CHICAGO YEARS: "SETTLEMENT UNITS" AND THE "RIBBON SYSTEM"

After immigrating to the USA in 1938, where he taught at the Armour Institute of Technology (renamed the Illinois Institute of Technology in 1940), Chicago, Hilberseimer's interest in best solar orientation of housing and its consequences regarding urban density remained central. George E. Danforth described an annual school party dedicated to Hilberseimer—known as "Hilb's Day"—that was celebrated close to the winter solstice, "a day central to his insistence on correct orientation—so that major rooms would receive at least four hours of sunlight" (Danforth 1988, 14). The requirements regarding solar orientation formulated in his 1935 and 1936 articles remained the basis of his teaching and later his leadership in the Chicago City Planning Office. The concept of the mixed settlement ("Mischbebauung") and the merging of urban and rural forms of living, already apparent in the schemes of the early 1930s, became driving forces in his further development of settlement structures. In the following decades, no new insights regarding solar orientation appeared. Hilberseimer, while sticking to his findings from 1935 and 1936,[10] focused on the development of "settlement units" that organized single-family L-houses and multi-family high-rise buildings with proper solar orientation along "fishbone-like street systems" that were connected to larger transportation arteries with commercial and industrial areas. These settlement units could be combined to "settlement aggregates" of various sizes to become a pattern spanning large regions (Hilberseimer 1944). Hilberseimer described this "ribbon system" as follows: "In spite of the fact that one of its aims is its decentralization, its metropolitan character will be maintained, only under much more satisfactory conditions. […] The city as a whole would emerge more or less with the landscape, in fact would become part of it." (Hilberseimer 1967, 34) Hilberseimer now claimed that 200 people per hectare or eighty people per acre would be the desired density, which was the average of Paris with 140, Greater Berlin with 120, London with sixty, and Chicago with fifty people per acre (Hilberseimer 1944, 93, and 1963, 49).

In 1955 the opportunity arose to build such a settlement unit: the Lafayette Park Detroit (in collaboration with Ludwig Mies van der Rohe and Alfred Caldwell). In early sketches, Hilberseimer drew his preferred building types—the L-shaped single-story house and the high-rise apartment building, both facing mainly toward south-east. In the completed project of 1963, however, both of them had disappeared, and one-story row houses, two-story townhouses and multi-story apartment buildings with single-sided apartments were realized, all of them facing in all directions, even to north-east and north-west (Fig. 8). Hilberseimer was not able to follow through with his preferred housing types for best solar orientation.

Figure 8: Lafayette Park Detroit: Sketch by Ludwig Hilberseimer from 1956 and final site plan; rearranged to show true north (Waldheim 2004).

RESEARCH, DESIGN, AND ACTUAL BUILDING PROJECTS

Hilberseimer's solar studies and adaptations to housing units and urban designs provide rich documents to reflect on the relationship of research and design in High Modernism and today. Modernist architects asked for a scientific foundation of building not only for social, technical, or economic progress, but also or even mainly for artistic reasons; grounding design on scientific findings was meant to create a cleansing effect for the—seemingly—superfluously and meaninglessly ornamented architecture of the nineteenth century. The underlying hope was that data-driven design could become an expression of the modern time. Hilberseimer, as one of many protagonists, embraced this goal by demanding, already early in his career, that "extreme objectivity, mathematical clarity, geometrical rigor, and exactest constructiveness are not only technical, but eminently artistic problems. They are the very essence of our epoch." (Hilberseimer 1922, 832, German)

Although there is no such urgent call for renewing architecture today, implementing research in design might still have a similar reasoning of using research for form finding. Architects are highly interested in parametric design or tools to compute big-data to arrive at new forms. Research to accommodate individual needs (above all ADA) or to reduce energy wasting has increased enormously and its impact is evident when looking at the built environment. However, if there is "scientifically optimized design," would not all buildings look the same? And if so, how then is our individuality expressed? Already modernist architects expressed an unease with respect to such questions. Hugo Häring, for example, raised concerns when he stated for Hilberseimer's and Le Corbusier's metropolis visions that their plans did "not allow any space for liveliness" and were "only optimization of objective concepts, debasing the human being to a thing. […] Truly social can only be what furthers the individual. The opinion that social life leads to uniformity, standardization and typification is wrong, the opposite is right. […] Even the existence of the sun only compels the concession of orientation. The city lives in the pure air of spiritual order." (Häring 1926, 172-175) While for Hilberseimer solar orientation became one of his central topics of investigation that allowed unquestionable results and design proposals grounded on substantiated knowledge, he knew well how to respond to arguments such as Häring's. He repeatedly stated that this knowledge led solely to abstract types that required adaptation to real, concrete situations. He distinguished research (also design as research) as the abstraction of a given problem from actual building projects at specific sites. He called the former "demonstration attempts": "Their task is, purely abstractly, to develop fundamental principles of urbanism out of current needs: to achieve general rules that allow the solution of particular concrete tasks. Only abstraction from the specific case allows showing how the disparate elements which make a metropolis can be brought together in a relationship-rich order." (Hilberseimer 1927, 13) With respect to his urban schemes, he repeated that "these proposals should be neither city designs nor standardization efforts of a city. Both is impossible since there is no city as such" (Hilberseimer 1927, 20). Similarly, he stated in 1944 that the "proposed combinations of settlement units to form cities […] are abstractions. Absolute cities do not exist. Cities are individuals. […] these elements which we have described, and their manifold possibilities of combination, must remain in the realm of theory. We need such theory as a starting point for the discovery of our methods of work. But when we undertake the actual work of planning, our methods must always be modified by reality." (Hilberseimer 1944, 128). One could argue whether Hilberseimer was even interested in concrete building projects. His abstract renderings of purified timeless ideas, created throughout his career, are his most powerful and captivating works, addressing intellect and emotions alike. Richard Pommer came to this conclusion, stating: "What mattered to him was not the realities of urban planning, but the perfect form alone, the representation of absolute types, whether a pure bedroom town or a self-sufficient urban center." (Pommer 1988, 40).

In Hilberseimer's case, the most straightforward lesson with respect to utilizing research for architectural form finding comes from his own rejection of his supposedly optimized early 1920s city plans after continued investigations during his time at the Bauhaus. Changing his position was entirely based on giving a different aspect of the problem more importance than it had before. In his metropolis and residential city projects, he emphasized the need for urban density, thus resulting in a preference of north-south streets and building façades that were lit longer in the winter time. In his later settlement units, he stressed four-hour insolation within the main rooms, thus resulting in preferring east-west streets and lower urban density. In other words, scientific knowledge in architecture is useful to understand particular aspects of a project, but this knowledge must still be weighed with respect to its importance in this project. This remains true with our computational tools today, which can calculate "optimized forms" out of an increasing number of variables or aspects. When it comes to real-world projects, the number of such variables will always remain indefinite and there is no way of quantifying all of them for computational simulation and scientifically weighing their importance. Beyond the increasing research in the architectural fields and the further optimization of identified problems, there are still innumerous aspects that require the architects' expertise in creating meaningful wholes. Storytelling as a strategy to unify an indefinite number of challenges and aspects would become obsolete only if we were able to reduce building to a set of identifiable, weighable variables.

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ENDNOTES

1 See Perlin 2013, Denzer 2014, Poerschke 2015 and 2016.
2 Pommer mentions that "[o]ne of the drawings is dated "Dez. 1924" (1988, 51, note 91). The project is published in Häring 1926, 172-175, and Hilberseimer 1927, 17-20. Cf. Hilberseimer 1930b, 610.
3 The scheme is described in Hilberseimer 1927, 18-19.
4 Cp. Pommer 1988, 30 and 50, note 84. The *Wohnstadt* was also published in Hilberseimer 1926 and 1927.
5 Cp. Hilberseimer 1963, 14.
6 Other are, for example: Atkinson 1905, De Fries 1919, Rey/Pidoux/Barde 1928, Schmitt 1930.
7 Cp. Pommer 1988, 23.
8 Baumeister 1876, 16, German. Baumeister addressed light and air but not a need of direct sun.
9 For the term "Durchsonnung," see Hoepfner 1921, 142. Hilberseimer referred to Hoepfner in 1935.
10 For example, Hilberseimer 1944.

Tim Frank

The Charnley-Norwood House: A Turning Point in the History of American Environmental Design

The Charnley-Norwood House: A Turning Point in the History of American Environmental Design

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ABSTRACT: The Charnley-Norwood House, situated along the Mississippi Gulf Coast, is a lesser-known vacation bungalow drawn by Frank Lloyd Wright as an experiment while working under his “Lieber Meister”, Louis Sullivan. Built in the latter part of the 19th century, it exemplifies a turning point in American architecture as the groundwork for Wright’s signature Prairie Style was taking root. Embedded within this structure are fundamentals about an organic approach to architecture, clearly demonstrated by the assimilation of the building into the interworkings of both site and climate. Sullivan and Wright scholars both agree that this house, undocumented to-date, serves as a significant milestone in the history of American environmental design.

What is unknown about the house is how the dictates of the coastal gulf climate influenced its spatial disposition and how this composition grew out of well-established traditions of environmental design. The T-shaped bungalow encompasses many distinctive features including its overall horizontality, an overarching parasol roof plane, a permeable building exterior and intermediary space types along its perimeter. The open plan organization follows its predecessors in its thinness with rooms dispersed along each axis, creating multiple exposures that alter the orientation of interior spaces to year-round climatic effects. Operating in concert, these attributes serve to admit prevailing breezes, extend views to the surrounding landscape, and shade inhabitable areas; hallmarks that would alter the course of 20th century residential architecture in America.

Using computational simulation tools, this paper discloses how the bungalow advances strategies of passive design utilized by early 19th century predecessors and paves the way toward an environmentally integrated 20th century period of residential construction. Additionally, this paper offers insight into a formative moment in architectural history when two American masters were in direct collaboration.

KEYWORDS: computational simulation, organic architecture, thermal zoning, Louis Sullivan, Frank Lloyd Wright

INTRODUCTION

Architect Louis Sullivan with his emerging assistant Frank Lloyd Wright designed the Charnley-Norwood House, originally constructed in 1890. Commissioned by James Charnley as a vacation retreat for his family during harsh Chicago winters, the house sits along the Mississippi Gulf Coastline, in Ocean Springs. In 1895, the house was sold to another Chicago merchant, Frederick Norwood. Following restoration in 1980 and severe damage due to Hurricane Katrina in 2005, the house was built to its current state with restoration efforts concluding in 2013. The house is managed by the Gulf Coast National Heritage Area Program under the Mississippi Department of Marine Resources and is currently open for public tours (Hoglund and Quinan, 2017). The T-shaped three-thousand-square foot bungalow is positioned along the southern edge of the estate, neighboring the waterfront, with expansive panoramic views of the Davis Bayou on the Gulf of Mexico to the south. The main axis of the house runs in the north-south direction while a secondary axis crosses perpendicular in the east-west direction. The distribution of programmatic spaces adheres to its formal composition where the private bedrooms are situated at the ends of the east-west axis while the public entry hall, octagonal dining room and service areas including the kitchen and the butler pantry run from south to north along the main axis. From the entry point at the southern end of the house, distinct programmatic zones flow freely from one to another, separated only by narrow passages defined by enclosed utility spaces. Each programmatic zone opens directly to the exterior with generous windows and doors to the outside that operate for ease of cross ventilation. Public spaces such as the entry hall and the octagonal dining space open directly to the exterior where intermediary porches further soften the transition from outside to inside. A large parasol roof plane unifies the composition, protecting all inhabitable spaces from the harsh summer sun and rain while its ventilated cavity helps exhaust hot air accumulating within the structure (FIG. 1).

While the house is unarguably distinctive within its late-nineteenth century Victorian context, its attribution is shrouded in mystery. Louis Sullivan and Frank Lloyd Wright scholars alike ascribe authorship to their respective subjects since both Sullivan and Wright take credit for the design on separate occasions.

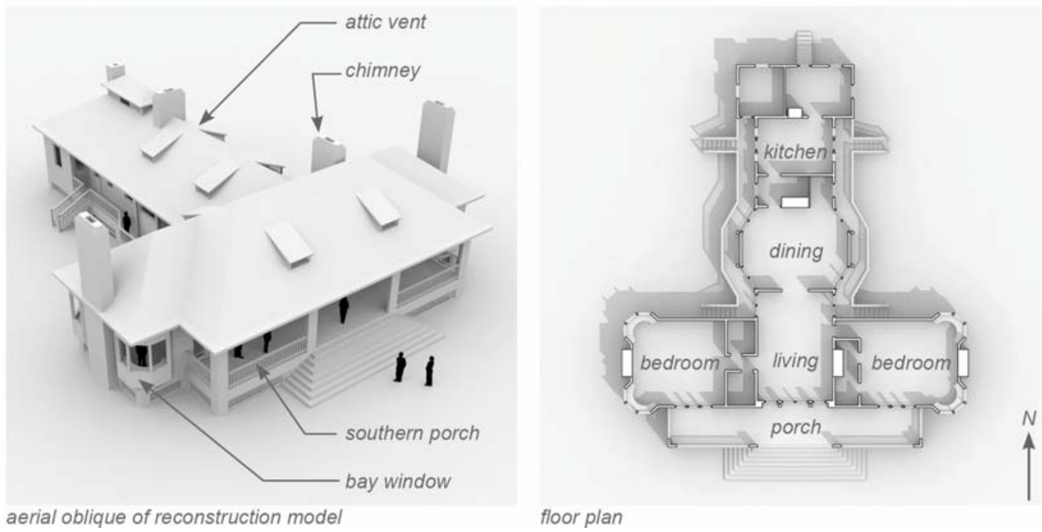

Figure 1: Digital reconstruction of the Charnley-Norwood House. Source: (Clark and Frank 2016)

Sullivan recollects giving a local carpenter drawings for the 'shack' to construct after designing the structure in hurried fashion (Sullivan, 1956 [1924]). The reconstruction of the house in 1897, following a fire, supports this point because it was built to the original specifications even though Wright was no longer working in Sullivan's office. Wright, on the other hand, takes credit for the drawing of the 'cottage', the first modern house in America from his perspective, in reflecting upon experimentation during his early career with Sullivan (Wright, 1949). This account is also sustained by the office workflow during this period, where Sullivan, occupied with much larger commissions at the time, often bestowed smaller projects to draftsmen like Wright to develop. Regardless, signatures of both Sullivan and Wright permeate the structure including its flowing disposition of spaces and sweeping intermediary zones along the perimeter, representing a time in American architecture where two masters were in direct collaboration, forging a distinctive approach to environmental design. Rooted within this house are Wright's early ideas about 'organic' architecture that extend Sullivan's principle that 'form ever follows function' (Sullivan, 1979 [1896]). The belief that a building should sustain its most fundamental purpose of physical dwelling within the particularities of a place is the shared principle that connects them and carries them both into the early-twentieth century era of modernism in America.

1.0 BACKGROUND

For Wright, the concept of Organic Architecture was the modern ideal that a building is an integrated network of relationships comprised of elements both internal and external to the structure itself (Conrads and Bullock, 1970). This understanding of architecture coincides with studies in human ecology that also emerged at the beginning of the twentieth century that holistically examines the mediating factors that regulate natural and human ecosystems (Raffestin and Lawrence, 1990). While formalized as such in the early-twentieth century, this understanding of the built environment's role in moderating relationships between people and their surroundings traces back to Hippocrates in the fifth-century BCE and was elaborated upon by Vitruvius in the first-century BCE, whose work Sullivan attributes as the core of his aforementioned adage (Sullivan, 1979 [1896]). According to Wright, the completeness of the structure, where the coherent whole is greater than the sum of its parts, should incorporate provisions for viewing, lighting, heating and cooling. Integrating these factors reinforces the symbiotic relationships that exist between the human inhabitant and the natural world instead of trying to merely replicate organic forms within the building itself, a prominent approach during the mid-to-late nineteenth century Victorian era (Wright, 1975 [1914]). In his outline for a new twentieth century modern architecture, Wright articulates the following architectural strategies that reinforce these organic relationships between people and place (Wright, 1960 [1957]). Decentralization is a model proposed by Wright for urban development and smaller tributary applications that extends inhabitable space along the ground plane to better connect to natural resources. Following suit, horizontality is a strategy employed by Wright to integrate building elements directly into the earth resulting in the planar stratification of space that softens the distinction between ground and the built environment. Permeability results from ingenuities in twentieth century material science that enables Wright to utilize larger structural spans and lighter building enclosure systems that result in direct connections between interior and exterior while offering freedom in planning. Moreover, open planning is a principle used by Wright to leverage new freedoms enabled by larger structural spans and increasingly slender supports that unify interior spaces, inviting more liberal planning and flexibility of use. This leads to the strategy of continuous space employed by Wright, opening interior spatial dispositions to the outside while enabling renewable natural resources to enter, diversifying the occupiable zones of a structure through the introduction of intermediary space types. While published at the end of Wright's career, evidence of these strategies pervade the Charnley-Norwood House, one of the earliest buildings in his oeuvre, demonstrating the lasting influence of his architectural roots from Sullivan's mentorship to the indigenous tactics used by their predecessors.

Scholars of both Sullivan and Wright agree that the Charnley-Norwood House, undocumented to-date, is a neglected milestone in the history of American environmental design (Twombly, 1986). While the environmental movement was scientifically explicated in forms of mid-twentieth century modern architecture, the Charnley Norwood House foreshadows the impact of structural and envelope advancements in the built environment. Moreover, correlations have been made between the house and southern vernacular building types including the bungalow and the dogtrot due to its characteristic central breezeway, multi-nuclear plan, parasol roof and sweeping verandas on the eastern, western and southern edges of the house (Storrer, 2017). These attributes are consistent with traditional buildings in the humid Southern United States that exhibit elevated floors to catch prevailing winds; parasol roofs to shelter from sub-tropical sun and rain; continuous porches to extend living areas outdoors; operable apertures to maximize cross ventilation; ventilated attic cavities to exhaust buoyant hot air; and shutters for ventilation and privacy (Banham, 1966; Fitch, 1961). By exhibiting many of these traits, the house provides ample evidence that the design was likely devised in response to the dictates of the southern climate. Furthermore, by echoing the strategies outlined in Wright's new architecture above, these indigenous characteristics appear to underpin his organic philosophy, a common theme of Wright's who often found inspiration in the work of pre-industrial societies (Fitch, 1990). However, the primary question posed in this paper is how the structure, identified as a milestone in the history of environmental design, advances passive technologies from vernacular to modern traditions, a question that requires further investigation with the use of state-of-the-art simulation and modeling tools.

In light of our ongoing climate crisis and the role buildings have in curtailing high grade energy usage, the survival of indigenous building strategies, especially those that moderate environmental forces using largely architectural means, is crucial and worthy of further investigation. Furthermore, a deeper understanding of environmental design principles is of great interest within today's socio-political climate which has tended to marginalize the significance of the natural environment and the impact human enterprises have on it. Understandably, if one is able to uncover and become aware of a wider array of climate-responsive techniques that underpin a building's compositional strategies, the preservation and promotion of these approaches becomes increasingly likely. With the emergence of building performance simulation (BPS) tools in recent decades, our ability to observe building boundary and environmental state interactions have increased exponentially. The simulation techniques presented below help measure the cause and effect of design decisions on the environment while making explicit connections between design, environment and quality of life within a shared domain. Through observation of simulation outcomes, we are able to tap into the vast body of knowledge that resides within case studies such as the Charnley-Norwood House to understand the progression of environmental design strategies over recent centuries for adoption in contemporary development.

2.0. METHODOLOGY

State-based BPS, within the full spectrum of computational simulation tools, involves the use of mathematical models to emulate the behavior of physical states such as light, heat and air. State-based BPS takes place within a defined digital domain comprised of geometric boundaries representing building elements, input states that approximate the prevailing climate conditions and output states that are measured against criteria for occupant well-being. Building data, obtained from reliable sources, serves as the basis for a digitally reconstructed model of the structure that is centrally located within the simulation domain. Climate data, recorded and logged from local weather stations is used to configure the input state profile and initiates the simulation analysis within the domain. Cultural data, taken from literary sources and adjusted in accordance with contemporary standards for comfort is used to evaluate output states to ascertain how the building provides occupant well-being with purely architectonic devices. Furthermore, the observation and measurement of state change, from input to output, within the modeling domain indicates the degree to which the building is able to modulate extensive climatic factors.

The initial stage in the analysis workflow involves the digital reconstruction of the case study using reliable sources. In the case of the Charnley-Norwood House, the fact that it is open to the public facilitated its on-site survey in addition to the restoration documents that are available to review during tour hours. From these on-site observations and orthographic datasets, a three-dimensional model of the house is constructed using

Rhinoceros™, a base interoperable modeling platform developed by Robert McNeel & Associates preferred for its navigable interface, interoperability and its facility in geometric alteration as it negotiates the formal language. As a non-uniform rational B-spline (NURBS) based platform, planar representations are imported into the domain, traced and translated to generate closed polysurfaces suitable for myriad forms of simulation analysis. At this stage, the ability to simplify complex building geometries for analysis abstraction is crucial to ensure the effective use of computational resources during periods of simulation. The interoperability between the base modeling platform and the simulation plug-in components in a shared interface eases the reiteration of testing sequences to give a more holistic understanding of a precedent's environmental design characteristics with state-based lighting, radiation and fluid dynamics analysis programs.

Once the building boundaries are digitally reconstructed within the NURBS-based platform, the workflow moves to the second stage, the systematic exposure of these geometric boundaries to input states that mathematically represent light, heat, and airflow patterns. This weather data, supplied by local instrumentation and maintained by the United States Department of Energy, supplies information on sunlight, temperature, moisture and wind on a continuous basis. The Mississippi Gulf Coast is classified in the Köppen system as temperate with hot and fully humid summer seasons. This climatic region resides 30 degrees north of the equator and 88 degrees west of the prime meridian. Significant seasonal variation is present with an average dry bulb temperature of 48° F in January and 82° C in July. The prevailing winds in the region generally come out of the north in the winter with average speeds around 10 mph while winds come off the Gulf from the south with speeds averaging 6 mph during hot summer months. Additionally, from the winter to the summer solstice, the sun's elevation angle along the coast shifts from 35–83° when measured at noon. The psychrometric chart indicates that only 5% of yearly hours reside in the comfort zone with shading, ventilation, cooling and dehumidification strategies providing a majority of the remaining comfort hours yearly in the region.

Changes in thermal, luminous and fluid states are observed in the context of the case study structure and evaluated against two cultural benchmarks. The first is comprised of qualitative performance outcomes desired by Wright, articulated in his late essay that underpins his organic philosophy while the second consists of quantitative norms for occupant comfort and wellbeing customary in the building practice today. In his 1957, "The New Architecture: Principles", Wright describes the multiplicity of views enabled by an organic architecture through spatial flows between outside to inside that cannot be controlled through singular points of view. Furthermore, the interpenetrating depths produced by permeable enclosure systems invites daylight from the outside to become an integral part of the built environment's interior disposition. An organic architecture also offsets the need for mechanical heating and air conditioning systems by integrating these functions into the building structure itself through elements with thermal mass including hearths. Cooling is prioritized in Wright's organic architecture through the operability of windows and doors that bring fresh air into the building while using an expansive roof plane to shade the interior during hot summer months (Wright, 1960 [1957]). In contemporary architectural practice, performance parameters are expressed in increasingly quantitative ways. These parameters include abundant access to uniform daylighting with a minimum of 250 lux over 90% of a floor plate, with maximum levels at 4000 lux to minimize discomfort glare and uniformity ratios of at least 0.4 when measuring the minimal daylight level over the weighted illuminance average to offset the need for electric lighting and to increase occupant wellbeing. The achievement of air quality occurs through the controlled distribution of fresh air to interior spaces with natural ventilation rates ranging from 0.2 - 1.5 m/s, providing evaporative cooling to inhabitants when temperatures elevate above the comfort zone. Finally, direct lines of sight to outdoor areas for 90% of regularly occupied floor areas are prioritized to maintain view sheds to outdoor areas to enhance the connection between occupants and their natural setting for the sake of well-being.

3.0. PRINCIPLES

The aforementioned organic strategies outlined by Wright in his essay, "The New Architecture: Principles" include decentralization, horizontality, permeability, open planning and intermediary space types. Together, these strategies underpin the basic disposition of the Charnley-Norwood House, carrying signatures of Sullivan's belief in a functional approach to building while reflecting earlier examples of vernacular traditions in the Southern United States.

3.1. Principle 1: Decentralization

Decentralization is a planning principle that disperses spatial volumes horizontally along the ground plane while using a strong horizontal datum, like a parasol roof plane, to gather up the spatial grouping below. This multi-nuclear schema is evident in the Charnley-Norwood House through the distribution of four service cores that loosely define the bedroom, living, dining and kitchen spaces between. This principle is tested using CFD tools to examine how the plan is climatically adapted to catch prevailing winds from the south in the summer and to buffer northern winds during winter seasons. During the summer, continuous wide open spaces like the bedrooms, the living room and the dining room preserve ample access to southerly winds off the Gulf through the T-shape plan and positioning of service cores to constrict the airflow, increasing air velocity between. On the other hand, the service cores buffer cold northerly winds in the winter and house internal heating elements like fireplaces to aid in warming interior spaces (FIG. 2). This principle is akin to the southern dogtrot housing typology with a central breezeway defined by a binuclear planning scheme used to intensify light winds and promote evaporative cooling for the occupants inside. Composing interior spaces in a manner that directly engages seasonal shifts encourages inhabitants to concentrate activities in zones of the home particularly well adapted to shifts in airflow and temperature, improving inhabitant well-being on the interior while reinforcing the collective identity of the occupant group.

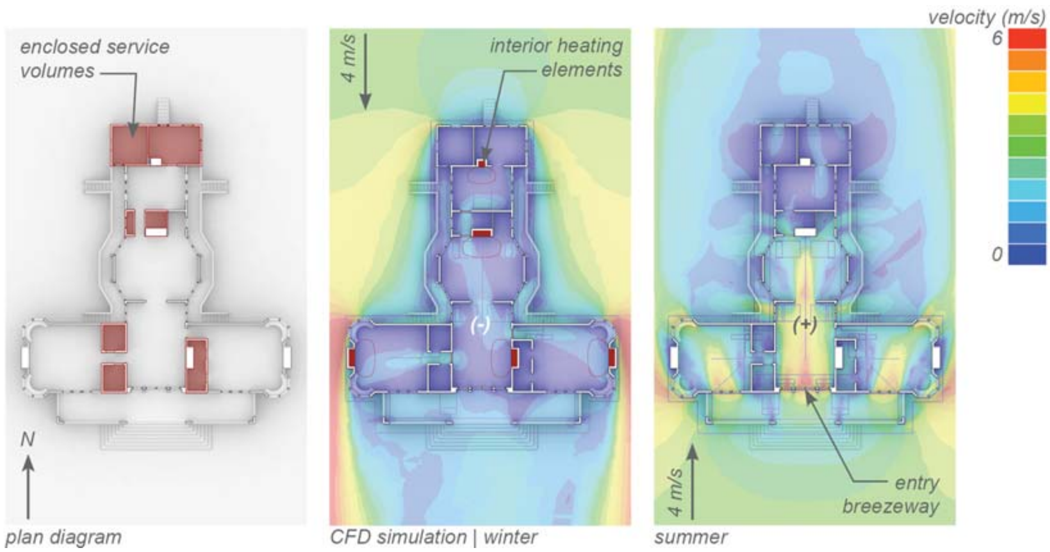

Figure 2: Decentralization analysis outcomes. Source: (Frank 2017)

3.2. Principle 2: Horizontality

Horizontality is a principle that uses architectural strategies like extensive roof planes or elevated floors as constructed systems to buffer interior spaces from climatic extremes. In the Charnley-Norwood House, the ventilated parasol roof plane provides overhead shade while collecting and exhausting buoyant hot air while the elevated floor places inhabitable spaces in closer proximity to prevailing breezes. This principle is tested using CFD and ray tracing tools to examine how the ventilated roof cavity promotes stack ventilation while shading interior spaces below. When winds prevail off the Gulf, large southern apertures draw air into the living and dining spaces that are vented into the roof cavity where they exit through apertures in the roof plane. The roof is expansive enough to provide adequate shading throughout the day with a high sun when measured at hourly intervals (FIG. 3). The parasol roof plane and the elevated floor plate are both common attributes of southern vernacular structures like the dogtrot and bungalow in response to heavy periods of rain and intense summer heat. Exaggerating the horizontal disposition of space through the combination of expansive floor and roof systems with low ceiling heights helps constrict airflow, increasing air velocities while providing amble shading to facilitate heat removal and evaporative cooling for occupants during hot summer seasons.

3.3. Principle 3: Permeability

Stemming from innovations in structural systems, permeability is a principle that opens interior space through the removal of large load-bearing interior walls. In the Charnley-Norwood House this results in large operable windows on the southern, eastern and western sides of the structure to source natural light, fresh air and views to transmit from inside out. CFD simulations are used to test the combination of open plans for cross ventilation and open sections for stack ventilation while raytracing tools reveal the amount of natural light transmitting into the interior spaces. While isovist analysis tools disclose the extensive view sheds enabled from even central areas of the plan the CFD and raytracing outcomes demonstrate increased air velocities due to constricted flows along with well-lit interior spaces attributed to the abundant use of glazing (FIG 4). Thin plans and aligned apertures are common features in southern vernacular housing yet the structural and glazing technologies that emerged in the 20th century exploit these characteristic traits. It is with this principle that the inhabitant's connection with their natural surroundings becomes clear through large expansive openings around the building perimeter and open planning that together blur the distinction between interior and exterior spaces.

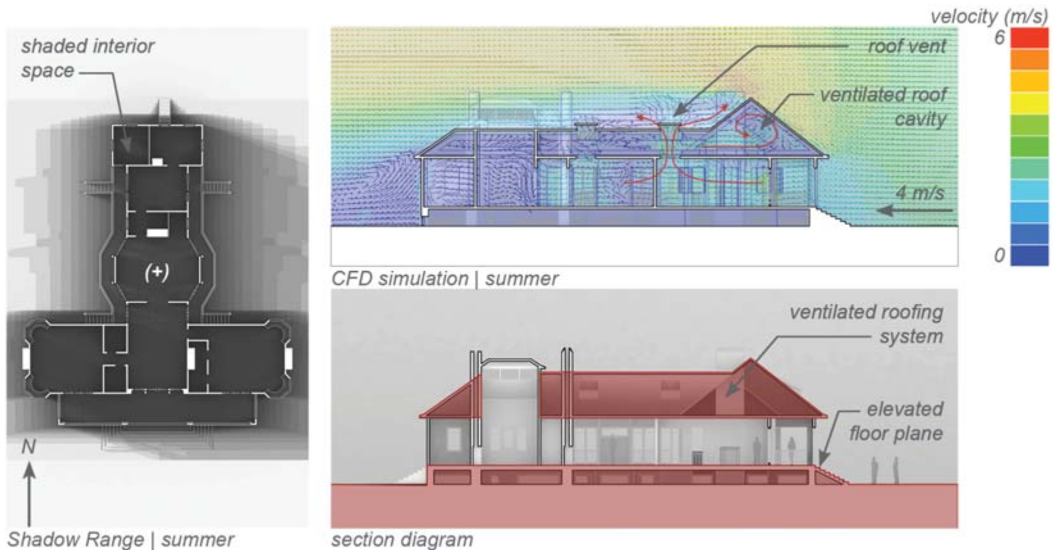

Figure 3: Horizontality analysis outcomes. Source: (Frank 2017)

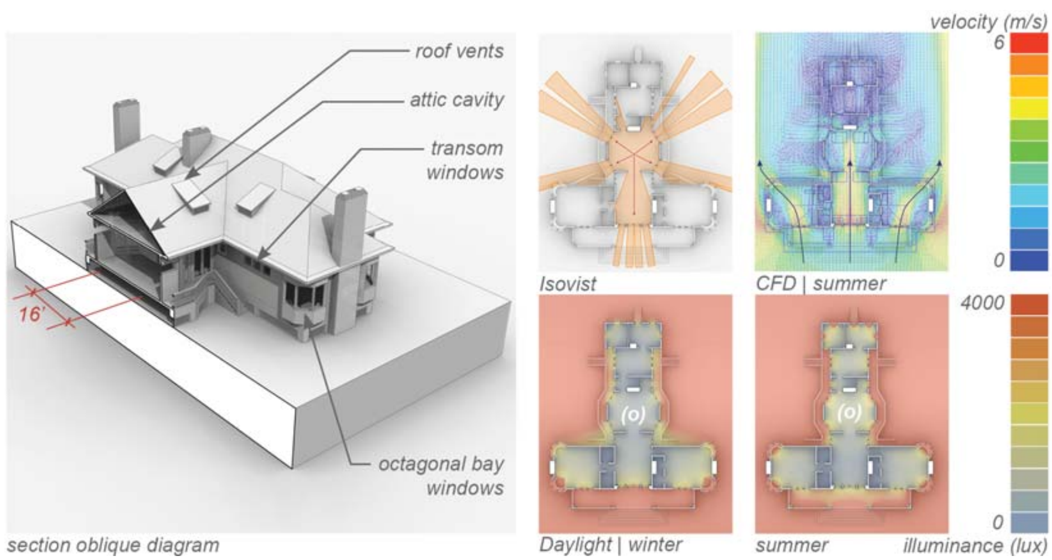

Figure 4: Permeability analysis outcomes. Source: (Frank 2017)

3.4. Principle 4: Open Planning

Also enabled by new structural technologies, the principle of open planning amalgamates interior spaces while offering flexibility in occupant use and interaction. With the Charnley-Norwood House, this flexibility promotes the migration of activities whereby interior and intermediary rooms are zoned to accommodate events based upon the climate profile at that point in time. CFD and solar radiation studies examine this variety of zones, looking at the comfort levels provided by each during different climate conditions, namely during summer and winter seasons. Summer space types include bedrooms and living areas, tuned by operable apertures and narrow floor plates to channel constricted southerly airflow while shaded from the hot summer sun overhead. Winter space types include the southern porch and enclosed areas supported by internal heating elements that moderate the cold northerly wind through mass buffering while opening to direct solar radiation from the south (FIG 5). In the dogtrot southern housing typology, a bi-nuclear planning scheme separate functions with and without internal heating elements while it’s orientation along cardinal directions makes use of east-west zoning for morning-evening migration. Heterogeneous thermal zoning accommodates various social patterns ingrained in dwelling through migration from one area of the house another, giving the occupant choice in determining the ideal location for desired activities and broadening the comfort range of the home for users with different inclinations.

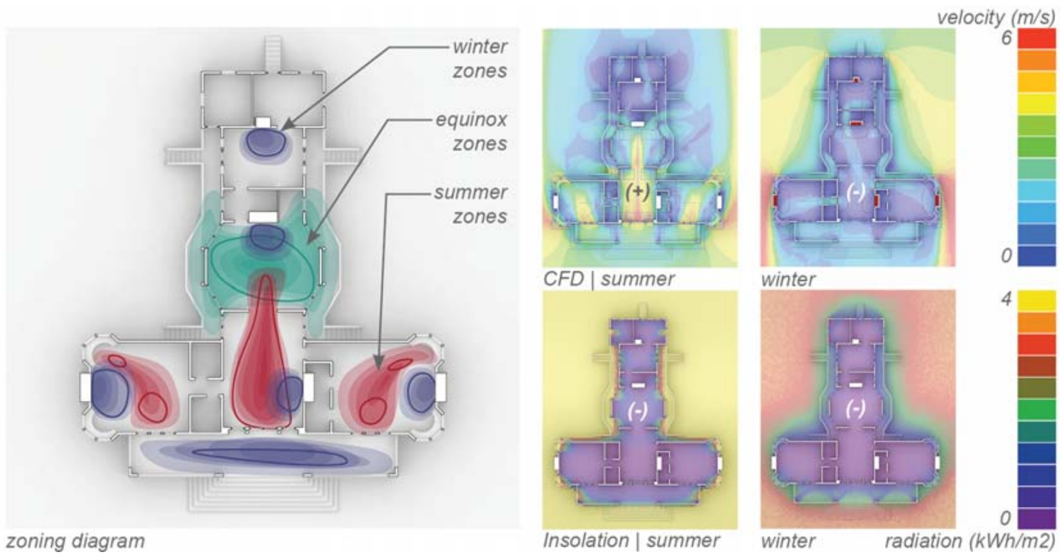

Figure 5: Open planning analysis outcomes. Source: (Frank 2017)

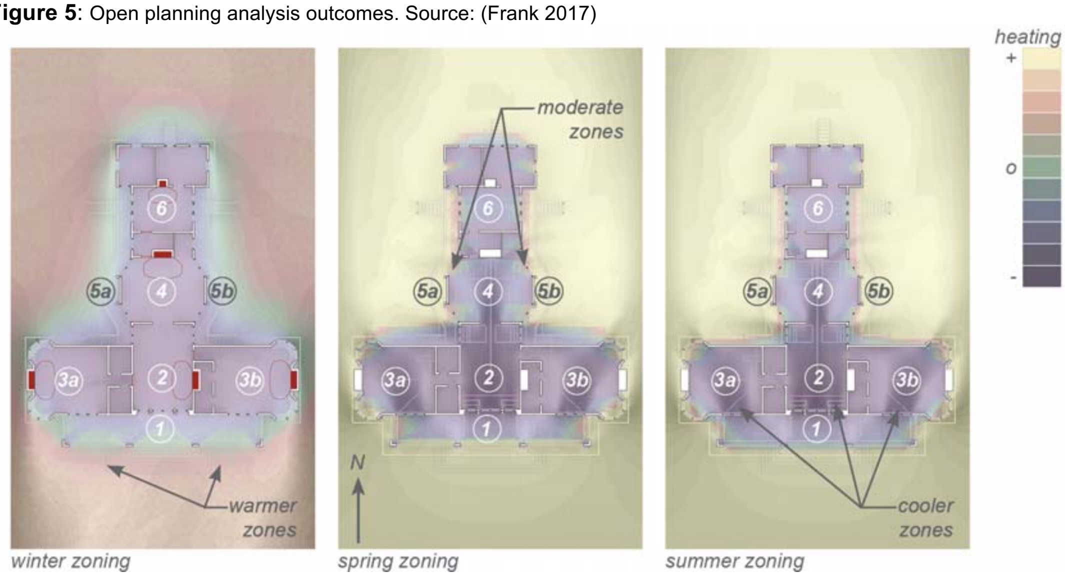

Figure 6: Intermediary space making analysis outcomes. Source: (Frank 2017)

3.5. Principle 5: Intermediary Space Making

Extending space beyond the conventional boundaries defined by a building is the basis of intermediary space making. This involves provisions for semi-enclosed outdoor rooms at the Charnley-Norwood House including sweeping east-west porches in addition to a long and deep southern porch overlooking the Gulf. Each of these intermediary space types are examined under the prevailing solar and wind conditions at three points annually; the winter solstice, the spring equinox and the summer solstice. Results from the analysis indicate that the southern side of the house, including the southern porch are the warmest areas due to solar exposure and protection from cold northerly winds. The middle of the house including the sweeping east and west porches are moderately exposed to both wind and sun depending upon the time of day while the southern zones of the house are both sun protected and exposed to constricted high-velocity southerly winds (FIG. 6). Intermediary space types like the southern porch are a common feature used in southern vernacular houses due to the oblique relations between the changing sun angle and the shifting wind direction from winter to summer seasons. Providing intermediary spaces, intended to be used year round, extends seasons for outdoor comfort, locating inhabitants along building edges to directly engage the site and the neighboring community.

CONCLUSION

Taken together, the principles embedded within the Charnley-Norwood House offers a high standard for American environmental design, one that softens the architectural boundary to embrace the continuity of space resulting in a rich inventory of passively conditioned zones that enhance occupant well-being. While contemporary society has been criticized for producing subpar architectural outcomes when compared to their predecessors, the Charnley-Norwood House offers ample evidence of how vernacular strategies can be advanced using technological innovations of the day. While this paper offers insight into a formative moment in architectural history when two early modern masters were in direct collaboration, it also concretizes their impact on environmental design and the important lessons it offers for contemporary adaptation in light of our ongoing climate crisis. This watershed moment in environmental design should underscore the urgency of continued advancement in the field that is needed using developing technologies at hand to offset the use of high-grade energy sources while maintaining the delicate relationships that exist between people and their surroundings.

ACKNOWLEDGEMENTS

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Ash Ragheb

Materials Choices Matter: An Eco-balance Evaluation of a LEED Certified Building

Materials Choices Matter: An Eco-Balance Evaluation of a LEED Certified Building.

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ABSTRACT: Since environmental sustainability becomes a central concern in the design process in both architectural education and practice, research on quantifying buildings impact on the environment is growing worldwide. Although many designers seek LEED certification, some claim their buildings to be sustainable based only on certification. In fact, unless a Life Cycle Assessment (LCA) study is carried out, it is difficult to *quantify* and *evaluate* the environmental burden a particular building, or a construction material, has on its surrounding environment. The study method employs a quantitative LCA approach in calculating these impacts. The paper models an office building over a service life of 60 years and its implications on the environment from cradle to grave. It also quantifies and compares the total impacts this building has throughout this life span. The case building is located in Michigan in the U.S. where steel construction is the dominant method of construction for commercial type. The building is a 1-story LEED certified building that uses a geothermal HVAC system and has many sustainable materials used. The study calculates the environmental footprint of the building per unit area (impact to air, water, and land). The study discusses the importance of setting metrics beyond LEED to choose more sustainable materials based on their environmental impact. To narrow down to the critical materials, the study provides an assessment to which building component (structure, enclosure, floors, roofs) contribute *the most* to the total building impacts where the worst burden and critical materials could be identified and replaced. The outcome highlights where LEED rating system may fall short regarding the best materials alternatives to use and in which component of the building. This contributes to reduced total impact through selecting these alternatives based on the least damage to the environment.

KEYWORDS: Environmental Profiling, Impact Assessment, Life Cycle Assessment, LEED.

INTRODUCTION

Life Cycle Assessment (LCA), or Eco-Balance Analysis, represents a quantitative tool for calculating the environmental impacts of products at all stages in their life cycle from cradle to grave. Throughout the life cycle of a building, various natural resources are consumed, including energy resources, water, land, and several pollutants are released back to the global/regional environment. These environmental burdens result in global warming, acidification, air pollution, etc., which impose damage on human health, primarily natural resources, and biodiversity. For example, in the United States, the construction and building sector has been estimated to be responsible for roughly 40% of the overall environmental burden (U.S.DOE 2002). The building sector, constitutes 40% of the nation's total energy demand and approximately 44% of the total material use as well as roughly 39% of the total CO2 emission, has been identified as one of the main factors of greenhouse gas emissions (U.S.DOE 2008). There is no doubt that reducing the environmental burden of the construction industry is crucial to a sustainable future.

Most research on the environmental impacts of buildings examine the issues at a relatively broad level though extensive description. For example, Finnveden and Palm (2002) stated that the use phase accounts for the majority of the environmental impacts of buildings. Klunder (2001) gave a description of environmental issues of dwellings, noting that assessments should focus primarily on components that involve large quantities of materials (e.g., foundation, floors, and walls), but there are also dangerous materials that should be avoided regardless of quantity (e.g., lead). Some of the building-related environmental studies present detailed quantitative data about the life cycle of a building (Scheuer et al., 2003). Junnila and Horvath (2003) quantify the most significant impacts of a high-end office in Europe. However, this study narrows down to the systems and materials that release most emissions for the studied case in order to test better retrofitting or fit out alternatives as building adapts to its future.

Building assembly systems (structural, envelope, floors, and roofs) are rarely studied on individual or as combined systems in LCA studies. Thus, such information and data indicating the significant impacts by building systems would be of great use in design and management of the building life cycle maintenance. Ragheb (2011a) concluded that that the walls system has the highest percentage of emissions among other components, mainly in global warming, acidification, smog, and respiratory effect impacts in comparative study office buildings. The study acknowledges that LCA stands among new metrics to quantify how sustainable our buildings are. The study also supports that the design process, especially for office buildings, is never a finished process and the procurement and building adaptation should support this fact. Thus, LCA could be a beneficial tool in this ongoing process as the findings support these flexible changes of these systems with way less impacts.

1. METHOD, AND ASSUMPTIONS

A life-cycle assessment (LCA) framework is selected to analyze the environmental impacts of a new office building in Michigan. Sixty years of use was assumed to be the basic life cycle. LCA is the most appropriate framework for the quantification and evaluation of the inputs, outputs, and the potential environmental impacts of a product, process, or service throughout its life cycle, from cradle to grave i.e., from raw material acquisition through production and use to disposal [as defined in ISO 14040, 1997]. The LCA had three main phases; *inventory analysis* for quantifying emissions and wastes, *impact assessment* for evaluating the potential environmental impacts of the inventory of emissions and wastes, and *interpretation* for defining the most significant impacts.

LCA is defined as a systematic, holistic, objective process to evaluate the environmental burdens associated with a product or process. The process identifies and quantifies *energy* and *materials* usage and environmental releases of the studied system and evaluates the corresponding impacts on the environment. Identification and quantification of material and energy flows of the building's life cycle were primarily derived from the floor plans and specifications of the building.

Some emissions data related to different energy and material flows were collected mainly from the actual manufacturers in Michigan. The *quality of the data* used in the life-cycle inventory was evaluated with the help of data quality pedigree matrix recommended by (U.S. EPA, 2016). The quality target for the LCA data was set to be at score of 2 (on a 5 scale, 1 being the highest), which means reliability of most recent documented data measured from actual drawings and specs sheets. In life-cycle impact assessment, the magnitude and significance of the energy and material flows (inputs and outputs) were evaluated. The impact categories included were those identified by EPA (2006) as 'Commonly Used Life Cycle Impact Categories'. Among the 10 listed categories, the impact categories in this paper include:

- Primary Energy (Fossil Fuel Consumption) *FFC*,
- Resources Use *RU*,
- Global Warming Potential *GWP* (Climate Change),
- Acidification Potential *AP*,
- Eutrophication Potential *EP*,
- Human Health Respiratory Effect Potential *HHREP*,
- Photochemical Ozone Creation Potential *POCP*, or Summer Smog,
- Ozone Depletion Potential *ODP*.

The chosen impact categories are also on the short list of environmental themes that most environmental experts agree to be of high importance in all regions of the world and for all corporate functions (Schmidt and Sullivan, 2002). The classification, or assigning of inventory data to impact categories, and the characterization, or modeling of inventory data within the impact categories (ISO 1997), were performed using the ATHENA 4.1 Impact Estimator (2012) which is used to model the building. The program filters the LCI results through a set of characterization measures based on the *mid-point impact assessment* methodology developed by the U.S. Environmental Protection Agency (U.S. EPA); the *Tool for the Reduction and Assessment of Chemical and other environmental Impacts* (TRACI) version 2.2 built in the software. TRACI "mid-point-impact" method includes emissions, fate, and exposure, and is less uncertain than the "end-point" method used by other LCA software. In the life-cycle interpretation section, the results are also examined from the building assembly systems (foundation, walls, floors, etc.) so that the environmental impact of each system's life cycle can be quantified. Some limitation on impacts included biodiversity, and indoor air quality are not assessed due to the lack of data and limitation of the modeling software. Some other elements like office furniture, computers, construction of infrastructure, were excluded to focus the attention on modeling the building itself as simply as possible.

1.1 Case Study Building Description

The case study is a new office building located in Michigan (climate zone 5) in the U.S. Its construction ended in 2010. The targeted use of the building is mainly medical offices. The building has 21,290 sq ft (1978 m^2) of gross floor area, and a volume of 351,285 cu ft (9947 m^3). The building consists of 1 main floor

16.5 ft (5 m) high with no basement. The structural frame is Hollow Structural Steel (HSS) columns and open web steel joist for roof support. Floors are light reinforced concrete of one floor. The exterior walls are brick veneer with steel studs backing. Interior walls are galvanized steel studs with gypsum board facing to receive paints or wall paper. Foundations are cast-in-place concrete. The annual energy consumption is calculated using eQuest 3.64 (2012). The estimated natural gas consumption, mainly for water heating, of the building is 34.42 Mbtu (1616 Btu/sq ft/year) and this is equivalent to 0.47 kWh/sq ft/year. The estimated electricity consumption is 183,870 kWh/year (8.6 kWh/sq ft/year, or 30,000 Btu/sq ft/year of energy intensity), which is below U.S. average consumption for a small office bldg. One important factor for this office building is that it is a LEED certified and that might interpret its slightly lower use of electricity because it uses geothermal ground loops in HVAC heating and cooling.

In the study, the life cycle of the building was divided into 5 main phases: building materials manufacturing, construction processes, operation phase, maintenance, and demolition. Transportation of materials was included in each life-cycle phase through the software. The building materials phase included all of the transportation to the wholesaler warehouse. The construction phase included the transportation from the warehouse to the site.

1.2 Building Elements and Materials Phase

The following building systems categories were included in the study: foundation, structural frame (beams & columns), floors, external walls (envelope), roofs, and some internal elements e.g., doors, partition walls, and suspended ceilings. The amount of each material used in the building was derived from the bill of quantities generated by the software. However, building modeling was mainly based on input from architectural and engineering drawings, and the architect’s specifications. Around 30 different building materials were identified and modeled.

1.3 Building Construction Phase

The construction phase of the building included all materials and energy used in on-site activities. Data were modeled for the use of electricity, construction equipment, and transportation of building materials to the site (average 100 mi). Some of the data were collected from the architect, contractor, and were further confirmed on-site.

1.4 Building Operation Phase

The use of the building was divided into mainly heating service (by natural gas) and electrical consumption. For the purpose of energy simulation, the building was estimated to be used 55 hr/week for 60 years. Energy calculations were performed using eQuest 3.64, a DOE 2 energy simulation program for electricity use and HVAC heating and cooling loads. All building parameters (dimensions, orientation, walls, windows, etc) were modeled.

1.5 Maintenance and Retrofit Phase

The maintenance phase included all of the life-cycle elements needed during the 60 years of maintenance; use of building materials, construction activities, and waste management of discarded building materials. An estimated 75% of building materials was assumed to go to landfill, and 25% was assumed recovered for other purposes such as recycling.

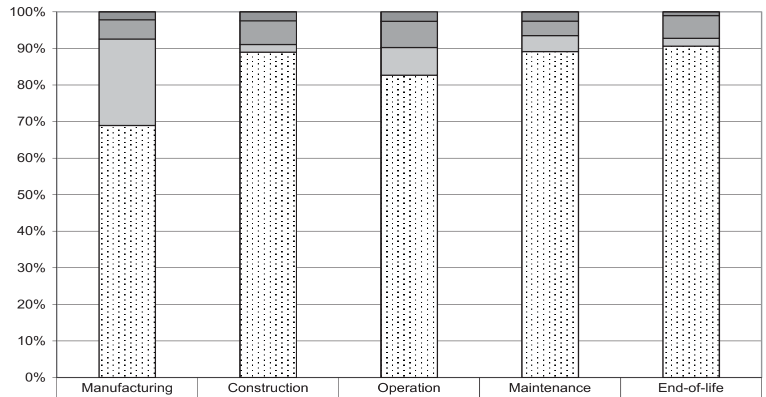
1.6 Demolition Phase

The demolition phase included demolition activities on-site, transportation of discarded building materials (75% of the total) to a landfill (100 mi), and shipping of recovered building materials to recycling site (100 mi, on average). The entire building was assumed to be demolished at end of its life.

2. RESULTS

Fig.1 shows the proportions of each life-cycle phase in every impact category with the associated numbers. Fuel consumption FFC in MJ has a notable 80% or more in 4 life cycle phases with exception in material manufacturing phase in which it constitutes 68% of the whole impact in that phase. This is consistent with most previous studies to show the significance of impacts due to fuel consumption. Global warming GWP seems to have a consistent ratio of 7% in all life phases. Resources use RU (kg) logically happens during manufacturing and represents 25% of impact in that phase and another 5% in the maintenance when some of building materials are replaced to adapt to future and new regulations. Acidification potential AP comes next to GWP at almost 3% in each phase. The study also found the summer smog impact POCP in the *manufacturing* and *operation* phases to be the largest contributor sharing the cause of smog formation at

40% and 50% respectively. This study along with very few others (Tekes 2000) discussed the potential of this important impact category.



	Manufacturing	Construction	Operation	Maintenance	End-of-life
Smog Potential (kg NOx eq)	1,398.294	161.184	1,202.575	309.748	32.072
Ozone Depl Potn'l (kg CFC-11 eq)	0.001	0.000	0.000	0.000	0.000
Eutrophication Potential (kg N eq)	204.840	6.977	67.430	20.432	1.405
HH Respiratory Pot'l (kg PM2.5 eq)	1,196.921	8.077	14,501.971	556.762	1.814
Acidification Potn'l (moles of H+ eq)	175,154.608	7,016.363	2,592,450.170	52,601.491	1,578.329
Global Warming Potn'l (kg CO2 eq)	424,850.162	18,582.554	7,167,320.013	81,907.481	9,958.732
Resource Use kg	1,914,690.199	6,047.485	7,616,817.736	90,918.010	3,413.710
Primary Energy Consumption MJ	5,586,223.336	257,074.704	82,983,906.872	1,857,422.684	144,929.029

Fig. 1: Environmental Impacts by Life Cycle Stage

3. INTERPRETATION OF RESULTS

During materials *manufacturing* phase, the greatest contribution to overall impacts in the manufacturing phase comes from the extensive use of energy (68%) in the manufacturing possess of the construction materials (steel, concrete, aluminum, glass, etc) that are required for construction. The resource depletion RU in this phase also represents 22% due to all virgin materials that are used and processed from the nature. GWP and AP represent the rest of the impacts at this phase at 10% mainly due to the releases from fossil fuel use in that phase.

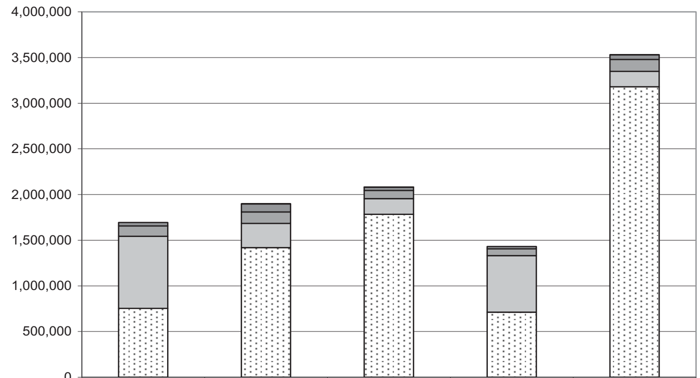
In *construction* phase, the use of construction equipment is the only life-cycle element with significant impacts (88%). That is due to the fuel and electricity used during the erection of the bldg. The other 10% attributed to GWP and AP with small fraction attributed to EP and Smog impacts.

The *operations* phase dominates life cycle energy consumption. Numbers show the building operational demands over a 60 year life span, representing 83% (82×10^6 MJ) of the total life cycle energy. Almost 90% of life-cycle impacts in the use phase caused by electricity and natural gas used for heating in cold climate like Michigan.

The *maintenance* phase comes third to operation and manufacturing in terms of life cycle impacts. This is the adaptation and modification phase where several parts of the buildings are replaced or renovated to match future codes and needs. Ozone Depletion Potential ODP, albeit almost negligible in the study, most of its causes are concentrated in the manufacturing and maintenance due to the VOCs released by paint manufacturing and the re-painting processes (every 7-10 years). The *end-of-life* phase does not have significant impacts in the overall life cycle, except for the Eutrophication category (2%) and Smog (4%). Transportation of the waste material to the landfill produces most of the impacts in this phase.

4. LIFE CYCLE IMPACTS BY BUILDING SYSTEMS

In practice the building design process typically proceeds by choosing building systems, not by chronological life-cycle phases. To interpret the results for the purposes of design management, an analysis of the result from the building assembly perspective has been performed.



	Foundations	Walls	Columns and Beams	Floors	Roofs
Smog Potential (kg NOx eq)	332.056	485.228	110.018	240.167	733.829
Ozone Depl Potn'l (kg CFC-11 eq)	0.000	0.000	0.000	0.000	0.000
Eutrophication Potential (kg N eq)	16.878	32.018	111.730	27.103	46.038
HH Respiratory Effects Potn'l (kg PM2.5 eq)	269.108	916.360	186.794	172.429	218.883
Acidification Potential (moles of H+ eq)	37,498.127	87,191.762	36,181.156	25,769.766	49,709.980
Global Warming Potential (kg CO2 eq)	114,390.026	125,834.761	90,013.128	73,189.859	131,871.155
Resource Use kg	788,919.885	265,856.129	172,308.960	620,503.241	167,481.191
Primary Energy Consumption MJ	753,049.237	1,417,895.559	1,783,170.886	711,331.734	3,180,202.337

Fig. 2: Environmental Impacts by Building Assembly

The life-cycle phases are divided into life-cycle elements, the elements belonging to different building assembly systems are grouped together. The life-cycle impacts of each building system; foundations, walls, structure (columns and beams), roofs, floors, are also modeled and calculated. Fig. 2 shows that the environmental impacts of the office life cycle are divided into 5 building assembly systems. Three significant systems accounts for the highest environmental impacts of this building. These are roof, structure (columns/beams), and the wall systems respectively. These results show energy consumption (embodied + transportation energy) as the most dominant impact category in the whole assembly (Fig.2). Resource use is the highest in foundations and floors systems due to the massive concrete weight and wide area both systems cover. GWP has more impact in roof and walls (due to insulation manufacturing emissions) than structure. Acidification AP is the highest impact in walls assembly due to some materials such as gypsum boards, fiberglass insulation, and vapor barriers which release SO2 and NOx during manufacturing that increase the AP impact category.

When breaking down the air emissions constituents of the case study, the findings also support previous results of high impact incurred by walls and roof systems, which share insulation as major component. Fig. 3 shows that more than 30% of the major air emissions are released by wall system and at lesser degree the roof system throughout the life cycle of the building

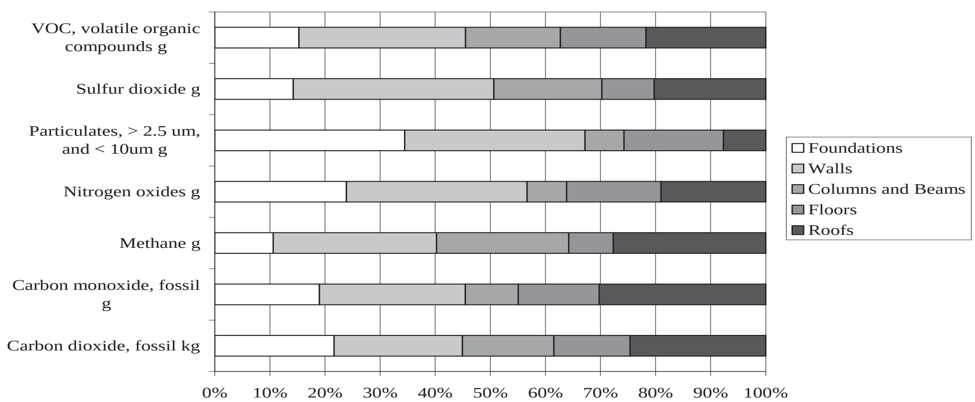


Fig. 3: Air Emissions by Building Assembly Systems

5. LEED VS. NON-LEED IMPACT COMPARISON

For a fair comparison between LEED vs. non-LEED buildings from previous studies, the results for all impacts in this study have been normalized per square meter of building area. Compared with a previous study (Ragheb, 2011b) using LCA to profile a non-LEED office building, the outcome showed that LEED building, in this study, performed environmentally better against non-LEED office building in the same climate zone 5 and with the same construction method (steel). The non-LEED building had more impact per sq. meter in all life cycle phases. For example, non-LEED scored 55% more in fossil fuel consumption FFC, 58% more in global warming GWP, 57% more in acidification AP, 22% more in Eutrophication EP, 5% more in smog POCP, 49% more in respiratory effect HHREP.

However, when comparing the environmental impacts of building assembly systems in this study to the previous study, it was surprising to find that the *roof system* in LEED building (Fig. 2) has almost double the impact of non-LEED building in most categories (FFC, GWP, AP, EP, POCP, HHREP). These results were primarily due to the increased roof insulation thickness to gain LEED points on energy reduction. The rigid insulation used (polyisocynurate), albeit high R-value per inch, has high embodied energy and releases huge emissions during manufacturing phase. Insulation also covers huge surface area (the entire roof and walls) to form the building enclosure. This surface area with increased thickness significantly increased the environmental burden of roof and wall systems. The other material responsible for this huge roof impact, is steel (with its massive embodied and transportation energy) in building structure. A third material (roof membrane) is found to contribute to roof impact at a lesser degree.

It is worth noting that a “what if” scenario analysis (LCA sensitivity analysis) in this study has been performed using alternatives to the existing materials in the LCA model. It showed total impact reduction of 6-19% in many categories if an alternative *expanded polystyrene* insulation (to achieve same R-value) is used in lieu of the polyisocynurate insulation. In addition, using a lighter color roof membrane (in lieu of the existing black EPDM rubber) also rendered 12% reduction in total impacts due to overall energy saving and lesser impact of such lighter membrane.

CONCLUSION

The purpose of the study was to show the relationship between LEED certification and LCA. It aimed to quantify and compare the potential environmental impact caused by an office building throughout life-cycle phases. The study examined the building assembly systems that most contribute to its life cycle impact. The study found that roof and wall systems to have significant environmental impacts due to the use of insulation and membrane materials. Using more environmental friendly materials can render a reduction 15% on average in different impact categories. Suggestions have shown the importance of LCA as tool to choose better alternatives during the design and maintenance (retrofit) phases of an office building.

LCA results demonstrated that the LEED certified building has significant lower energy consumption rate for an office building in the U.S. This is mainly due to using geo-thermal loop HVAC system during the operation phase in which most of the building impacts would occur. One shortcoming though was the use of tighter envelope and thicker insulation to gain LEED credits without considering the negative impact of using such insulation alternative (polyisocyanurate). This resulted in that the roof system of this LEED building had the highest impact in most categories even when compared to a non-LEED building from a previous study in the same climate. Using LCA method in this study opens the way for more testing of LEED certified buildings with high ratings e.g. gold or platinum using LCA impact analysis to verify their environmental performance. This helps to narrow down on the sensitive area of design and material choices (e.g. insulation, membrane) that LEED may fall short by awarding points for overall energy savings without looking at the significant environmental impact of material alternatives that achieve this saving.

One of the limitations of this study relates to the single-case study method used, because wider generalization based on a single case is not possible. However, the results of the study can be interpreted and compared with the results from previous LCA studies. The findings of this study support previous arguments that operation energy is a major environmental issue in the life-cycle of an office building. In addition, some building materials e.g. rigid insulation and roof membrane have significant impact. This is typical for an office building in the U.S. For other countries, it is more difficult to generalize findings based on the results of this study. There are many regional conditions used in the calculations that could affect considerably the results outside the U.S. Building design, intensity of materials, construction methods, and intensity of energy use in the operation phase differ. Most importantly, there are differences in electricity generation and energy use (grid mix); e.g. a higher proportion of coal is burned in the United States to generate electricity. Europe and Canada have a higher percentage of electricity from hydro power (almost no emissions) and non-fossil fuels. These relatively clean sources affect the final emissions especially the release of CO_2, SO_2, and Nitrogen Oxides (NOx) to air as major contributors to the impact categories previously measured. The study is also unique in modeling the building with the U.S. electricity grid which depends on coal as one major source at a relatively higher percentage of 31% (DOE, EIA 2016), which in turn render more air emissions than western Europe and Canada.

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Facilitating the WELL Building Standard through Wellness Programs in the Workplace

Facilitating the WELL Building Standard through Wellness Programs in the Workplace

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ABSTRACT: This study explores establishing a theoretical connection between wellness programs and the built environment based on the WELL Building Standard, aiming to identify affordable building strategies which can support wellness program implementation. First, this study outlines the process of building a wellness program designed under both U.S. regulations and programs designed by wellness program providers. Second, existing wellness programs are broken down by respective categories in the outlined structure. Third, the categorical concepts and criteria of the WELL Building Standard are arranged according to the established categories and programs. Fourth, overlaps between the subdivided wellness programs and the WELL Building Standard are compared to identified elements of existing wellness programs. Finally, this paper suggests the incorporation of the WELL Building Standard into wellness programs by changing the paradigm of the built environment from an environmental context to an active contributor to a wellness program.

KEYWORDS: Workplace, WELL Building Standard, Wellness Program, Health, Built Environment

INTRODUCTION

As public interest in health and well-being has increased and researchers have found a correlation between health and productivity of employees, various governmental, corporate, and organizational services have been developed to support increasing employees' health outcomes in the U.S. The U.S. government established regulations to release wellness programs[1] with additional small business support programs. However, the wellness program, as part of the governmental and corporate services, does not meet expectations of employee or employer because of (1) the associated increase of healthcare service costs, (2) the limit to eligible participants and program options, and (3) the absence of an integrated program approach rather than independent programs. These obstacles hinder the expected outcomes of wellness programs for participants. To improve the efficiency of wellness programs using existing resources and effort, this research suggests that the built environment is a medium which can reduce the burden of healthcare cost, expand the range of program participants, and connect currently independent services. Americans spend 90% of their time in indoors[2] and it is not generally an option to eliminate the built environment from daily work life. In 2014, the International Well Building Institute launched the WELL Building Standard, which assesses each element of the built environment by exploring the impacts of built environment strategies to improve the human health and wellness. This research explores how the WELL Building Standard can be a medium for connecting the built environment securely with wellness programs.

1.0 LITERATURE REVIEW

1.1. Context in Health Economics

In a healthcare system model (Santerre R.E. and Neun S.P. 2010), the three major players are *Patients*, *Healthcare providers*, and *Insurers*. These three players interact through transactions with a minor player, the *Sponsor (Employers or Governments)*. Since 2005, the Consumer Price Index (U.S. Bureau of Labor Statistics) has been surpassed by health care inflation (except 2008[3]), while the average health insurance premium increase for singles and families has overwhelmed the real personal income inflation index[4] in the U.S. As a result, *Patients* have two options for insurance: either pay the increased premiums or accept lowered health insurance coverage. In this context, academic researchers and organizations have warned of potential risks which are (1) a Gross Domestic Product(GDP) decline when the health of working population fails and (2) a National competitiveness decline because the health care cost is a large part of GDP[5]. When *Patients* are continuously burdened or unprotected in terms of their health, a governmental or corporate intervention is thought to be needed to preserve the public health levels, especially in the working population.

1.2. Wellness Programs in the U.S.

Wellness programs appeared as a part of a governmental and corporate intervention to address this issue. Though the first wellness program appeared in the 1700s (Pheasant S. 1991), the current conceptualization of a wellness program, which covers not only health promotion plans but also health education, a supportive social and physical work environment, and the integration of the program into the administrative structures, related programs, and screening programs, was established in 2000 by the United States Department of Health and Human Services. To help control the increase of healthcare costs, the U.S. government also established wellness program regulations, which include the Affordable Care Act (ACA) (U.S. Department of Labor 2014), Americans with Disabilities Act (ADA) (U.S. Equal Employment Opportunity Commission 2016), and Genetic Information Nondiscrimination Act (GINA) (U.S. Equal Employment Opportunity Commission 2016), to enhance wellness programs with the goal to improve employee health. As these regulations have been implemented, employers have offered wellness programs to their employees (Jame J. 2013) in collaboration with health insurance providers, structuring rewardable wellness programs at an organization level. Health insurance providers have also developed technology-based incentive programs for implementation at an individual level[6], often using wearable devices.

Many of these implementations received negative feedback. For example, 85% of large firms, which hire more than 200 employees, and 58% of small firms, with 3 to 199 employees, offer at least one specific wellness program to their employees, such as programs to stop smoking, weight loss, or behavioral coaching (Claxton C., Rae M., Long M., and Damico A. 2017, 195). While it appears that many people benefit from wellness programs, small businesses account for 99% of U. S. business. Because smaller firms are less likely to offer programs, this means that there are actually relatively few participants in wellness programs (U.S. Small Business Administration 2017). Even though the U.S. Centers for Medicare & Medicaid Services has offered grants to support wellness programs and promote the benefits of wellness programs to small firms since 2010, the small firms have still hesitated to offer wellness programs because of associated financial and administrative costs[7]. Moreover, programs offered in large firms see limited and low participation rates[8] (Mattke, S. et al 2015). Even further, only 44.1% of employees participating in wellness programs have wearable devices to monitor their health information, and documenting whether or not the requirements of their wellness program are achieved (Springbuk 2017, 4). Organizations hesitate to introduce wellness programs requiring wearable devices because of the invalid and unstable data gathered from these devices (Ledger D., McCaffrey, D. 2014, 4), despite being the primary method by which many of these programs are monitored.

1.3. The WELL Building Standard: a Building Certification for Health

Since 1993, the U.S. Green Building Council (USGBC) has been managing the Leadership in Energy and Environmental Design (LEED) certification for the built environment, which adopts a performance-based approach to achieve occupant comfort and system efficiency. In 2014, by collaborating with USGBC and adapting part of LEED, the International Well Building Institute (IWBI) launched the WELL Building Standard. The WELL Building Standard has 8 concepts: Air, Water, Nourishment, Light, Fitness, Comfort, Mind, and Innovation. It outlines 105 criteria related to wellness and 11 body systems: cardiovascular, digestive, endocrine, immune, integumentary, muscular, nervous, reproductive, respiratory, skeletal, and urinary. This certification focuses on developing healthier buildings, fundamentally prioritizing occupant health. Also, it allows people to measure health and wellness strategies in the built environment based on a systematic approach (IWBI 2017). Since all established criteria have target conditions and references, the purpose of each credit can be identified focusing on employee's health, absenteeism, and productivity. Furthermore, according to the WELL system, users can understand what criteria were achieved in a certified building; the building performance in continuously tracked after occupancy. However, a WELL-certified building owner is required to pay for continued monitoring. Even though there is research addressing the return on investment and importance of WELL-certified buildings (ALPIN LIMITED[9] 2017, Barth B. 2015, and Cortese A. 2016 Nov., 69), the financial and administrative costs of the system are seen as obstacles to obtaining the WELL certification for buildings.

To compensate for criticisms to the wellness programs and the financial issue of the WELL certification, the built environment can be explored as a medium, because everyone experiences it daily. If the built environment scale can be used to facilitate a wellness program, it is possible (1) to offer a wellness program regardless of the size of the company, which reduces the restriction on individual participation in the program, (2) to provide valid data regularly and continuously in comparison to wearable devices, (3) to achieve eventual administrative cost savings as employers are able to integrate wellness program costs into operation and maintenance costs for buildings, and (4) to judge the value of wellness programs and the WELL Building Standard by ROI not only from the developer's perspective but also from the healthcare and insurance systems. Finally, this approach at the built environment scale allows us to uniformly promote wellness programs and the WELL Building Standard for the employee's health.

2.0 CONCEPTUAL FRAMEWORK AND RESEARCH QUESTIONS

2.1. Theoretical Perspective

According to the Oxford dictionary, the definition of the built environment is *"Man-made structures, features, and facilities viewed collectively as an environment in which people live and work."* Since the built environment is a tangible space for physical activity, it influences a person's behavior (Centers for Disease Control and Prevention 2011). Therefore, designing and zoning spaces can promote a healthier environment and lift the quality of life up for all (Roof K., Oleru N. 2008). The approach to the built environment has been shifted from of tangible spaces to also include intangible consequences from these spaces (Kuhn T. 1970).

By exploring an arrangement of wellness at the built environment scale, this research uses a paradigmatic innovation approach (Wang and David 2013, 387) to use the built environment as a medium between the wellness program and the WELL Building Standard, aiming to increase the health and productivity of employees. To function as the medium, the built environment is needed to engage not only the WELL Building Standard but also the wellness program system. The wellness program is a part of the health care system because the program was started to mitigate the cost of healthcare inflation. Under this framework, the built environment can be an integral part of a wellness program system when it addresses the WELL Building Standard and shares the goals of wellness programs. Once recognized as a part of the wellness program framework, the built environment can promote and provide a healthier workplace.

2.2. Conceptual Framework

Hillier and Hanson (1984) analyzed space by establishing a linear concept of space for understanding social relationships based on spatial structure. This model enables a transition between a physical space structure and a social network structure by creating hierarchical connections between occupants in each room. This linear structure can also illustrate the relationship between wellness programs, the built environment, and the WELL Building Standard. Though these three elements start separately, wellness programs and the WELL Building Standard move closer to built environment by sharing design strategies and activities found in the built environment. Then, the designed and programmed elements can support employee health and productivity which achieving cost saving and expanded opportunity to promote both wellness programs and WELL certification.

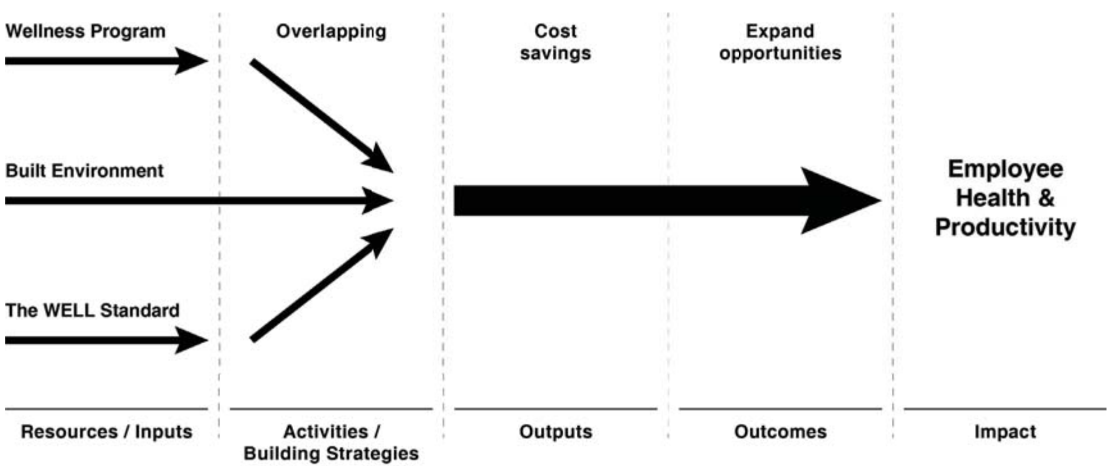

Figure 1: A Framework to Incorporate Wellness Programs, Built Environment, and the WELL Building Standard

A logic model is beneficial to systematically show a process of a program (W.K. Kellogg Foundation 2004). The model shows phases of Resources/Input, Activities, Outputs, Outcomes, and Impact. Each phase identifies a part of the considerations what reference should support each phase. In this research, the wellness program, built environment, and the WELL Building Standard are located in the resources/inputs phase of the program. To achieve the goal of reducing operation and maintenance costs while expanding opportunities to participate in wellness programs or promote the WELL certification, this paper concentrates on the Activities phase and investigates overlapped areas of wellness programs, the built environment, and the WELL Building Standard.

2.3. Research Objective

This exploration is to propose the WELL Building Standard as a part of a wellness program in the workplace by using the built environment as a medium. This paper theoretically explores a way to save on administrative costs and expand opportunities to participate in the wellness program for employee health and productivity by incorporating wellness programs and the WELL Building Standard in the built environment, aiming to identify supportive roles of built environment elements for wellness programs. Therefore, this paper illustrates (1) the process of developing a wellness program; (2) exemplary sub-programs offered by industry leading companies; (3) the WELL Building Standard criteria matched with the identified exemplary sub-programs; and (4) overlapped, aligned, or overarching parts of wellness programs and the WELL Building Standard. Finally, this paper proposes a new approach to synergize building certification criteria and wellness programs based on the built environment.

2.4. Research Scope

This exploration is the first part of a larger research to develop an actual wellness program based on the built environment, as well as shifting the paradigm of the built environment from architectural material to healthcare system. This paper illustrates the built environment as a method for synthesizing the WELL Building Standard and wellness programs and supports a paradigm shift to set the foundation of wellness program development. To achieve the development of actual wellness program based on the built environment, the subsequent research will cover the program feasibility with corporate partners.

2.0 STUDY METHODOLOGY

3.1. Research Design

This research uses a linear structure analysis and logic model. First, this study outlines the process of building a wellness program by considering program categories from both regulations and program operators. Second, information on exemplary wellness programs is collected. Third, the collected exemplary wellness programs are broken down according to the previously determined categories and programs. Fourth, the categorical concepts and criteria of the WELL Building Standard are arranged to align with the elements outlined in wellness programs. Here, overlaps between the subdivided wellness programs and WELL Building Standard illustrate applicable criteria of the WELL Building Standard to support wellness programs, comparing each element in the outlined data.

3.2. Research Samples

3.2.1. The U.S. Health and Medical Insurance Industry

In health and medical insurance in the U.S., there are five major companies: UnitedHealthcare Inc., Anthem Inc., Aetna Inc., Humana Inc., and Cigna Corporation. The sum of market share by these companies is 56.7% of the industry (Curran J. 2017). This study assumes that these companies represent the industry and are appropriate samples of the insurers' population. Therefore, the five companies' wellness programs are used as the industry standardized samples.

3.2.2. The U.S. Corporate Wellness Services Industry

In the U.S. corporate wellness service industry, there are only four companies who have a market share of at least 1%: ComPsych, OptumHealth Inc., ValueOptions Inc., and Ceridian HCM Inc. The sum of market share by those companies is 14.1% of the industry (Turk S. 2016). Because of the low market share, this study does not use these major companies' products and services as samples. Instead, this study assumes that the products and services found in the market represent the industry. Therefore, the representative products and services seen in the industry are used as the industry standardized samples: Health Risk Assessments (HRAs), Nutrition and weight management, Smoking cessation, Fitness services, Alcohol and drug abuse services, Stress management, and Health education services.

3.3. Data Collection

To outline the process of building a wellness program, understanding how to implement a wellness program is needed. Establishing and designing a wellness program uses the guidance of the Centers for Disease Control and Prevention (CDC), the Equal Employment Opportunity Commission (EEOC), and the Health Insurance Portability and Accountability Act (HIPAA) by incorporating the regulations of ACA, ADA, and GINA which were previously discussed. These regulations were collected from each organization's web page. For exemplary wellness programs, the web pages of five sample companies in the insurance industry were used, as well as the corporate wellness service industry's seven representative products and services from IBISWorld industry report (Turk S. 2016). The WELL Building Standard information was gathered through the recent The WELL Building Standard reference guidebook (IWBI 2017).

3.4. Data Analysis

To achieve the goal of this research, first it is required to understand the process of establishing and designing a wellness program under the regulations and organizations' guidelines: CDC, EEOC, HIPAA, ACA, ADA, and GINA. Then the regulations are arranged into principle categories of wellness programs for regulated purposes. Under these categories, the exemplary industries' products and services are categorized. Next, the WELL

Building Standard's concepts and criteria are also categorized under the exemplary programs into the previously determined categories. Finally, the organized structure illustrates what elementary of wellness programs overlap. Based on these analyses, this research suggests how the wellness programs and the WELL Building Standard can be better incorporated through support of the built environment.

3.0 FINDINGS

4.1. Design Process of Wellness Programs

Each wellness program is designed by each employer by considering the specific context of their workplace, so there is no standard program structure. In this context, there are several guidelines[10,11,12] for how to design a wellness program, even though there is no comprehensive regulated process. The guidelines have common cores of process: research, planning, implementation, and evaluation. Applying the above elements to the logic model, research is aligned with resource/inputs, planning is aligned with activities, implementation is aligned with outputs, and evaluation is aligned with outcomes. As stated in Section 2.2, this paper investigates how the wellness program and the WELL Building Standard might work together in the built environment.

4.2. Categories of Wellness Program

The wellness program, under ACA regulation, is categorized into three categories: "Participatory", "Activity-only Health-contingent", and "Outcome-based Health-contingent". The "Participatory" wellness program is determined by the character of programs whether to participate in a program without activity such as a health assessment. The "Activity-only Health-contingent" wellness program is an activity-based program without required achievement such as running regularly. The "Outcome-based Health-contingent" is an activity-based program with a goal such as steps per day or BMI reduce rate. However, by using the WELL Building Standard, some programs could use both Activity-only or Outcome-based Health-contingent programs. Because the WELL Building Standard includes invisible condition measurements such as Air Quality, Toxic Management, or Right Lighting Design, the Activity-Only Health-Contingent program can be proved with quantifiable data through the WELL Building Standard. For example, a stress management program is categorized into the Activity-Only Health-Contingent Program, since the program is operated by education or counseling. However, the WELL Building Standard can provide measurable alternatives such as sound masking to reduce noise or thermal comfort based on "79 SOUND MASKING" (IWBI 2017, 127). In detail, the strategy prevents negative influence on Immune nervous, which is affected by excessive stress, through reducing acoustic disruptions and increasing speaking privacy. Furthermore, the strategy established a quantifiable metrics to determine a proper acoustics condition with reference (U.S. General Services Administration Center for Workplace Strategy Public Buildings Service 2012; Loewen LJ and Suedfeld P. 1992; Jensen KL et al 2005). Therefore, a new category of "Both of Activity-only or Outcome-based Health-contingent program" would be useful to expand opportunities to promote wellness programs.

4.3. Exemplary Wellness Programs

According to CDC, EEOC, and HIPAA, the standard of wellness programs is designated and occurred by industries. According to Employer Health Benefits: Survey 2017, the majority of large firms offers six wellness programs: health risk assessments, biometric screening, administration of health screening programs, wellness and health promotion programs, disease management, and penalties for tobacco use (Claxton C., Rae M., Long M., and Damico A. 2017, 182). This research selected two industries to investigate exemplary wellness programs. In the U.S. corporate wellness services industry, there are seven exemplary wellness programs: Health Risk Assessments (HRAs), Nutrition and weight management, Smoking cessation, Fitness services, Alcohol and drug abuse services, Stress management, and Health education services. In the U.S. health and medical insurance industry, there are thirteen exemplary wellness programs: Health assessment, Cholesterol, blood pressure, and body mass index (BMI), Medical history and health status monitoring, Financial management, Women's health care, Fitness center discount, Educating and suggesting the treatments for disease, Sleeping counseling, Safety and prevention, Tobacco-free, Exercise programs, Stress-management counseling, and Diet control. These programs are used as the focus of this analysis.

4.4. The WELL Building Standard Criteria Related to the Wellness Program

Among the eight concepts and 105 criteria of the WELL Building Standard, seven concepts and 69 criteria share goals or activities with the selected exemplary wellness programs. By WELL concepts, Air has 13 of 29 credits that share goals; Water has 6 of 8; Nourishment has 15 of 38; Light has 7 of 11; Fitness has 8 of 8; Comfort has 12 of 12; Mind has 8 of 17. These criteria which are shown in Figure 2. Because these 69 criteria also contain every Precondition for the WELL certification or credits that must be addressed, the wellness program can support a WELL certified built environment. Conversely, a WELL certified building can offer 69 activities to support wellness programs without any additional implementations. Furthermore, because the WELL certified building should be recertified every three years, the WELL certification can guarantee the wellness programs. Moreover, with the guarantee of WELL certification, the wellness programs can save the evaluation and administrative cost.

Program Categories		Corporate Wellness Services Industry	Health and Medical Insurance Industry	The WELL Building Standard Concepts	The WELL Building Standard Criteria No.
Participatory		Health Risk Assessments (HRAs)	Health assessment	-	-
			Cholesterol, blood pressure, and body mass index (BMI)	-	-
			Medical history and health status monitoring	-	-
		-	Financial management	-	-
		-	Women's health care	-	-
		-	Fitness center discount	Fitness	64
Health-contingent	Activity -only	Alcohol and drug abuse services	Educating and suggesting the treatments for disease	Nourishment	39, 40, 42, 43
		Health education services		Fitness	66, 68
				Mind	84
		-	Sleeping counseling	Mind	90
		-	Safety and prevention	Air	1,4,5,6,8,10,13, 17, 18, 22, 23, 25
		-		Nourishment	41, 46, 49, 50, 51
		-			
		-		Light	53, 54, 55, 56, 57, 59, 61
		-		Comfort	72, 73
		-		Mind	85
		-		Water	30, 35, 36
		-	-	Fitness	67, 69, 70, 71
	Outcome -based	Smoking cessation	Tobacco-free	Air	2
	Both of activity or outcome -based	Fitness services	Exercise programs	Fitness	65
		Stress management	Stress-management counseling	Comfort	74, 75, 76, 77, 78, 79, 80, 81, 82, 83
				Mind	86, 87, 93, 95, 99
		Nutrition and weight management	Diet control (BMI or not)	Nourishment	38, 44, 45, 47, 48, 52
				Water	32, 33, 37

The WELL Criteria related to the wellness programs

01 Air quality standards, 02 Smoking ban, 04 VOC reduction, 05 Air filtration, 06 Microbe and mold control, 08 Healthy entrance, 10 Pesticide management, 13 Air flush, 17 Direct source ventilation, 18 Air quality monitoring and feedback, 22 Pest control, 23 Advanced air purification, 25 Toxic material reduction (Air), 30 Fundamental water quality, 32 Organic contaminants, 33 Agricultural contaminants, 35 Periodic water quality testing, 36 Water treatment, 37 Drinking water promotion (Water), 38 Fruits and vegetables, 39 Processed foods, 40 Food allergies, 41 Hand washing, 42 Food contamination, 43 Artificial ingredients, 44 Nutritional information, 45 Food advertising, 46 Safe food preparation materials, 47 Serving sizes, 48 Special diets, 49 Responsible food production, 50 Food storage, 51 Food production, 52 Mindful eating (Nourishment), 53 Visual lighting design, 54 Circadian lighting design, 55 Electric light glare control, 56 Solar glare control, 57 Low-glare workstation design, 59 Surface design, 61 Right to light (Light), 64 Interior fitness circulation, 65 Activity incentive programs, 66 Structured fitness opportunities, 67 Exterior active design, 68 Physical activity spaces, 69 Active transportation support, 70 Fitness equipment, 71 Active furnishings (Fitness), 72 Accessible design, 73 Ergonomics: visual and physical, 74 Exterior noise intrusion, 75 Internally generated noise, 76 Thermal comfort, 77 Olfactory comfort, 78 Reverberation time, 79 Sound masking, 80 Sound reducing surfaces, 81 Sound barriers, 82 Individual thermal control, 83 Radiant thermal comfort (Comfort), 84 Health and wellness awareness, 85 Integrative design, 86 Post-occupancy surveys, 87 Beauty and design I, 90 Healthy sleep policy, 93 Workplace family support, 95 Stress and addiction treatment, 99 Beauty and design II (Mind).

Figure 2: Comparison of Wellness Programs and the WELL Building Standard.

4.5. Degrees of Matching: Overlapped, Aligned, or Overarching

In analyzing overlaps between wellness programs and the WELL Building Standard, three different types of relationships become apparent: overlapped, aligned, and overarching. First, the overlapped relationship is when an implementation of both wellness programs and the WELL Building Standard are the same, such as the Fitness Center Discount program in wellness programs and Fitness Activity Support criteria in the WELL Building Standard. Second, an aligned relationship is when the two share aligned goals, but the implementation is different. For example, a tobacco-free program seen in wellness programs and the Smoking Ban requirement in the WELL Building Standard both aim to stop smoking at the individual level. But, the WELL requirement establishes a smoking ban area, prohibiting smoking while using peer motivation. Last, the overarching relationship is a case in which one implementation encompasses other implementations. For example, the nutrition management program in wellness programs and the Nourishment and Fitness concepts in the WELL Building Standard show an overarching relationship. These outcomes are typically judged by a change in BMI or the frequency of eating a salad. But the WELL Building Standard controls the menu of cafeteria, nutrition, water quality, availability of workout, and so on. Through the segmented investigation of matching relationships, this study illustrates how wellness programs can become richer and more effective by utilizing the built environment.

CONCLUSION

This paper aims to support wellness programs through use of the WELL Building Standard by shifting the paradigm of the built environment as merely a physical setting to an active contributor in wellness programs. This research illustrated the design of wellness programs, exemplary wellness programs, the WELL Building Standard criteria overlapped with wellness programs, enlighting the possibilities of integrating wellness programs and the WELL Building Standard in the built environment. As a result, by applying the WELL Building Standard into wellness programs, (1) a new category "Both of Activity-only or Outcome-based Health-contingent program" should be created in the wellness program categories, (2) the seven concepts and 69 criteria of the WELL Building Standard are matched with exemplary wellness programs, (3) the overlapped goals or activities with the exemplary wellness programs are identified, and (4) various alternatives are provided to wellness programs in the built environment. Therefore, shifting the contribution of the built environment in the wellness conversation by incorporating the WELL Building Standard and wellness programs is feasible and worthwhile. In the future, this research can be expanded by including the other building certifications such as the Living Building Challenge and Fitwel, and exploring economic feasibility and actual implementational validity.

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ENDNOTES

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Resilient & Affordable Housing for the US Gulf Coast: Earthen Building Materials Re-appropriated for Use in Hot Wet Climates

Resilient & Affordable Housing for the US Gulf Coast:
Earthen building materials re-appropriated for use in hot wet climates

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ABSTRACT:

Objective:
Southern Louisiana is currently under great pressure to increase the quantity of resilient and affordable housing available within its local communities. Can earthen building mediums traditionally used in hot dry climates be re-appropriated for use in hot wet climates to help address this need?

Methodology:
In our current period of climate change, unpredictable events have and will continue to displace thousands of residence in the coastal region of Louisiana. This historic unseating of entire communities necessitates a reconsideration of standard housing solutions. Constructed primarily of materials accessible from the building site, compressed stabilized earth block design and building techniques offer an economical and sustainable approach to the current increase in demand for weather resistant housing.
To investigate the composition of earthen material in Southern Louisiana, a United States Geological Survey soil classification map and chart were consulted to identify locations of different regional soil types. Several locations in the area proved to be potential sites being composed of material that fell within the guidelines for soil compositions suitable to making compressed stabilized earth blocks. Forming the tested soil into earth blocks was realized by fabricating a manual block press to produce the 10” x 6” x 3” modules. Varying mixtures with differing percentages of cement, the stabilizing agent, were formulated to test how the stabilizer influenced the blocks strength and durability. After curing for 28 days, blocks were tested for resistance to compressive and tensile forces with successful results in line with building regulations of hot dry areas.

Achieved outcomes:
In response to the need for affordable, climate responsive, housing in coastal Louisiana single-family prototype designs were then developed using compressed stabilized earth blocks as the primary construction element. The critical demand for housing in regions around the gulf coast has been recently documented in the article, *Resettling the First American ‘Climate Refugees’* by Coral Davenport and Campbell Robertson published in the New York Times on May 3rd 2016. The article, focusing on Isle de Jean Charles located along the Louisiana gulf coast, details the experience of resettling local residents due to flooding. Unfortunately, this phenomenon of water inundation is more than an isolated event. In August 2016 thousands of residents across southern Louisiana were displaced by severe flooding, a likely outcome of climate change. The need for affordable housing for the numerous families driven out of their homes, as well as for other low-income families, is an essential and pressing concern for the region.

Through the novel use of engineered earth blocks in a hot wet environment and an awareness of local contextual parameters, the prototype designs offer an affordable, resilient, and sensitive way to bring about housing for the many individuals in need. From our research we have concluded that it is feasible to re-appropriate earthen building materials found in hot dry climates to construct enduring structures responsive to a hot wet environment.

KEYWORDS: Affordable, Sustainable, Housing, Climate-Change

1.0 OBJECTIVES:

The US Department of Housing and Urban development recently published data showing that almost 400,000 low-income households in Louisiana are in need of affordable housing (LHFA. 2010). The critical demand for housing in regions around the gulf coast has been recently documented in the article, *Resettling the First American 'Climate Refugees'* by Coral Davenport and Campbell Robertson published in the New York Times on May 3rd 2016. The article, focusing on Isle de Jean Charles located along the Louisiana gulf coast, details the experience of resettling local residents due to flooding. Unfortunately, this phenomenon of water inundation is more than an isolated event. In August 2016 thousands of residents across southern Louisiana were displaced by severe flooding, this disaster impacted entire neighborhoods and caused an enormous financial hardship at both a state and local level. To this day, many individuals forced out of their home due to the flooding have yet to return to adequate living conditions. The need for affordable housing for the numerous families driven out of their homes after natural disasters is an essential and pressing concern for the region. Southern Louisiana is currently under great pressure to increase the quantity of resilient and affordable housing available within its local communities, not only in response to population displacement after severe hurricane events, but also for large portion of the low-income families that cannot afford adequate housing at the current marketplace cost. Can earthen building mediums traditionally used in hot dry climates be re-appropriated for use in hot wet climates to help address this need?

2.0 METHODOLOGY:

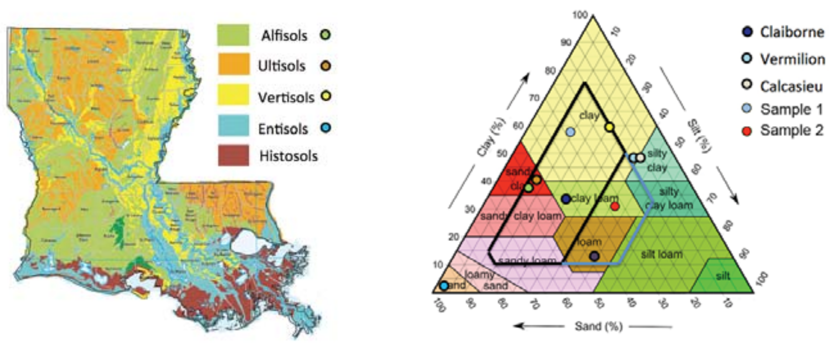

Figure 1: Louisiana soil textural classification map (left) and soil composition chart (right). Source: (US Dept. of Agriculture)

2.1. Soil composition

To investigate the composition of earthen material in Southern Louisiana, a US Dept. of Agriculture soil classification map and chart were consulted to identify regional soil types and compositions (Fig.1) (USDA 1999). A further understanding of the ground makeup was achieved by collecting samples from depths of 40 to 80 inches. It was necessary to extract the soil from this depth to ensure a uniform consistency of the material and minimize the amount of organic components. These samples were analyzed by performing cigar and jar tests to see if the soil possessed the necessary qualities to be made into earth blocks (Fig. 2) (Kumar et al. forthcoming 2018). Following successful testing, additional lab tests were undertaken to further analyze the suitability of the soil. The results from both sieve and hydrometer testing substantiated that the soil was composed of material that fell within the guidelines for soil compositions suitable to making compressed stabilized earth blocks (Fig. 2) (Kumar et al. forthcoming 2018).

Figure 2: Soil sample analysis: cigar test (left), sieve test (center), and hydrometer test (right). Source: (Author)

2.2. Modular components

Forming the tested soil into earth blocks was realized by fabricating a manual compression block press capable of producing 10” x 6” x 3” modules. The press was constructed of plate steel to withstand the forces exerted when compacting the soil. A cam mechanism was used to compress the soil when the lever was positioned to one side and then lift the compressed block from the mold when positioned on the other side. The press design was modified several times in response to performance demands and safety concerns. Fabrication of the blocks was a multi step process including preparing the soil, mixing ingredients, pressing the materials, and curing (Fig. 3). Soil preparation followed a process of removal from the site, dehydration for several days in a conditioned environment, crushing to a relatively fine grain, and then passing it through a 1/4” screen to achieve a particle like consistency. All materials were weighed, measured, and recorded in preparation of specific ratios. The idea was to develop several unique mixes that could be tested for comparable strengths and weaknesses at a later time. An electric concrete mixer evenly unified the three main ingredients: soil, cement, and a reactive agent. The mixture was then placed into the press and compressed into the module block form and lifted out with the cam action of the machine. Varying mixtures with differing percentages of cement, the stabilizing agent, were formulated to test how the stabilizer influenced the blocks strength and durability. Post fabrication the blocks were cured using both the covered wet and open-air dry methods.

Figure 3: Multi-step compressed stabilized earth block fabrication process. Source: (Author)

2.3. Component Testing

After curing for 28 days, the blocks were tested for resistance to compressive and tensile forces in a controlled environment (Kumar et al. forthcoming 2018). Using consistently calibrated lab equipment, the blocks of varying cement content were mechanically put under pressure to determine their average strength. In addition, each of the block types were tested in a dry state and after an extended exposure to moisture. The minimum strength requirements stipulated in the New Mexico code were used as a standard to evaluate the results (NMAC 2009). Blocks with around 10% cement composition produced successful results that fell in line with the building regulations used in hot dry areas (Kumar et al. forthcoming 2018).

Figure 4: Earth block wall components and construction: earth blocks (right), wall during construction (center), and completed wall (right). Source: (Author)

2.4. Component Assemblies

To better understand how the blocks would perform over time in the hot wet climate of the Mississippi Delta, a wall measuring 48” x 36” x 6” was built on an exterior concrete foundation running from the east to the west (Kumar et al. forthcoming 2018). Made of 40 blocks, the constructed earth wall was 10 rows of 4 blocks each and bound together with a mortar mixture of soil and cement similar to the block composition (Fig. 4). After construction, half of the blocks in the wall were left exposed to the natural weather conditions and half were protected from the environment with a 1/16” thick cement coating. The wall construction was openly exposed to the natural weather conditions for a period of six months, enduring several severe storms with heavy rain and high winds (Fig. 5). On a weekly basis, the wall was inspected and photographs were taken to develop a comparative weathering analysis over time. After the exposure period, the coated side of the wall remained structurally intact with no degradation. The unprotected blocks experienced some surface erosion with the top course and connective mortar showing the most wear. To test the structural strength of the blocks after exposure to the weather, the wall was disassembled and the blocks from both sides were reanalyzed in the testing lab. The results revealed that the protected blocks actually gained strength over time, as the soil-cement mix continued reacting (Kumar et al. forthcoming 2018). After testing blocks exposed to the climate and local weather conditions, compressed stabilized earth blocks appear to be a building material suitable to the rigorous demands of a hot wet environment if a proper protection is provided.

Figure 5: Earth block wall weathering, one month (left) & six month (right) durations. Source: (Author)

2.5. Housing

In response to the need for affordable, climate responsive, housing in coastal Louisiana, single-family prototype designs were developed using compressed stabilized earth blocks as the primary construction element. A thorough precedent analysis was developed in the goal of understanding community values and standards. In appreciation of the rich cultural heritage and environmental context of the gulf coast, the prototype housing designs embrace many qualities inherent to local vernacular architecture. The vernacular architecture, made up of Creole and Acadian influences, presents a heritage of building types composed of common elements that evolved from living in a hot wet climate (Edwards 2004). Fundamental aspects, incorporated into the housing designs, include deep porches, high ceilings, floor to ceiling openings, raised ground floors, and program specific room volumes all help to facilitate air movement by means of passive cross ventilation. Multiple design iterations were explored developing both traditional and non-traditional organizational compositions composed with the vernacular components.

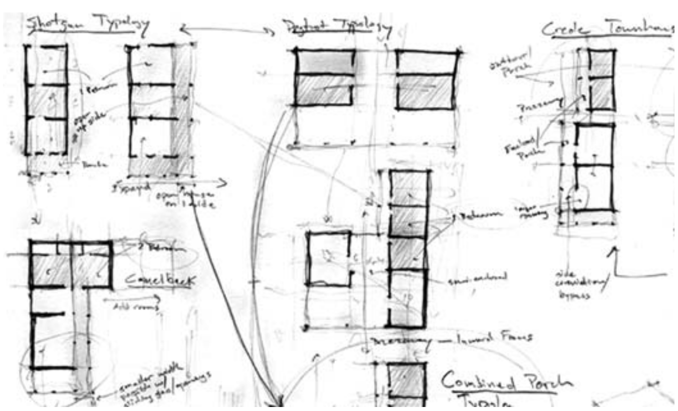

Figure 6: Precedent analysis and iterative design process sketches. Source: (Author)

2.6. Architectural typologies

Two significant housing types, the shotgun and the dogtrot (Edwards 2004), which utilize passive ventilation systems, were influential in the design of the single-family prototypes. Both the shotgun and dogtrot typologies have evolved from traditional regional influences and offer relevant design strategies for living in the local environment. These housing types represent optimal solutions to obtain comfortable dwellings through natural airflow even in the hot humid weather of Southern Louisiana. The shotgun type, based on customs of the Creole citizens who migrated from Haiti, has an organization based on 3 to 5 rooms in a row. The linear arrangement allows for efficient cross ventilation in every room. The main body of the shotgun type has an added outward facing porch that acts as a place of social meeting in urban communities. The dogtrot type, based on customs of the Acadian who stemmed from Nova Scotia, has an organization based on a central porch flanked by public living spaces on one side and private on the other. The central arrangement provides a space for air to flow thru and ventilation for adjacent rooms. The mass of the dogtrot type has a recessed, inward facing porch that functions as a private social space in less dense rural communities. Gradually developing over a century, both typologies are housing models familiar to and accepted by the local communities.

Figure 7: Dogtrot (left) and shotgun (right) housing prototype renderings. Source: (Author)

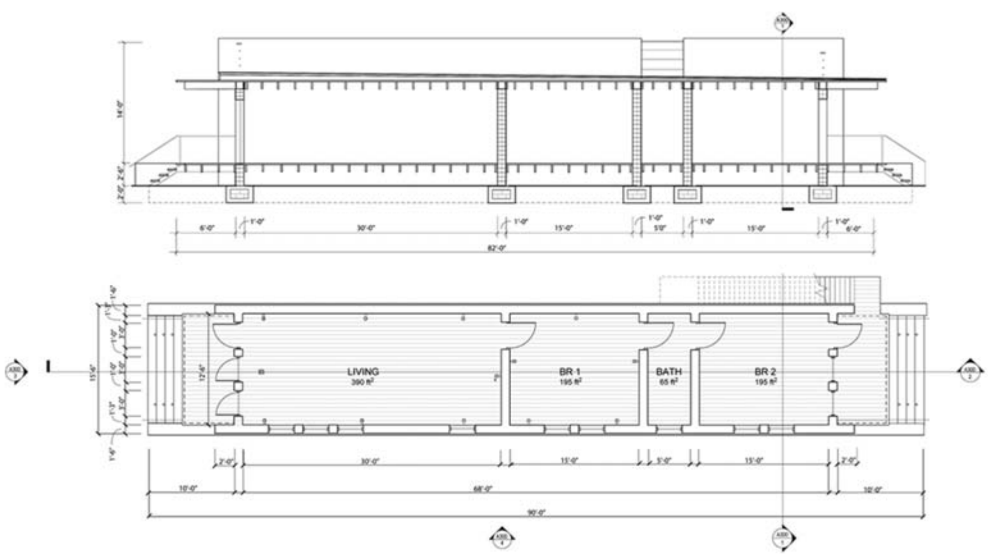

Figure 8: Shotgun housing prototype plan (bottom) and section (top) drawings. Source: (Author)

2.7. Architectural parameters

The architectural parameters of both housing prototype designs have several similarities. Each prototype is based on a single-family program of around 1000 square feet on one level with an interior volume of 10 to 12 feet in height. They are composed of a main living area, kitchen, bathroom, two bedrooms, and outdoor porches. Beyond these equivalent features, unique characteristics of the housing designs were developed based on specific contextual qualities. The urban prototype, influenced by the shotgun typology, has a long thin linear arrangement with minimal frontage following the organization of dense inner-city land allotment (Fig. 7). The rooms are organized in a straight line one after the other entering on the living area then proceeding to the kitchen, first bedroom, bath, second bedroom, and then exiting to a small exterior space in the back (Fig. 8). A covered exterior porch faces the street and is open on the sides to promote social interaction with city residents and adjacent neighbors. The rural prototype, influenced by the dogtrot typology, has a boxy rectilinear arrangement with an expansive frontage following the wide-open qualities of a sprawling pastoral countryside (Fig. 7). The rooms are organized in an arrangement based on two halves with the public living area and kitchen on one side and private bedrooms and bath on the other side. A recessed covered porch, located between the two halves, functions as an entry way and a central exterior space for social gatherings.

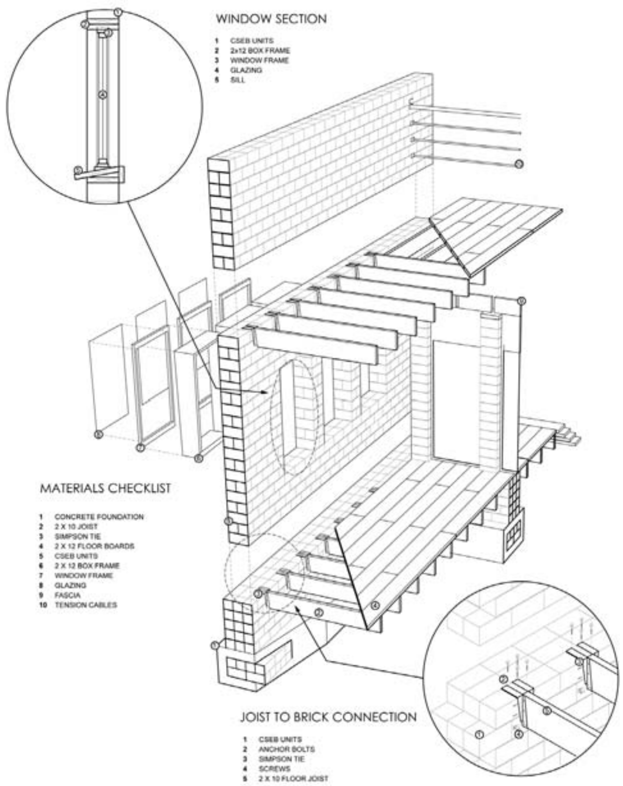

Figure 9: Housing prototype typical foundation, floor, wall, roof, and opening assemblies. Source: (Author)

2.8. Architectural systems

The proposed designs are developed around an architectural logic based on the 10”x6”x3” module of the compressed stabilized earth block (Kumar et al. forthcoming 2018). Each structure is anchored with a continuous grade beam foundation composed of multiple block layers surrounded by a 6” concrete protective coating on all sides. On top of the foundation, a 2’-6” high triple layer block stem wall supports a series of elevated floor joists to promote improved air circulation and ventilation. Wood planks are layered on top of the joists and provide a finished floor for the interior spaces. The raised floor elevation also helps resist building material decay, a common problem when building on moisture rich soils. The load bearing, double layer, exterior block wall continues vertically from the stem wall and rises to a height of up to 17’. With a maximum allowable span of 30’, the exterior wall is reinforced by a series of block interior walls that function as buttress bracing for lateral loads. Wall thicknesses and spans were selected based on simple calculations to ensure that the structural system can resist the high wind pressure generated by hurricane force winds (Matta et al. 2015, Kumar et al. forthcoming 2018). The shorter interior walls span between the longer exterior walls and provide a series of thresholds to access the living spaces. The interior is finished with a smooth stucco coating that can remain exposed or covered with a paint finish. Visually similar to the interior walls, the exterior wall is finished with a thin cementitious stucco coating to form a waterproof protective layer. The roof system employs a simple wood joist framing technique supported by the foot thick exterior wall and anchored with mechanical fasteners (Fig. 9). Roof and floor joist connections with the walls are dimensioned to resist lateral and vertical wind loads. Again, wood planks are layered on top of the joists to make the roof enclosure and left exposed on the interior face revealing the structure and sheathing. In the shotgun typology, the exterior face of the roof is finished with a layer of rigid insulation that is sloped ¼" per foot from the front to the back for drainage. The dogtrot typology has a more steeply pitched roof structure and sheds water on multiple sides. Moisture and protection layers are applied to finish the roof exterior. Floor to ceiling openings are located at the front and rear of the houses to bring in light and help foster air flow or in the case of the dogtrot face the covered interior porch. Smaller side openings are supported by a wood box frame and allow additional natural light and air to enter interior spaces (Fig. 9). The frames are mechanically anchored to the compressed earth block walls to provide a high wind load resistant enclosure. The components, details, and connections are intentionally simple to help achieve the goal of affordable materials and labor that are readily available.

2.9. Affordability

Economically, the proposed designs were compared to traditional local building methods to determine the relative affordability of compressed stabilized earth block dwellings (Kumar et al. forthcoming 2018). When constructed by unskilled labor, the comparison showed that the earthen construction materials and techniques were significantly less expensive than brick and concrete masonry unit dwellings. Wood construction, a technique commonly used in the area, was more similar in cost. However, timber constructed dwellings are significantly less resilient to hurricane force winds.

3.0 ACHIEVED OUTCOMES:

In our current period of climate change, unpredictable events have and will continue to displace thousands of residence in the coastal region of Louisiana. This historic unseating of entire communities necessitates a reconsideration of standard housing solutions. Constructed primarily of materials accessible from the building site, compressed stabilized earth block design and building techniques offer an economical and sustainable approach to the current increase in demand for weather resistant housing. Through the novel use of engineered earth blocks in a hot wet environment and an awareness of local contextual parameters, the prototype designs offer an affordable, resilient, and sensitive way to bring about housing for the many individuals in need. From our research, we have concluded that it is feasible to re-appropriate earthen building materials found in hot dry climates to construct enduring structures responsive to a hot wet environment.

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Design Optimization Workflow for a Dynamic Mass Envelope System Using Complementary Digital and Physical Testing Methods

Design Optimization Workflow for a Dynamic Mass Envelope System using Complementary Digital and Physical Testing Methods

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ABSTRACT: Building envelopes significantly contribute to energetic gains and losses, relying on insulation and HVAC systems to maintain thermal comfort. The Thermally Active Ceramic Envelope (TACE) is being developed to capture, transform, re-distribute bioclimatic energy flows rather than act as a barrier. By redirecting rather than rejecting thermal energy, building envelopes act as on-demand variable mass systems which can achieve the same balancing effects as traditional thermal mass approaches, without such intensive material requirements. By managing entropy production at the envelope, it is reasonable to expect lower mechanical system energy expenditures to maintain thermal comfort.

This paper outlines two parallel methods of analysis, physical and digital, used to inform design decisions in the development of TACE systems. In the first method, digital simulation, multiple digital models were prepared to characterize the thermal performance of TACE tile modules. With a well-prepared simulation model, design iterations can be quickly tested for efficacy. The digital simulation model was developed using conservation of mass and energy equations and validated against CFD testing to assess possible performance of the TACE system. The second method of analysis is physical thermal characterization testing of TACE tile assemblies, using a modified hot-box test chamber to provide accurate thermal results. To leverage the benefits and minimize the shortcomings of each of the two methods, experimental results from this physical testing are used as a calibration tool for the digital simulation models.

Calibration inputs from the physical testing were used to adjust the digital simulation models to correlate all analysis results. With a calibrated digital simulation framework, TACE tile modules can be proposed and tested before investing time and materials into developing further prototypes. The end result is a design workflow to evaluate and assess thermal performance of TACE tile modules.

KEYWORDS: Active Façade, Thermal Transfer, CFD, Energy Modeling, High-Performance Façade

INTRODUCTION

The trend in building product development is to present solutions that serve multiple roles. To be of significant value, for example, a new building product should contribute to energy efficiency, utilize abundant or recyclable materials and encourage local economic development through appropriate available technologies. Ceramic building materials fundamentally meets the requirement for material abundance, and because of its wide range of material properties can be intelligently designed and manufactured to meet the requirements related to energy efficiency. To more widely reintroduce architectural ceramics to the construction industry, traditional terracotta must be “reinvented” to support the thermal management of energy transfer across the building envelope.

When considering the transfer of energy across the building envelope, there are two broad categories of systems: active and adaptive. Mike Davies’ characterization of the polyvalent wall in 1978 is an early provocation towards the development of these types of building envelopes. The contemporary work being developed at TU Delft in the Architectural Engineering + Technology Department, the Façade Research Group, and specifically the development of the integrated wall strategy by Professor Ulrich Knaack provides a guideline for the characterization of adaptive envelopes as a multivalent wall that engages the building envelope construction with bioclimatic forces, lowering reliance on energy intensive mechanical systems (Knaack, 2007)

A common passive approach to managing heat flows in building envelopes is through the utilization of high thermal mass materials such as concrete, stone, and brick. With these materials applied in walls and floor systems, sensible heat can be stored for later use or overall stabilization of temperatures in the building. One of the drawbacks of using these types of systems (e.g., terra cotta, clay brick, concrete, etc.) is the unregulated time lags of energy transfer and significant mass required to store the quantities of energy necessary to effect thermal comfort and overall energy balance. One solution to this problem that makes the qualities of thermal mass more effective in modern building operation is to activate these thermal mass materials through the integration of a controllable counter current heat exchanger device into the thermal mass building system. By controlling the transfer, storage and release of thermal energy across the building envelope, a thermal mass-based system can achieve the same balancing effects, without the unmanageable time lag while significantly reducing the overall mass of materials that would otherwise be required to make use of traditional, passive thermal mass strategies.

Thermo Active Building Systems (TABS) are considered to be active systems where a working fluid is used to heat or cool the thermal mass, typically an interior floor slab or mass based wall, through integrated piping (Olesen, 2012). One common application of this type of system is hydronic heating systems integrated into floorplates. TABS have typically, though not exclusively, relied on an active energy source (e.g., boiler, chiller, etc.) to charge the mass. An alternative to using an active energy source is to use locally available energy sources (e.g., ground or water temperature, ambient air temperature, solar insolation, etc.). While not a high quality of power, a system relying on locally available or even renewable energy resources uses significantly less input energy. Unlike systems that use energy intensive energy sources, this approach is not a brute force system. Available resources are often low grade or fluctuate and may not be able to be used based on weather, climate and building energy demand profiles; the system 'adapts' to the conditions to best use the resources available at the times where this is effective.

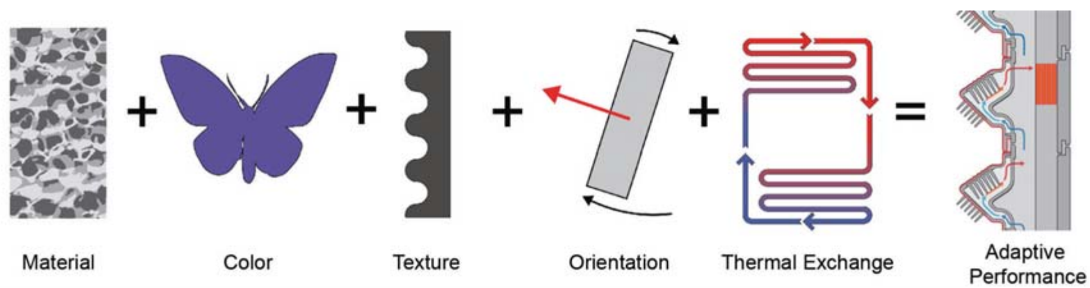

Figure 1 - TACE module design performance variables

The Thermally Active Ceramic Envelope (TACE) described in this paper, is designed to use a multivalent strategy to absorb, release, and redirect heat to conserve energy by managing entropy production, is one instance within the larger field of Thermo Active Building Systems. TACE systems leverage morphology, color, texture, thermal mass and active energy vectoring, approaching the behavior of biotic systems (Fig.1). The system makes use of a working fluid within the façade assembly to assist in the heating and cooling of the interior of the building. It is active because it deliberately transfers energy, captured primarily from solar insolation, to achieve desired results. The differentiating quality, compared to traditional hydronic systems, is that the system adapts to the local conditions of energy resource and demand with minimal external energy inputs.

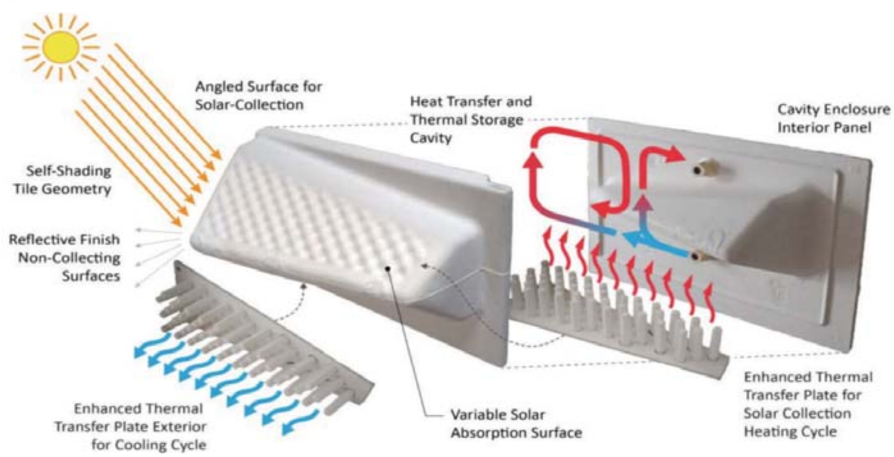

Figure 2 - TACE Minimum Viable Prototype Diagram. Image credit CASE/RPI

The TACE minimum viable prototype (MVP) (fig. 2), used as a platform for research in this paper, is developed to leverage specific design attributes that are hypothesized to affect the energy performance of the TACE system. In order to accurately evaluate the potential performance of the TACE system, a comprehensive energy model using industry standard metrics was developed. Without this model and testing data, it is difficult to 1) understand which design attributes are contributing to the performance of the TACE system, and 2) which future directions for refinement should the TACE be developing. This paper describes a workflow that leverages digital simulation and physical testing methodologies to isolate system components and evaluate effectiveness of various TACE design parameters. The concept of using both digital and physical simulation methods in parallel can be used as a tool to evaluate and characterize other dynamic building technology proposals.

1. CALIBRATED SIMULATION FRAMEWORK

The primary research methods used for this paper are digital simulation and physical testing as a means of calibrating the digital simulation tools. The multi-modal simulation testing of TACE tile modules, leverages a combination of computational fluid dynamics (CFD) modeling, mass-energy balance modeling, and physical lab-scale testing to accurately characterize energy flows through the TACE system and evaluate the performance of the component as part of a building envelope assembly. A CFD environment was used for thermal transfer analysis in a steady state environment. Additional mass-energy balance modeling, using CFD results as calibration inputs, was completed in Modelica to understand the thermal behavior of the TACE tile modules in a dynamic (real-world) environment. Physical testing of TACE assemblies was conducted within a hotbox test chamber to more accurately characterize the thermal behavior of prototype TACE modules and compared to results from simulation testing. Physical quantitative test results from the hotbox test chamber were used to further refine and validate the digital simulations. The final results from this calibrated simulation framework can later be integrated with energy analysis tools to assess the potential energy savings of TACE assemblies compared to a baseline façade system (fig.3).

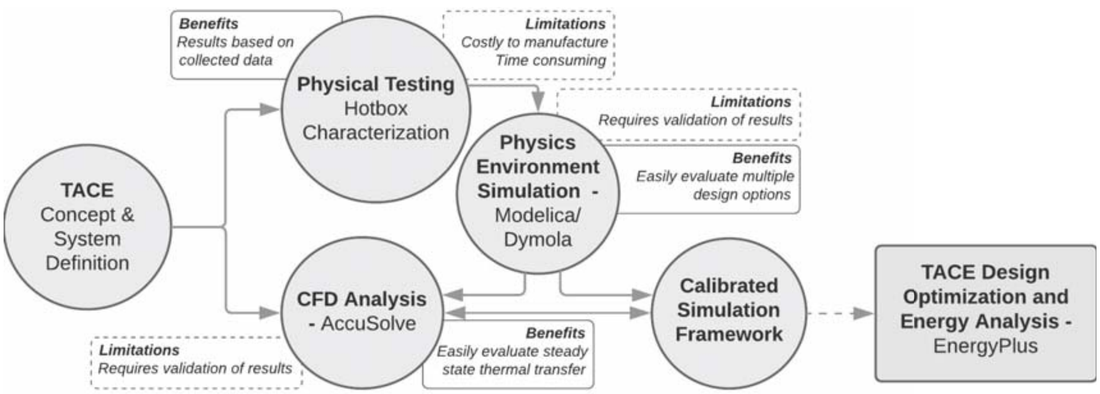

Figure 3 - TACE Simulation Framework

The current validated standard for modeling the performance of buildings in the United Sates is the EnergyPlus platform. It is widely used to model energy use in buildings, accurately characterizing internal and external loads. EnergyPlus is being used to develop an apples-to-apples comparison of TACE configurations in terms of Energy Use Intensity (EUI) a direct output of the model as well as relating and comparing TACE system performance to baseline building configurations. Because of the custom and dynamic nature of a TACE system, it is not able to be directly plugged into the EnergyPlus environment. However, due to the open-source nature of EnergyPlus, it can readily take inputs from other simulation environments. For EnergyPlus to accurately reflect the performance of the TACE system, the TACE components needed to be modeled in a more resolute environment that accounted for the dynamic performance. Modelica is an industry standard modeling language for building physics simulation environments and was therefore used to model the TACE module.

1.1 TACE MODULE DESIGN

The TACE system prototype being evaluated is ceramic tile module where the clay body used is alumina based for enhanced thermal transfer properties. The alumina formulation started with 97% industrial grade alumina (Al^2O^3), with minor constituents like SiO^2 and MgO from added materials. Recycled glass is added to increase silica content (SiO^2) up to 10%. The tile assembly is composed of three primary components all manufactured by Tegula Tile in Rensselaer NY for these experiments: 1) Outer tile face/primary solar absorber surface, 2) thermal transfer pin plate, 3) cavity enclosure interior panel (fig.2) The three primary components are bonded together to create a hollow cavity within the assembly that is filled with the working/heat transfer fluid (water was used in these tests). The experimental setup for both digital and physical testing was to isolate and compare two separate variables: 1) pin plate length, and 2) working fluid flow rate. The three pin plate lengths used for digital simulation are: 11.11mm (0.4375in), 29.34mm (1.155 in), and 44.45mm (1.75in). The three flow rates used for comparison were: Static/no flow, 1.25LPM(0.33GPM), and 2.5LPM(0.66GPM).

1.2 SIMULATION DESIGN

The simulation framework is designed to explore a wide range of tile and system designs. Calibrating the computational model that is the basis for the simulation framework is essential to developing results can be extrapolated to the building scale simulations. To validate the simulation framework, both a Computational Fluid Dynamics (CFD) model using Altair AcuSolve and quantitative physical testing was used to compare temperature profiles across the MVP TACE component filled with water which is used as the heat transfer medium.

Modelica is an open source modeling language that is used to solve complex physics-based problems. It is therefore useful in simulating complex building physics scenarios like mass and energy transfer at the building envelope. The TACE components are arranged within Modelica as a series of interacting physics objects. Modelica then outputs these interactions into a larger building simulation environment. The initial Modelica simulation was built based on assumed material properties of the TACE assemblies, without validating those assumptions. Variables such as effects of tile bonding or manufacturing inconsistencies were not able to be accounted for in the simulation. Results from physical were compared against Modelica results and the Modelica Model was adjusted to develop a fit curve that approximates these quantitative testing data.

Dymola is a Modelica modeling environment developed by CATIA Systems. Since Modelica is object oriented, specific performance components can be developed and link together as a connected network of blocks, each representing different transport phenomena. Dymola can also package and compile the model as a defined object called a Functional Mock-up Unit (FMU). The FMU is exported from Dymola as a code object that is compatible with an EnergyPlus IDF file for use in later simulations to characterize overall system performance.

1.3 MODELICA/DYMOLA CALIBRATION

The Modelica system model was configured to the same parameters and measurement points as the hotbox chamber set up (described below) to set up a direct comparison and calibration routine between the two test methods. The temperature of the working fluid in the storage tank was used as the baseline fluid inlet temperature for the Modelica model. A convection heat transfer coefficient was calibrated in the model on the hot side of the TACE exterior component to match the surface temperature as seen in the experiment. This convection heat transfer coefficient was assumed to be 100 W/ (m^2 K) due to the chambers of the hotbox being a small encapsulated space, resulting in a larger amount of air movement from the heating unit and the large temperature difference observed between the air in the exterior chamber and the TACE MVP module exterior component.

1.4 CFD MODEL CALIBRATION

The CFD model was developed to observe temperature rise based on a steady state system. A steady-state heat transfer problem was setup in AcuSolve where the alumina material of TACE was modeled with a water fluid cavity. This first phase of the calibration process compared the temperature increase between the TACE MVP Modelica system model and the outcomes of the CFD simulations conducted on the Altair AcuSolve software platform.

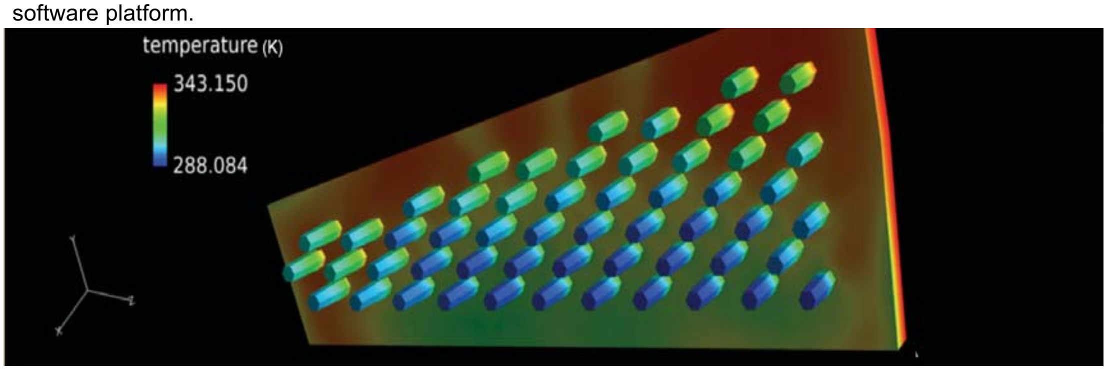

Figure 4 - CFD Analysis setup and results (Porterfield, 2017)

The steady state CFD model, as shown in figure 4, and a TACE MVP Modelica system model was produced with the same boundary conditions for direct comparison. A 70°C surface temperature was modeled on the top of the exterior TACE component. Simulations were run for a selection of flowrates: 0.625LPM(0.165GPM), 1.25LPM(0.33GPM), and 2.5LPM(0.66GPM) and the energy transfer component with specified pin lengths 11.11mm (0.4375in), 29.34mm (1.155 in), and 44.45mm (1.75in). Each configuration was run within the CFD model and Modelica system model for the duration required to achieve a steady state. The Modelica model was observed to be overestimating the temperature increase for each of the flowrates by about 2°C in comparison to the CFD model.

To adjust for the trending 2°C increase in temperature from the Modelica model as observed by the CFD model, the pin convection heat transfer coefficient was reduced in scale by 30%, resulting in an overall efficiency of 70% in the Modelica model. The overall efficiency factor was also confirmed when observing that not all the pins transfer heat to the working fluid at the same rate, as shown in the CFD image in Figure 4 below. This reduction was developed from the steady state CFD simulation for the low (0.625LPM), medium (1.25LPM), and fast (2.5LPM) flowrates. However, the efficiency factor alone resulted in the Modelica model having a lower outlet water temperature than the CFD for lower flowrates and higher temperatures for fast flowrates. As shown in the figure 4 below, not all the pins transfer heat to the working fluid at the same rate. To account for this uneven thermal transfer rate observed at specific flowrates, a flowrate contingent function (f) described in Equation 1 below was applied that further refined the Modelica model by modulating the efficiency factor from 67% for 2.5LPM of flow up to 72% for 0.625LPM of flow based on aligning the Modelica results to the CFD more closely.

$\mathrm{f} = -2314.8 * \dot{\mathrm{v}} + \mathrm{d}1.0509$ (where $\dot{v}$ is the volumetric flowrate in m^3/s.)

Equation 1 – Flowrate contingent function (f)

1.5 RESULTS AND DISCUSSION: CFD MODELING

After applying the efficiency factor and the flow dependent factor, the average temperature difference between the Modelica calibration model and CFD model did not exceed more than 0.41°C for each tested flowrate; a 4.04% disparity (table 2). The medium pin length TACE configuration was used in the subsequent physical testing had an average temperature divergence of 0.18°C; a 2.37% disparity (table 2). The CFD model did not take into account the ambient, transient or cumulative effects that might occur outside of the bounded steady state model.

	Temperature Difference (˚C) Before CFD Calibration			**Temperature Difference (˚C) After CFD Calibration**		
Pin Length	**0.625LPM (0.165GPM)**	**1.25LPM (0.33GPM)**	**2.5 LPM (0.66GPM)**	**0.625LPM (0.165GPM)**	**1.25LPM (0.33GPM)**	**2.5 LPM (0.66GPM)**
11.11mm (0.4375in)	13.06	9.57	7.17	9.83	7.46	5.37
29.34mm (1.155in)	13.15	9.78	7.23	10.29	7.64	5.42
44.45mm (1.75in)	13.19	9.79	7.14	10.3	7.64	5.42
Average	13.13	9.71	7.18	10.14	7.58	5.40
CFD Results	10.55	7.76	5.48	10.55	7.76	5.48
Difference between Modelica and CFD(˚C)	-2.58	-1.95	-1.70	**0.41**	**0.18**	**0.08**
Percentage change between Modelica and CFD	-19.67%	-20.11%	-23.68%	**4.04%**	**2.37%**	**1.42%**

Table 2 - Modelica Model Results Before and After CFD Calibration

The TACE MVP module was initially designed to have offset working fluid. inlet and outlet ports, the logic being that the ports should be as far apart from one another as possible to maximize the potential for uniform heating of the working fluid. The inlet port was on the lower left side of the interior components when viewed from the inside; the outlet was placed on the upper right when viewed from the inside as shown in figure 5. However, the Modelica model and the CFD model were originally simulated with aligned inlet and outlet ports in the center of the module, bottom and top respectively, as shown in figure 5.

It was observed in CFD analysis that the model with the in-line central port configuration had a more even spread of heat transfer between the pins and fluid because of the inlet more evenly injected fluid flow into the pin region (fig. 5), while the offset inlet and outlet ports had a streamline fluid flow that would short-circuit the pin region thereby delivering less heat transfer from the pin components to the working fluid (fig. 5). The offset ports performed at a decrease of about 75% from the parallel ports.Therefore an additional 75% efficiency factor was added to the Modelica model when calibrating against the measure results to simulate the use of offset ports.

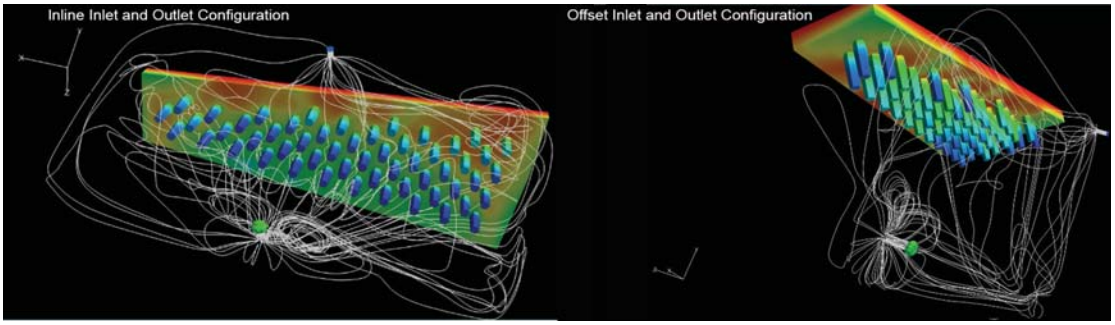

Figure 5 - Inline inlet and outlet streamline visualization from CFD (left). Inlet injects fluid more evenly into the pin region vs. offset inlet and outlet streamline visualization from CFD (right). Fluid flow from inlet to outlet can short circuit and avoid the pins entirely, reducing heat transfer (Zeng, 2017)

1.6 PHYSICAL TESTING SETUP

The physical testing was designed to thermally characterize the TACE MVP module and observe temperature profiles of the module assembly and working fluid over a period of time. Physical testing was completed using a modified hotbox test chamber, designed and constructed with guidance from ASTM C1363 Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus. The fundamental hotbox arrangement consists of two equally sized thermal chambers. These chambers are divided by an insulation panel which serves as a mounting frame for the TACE MVP. The outside of the TACE module is exposed to the interior of one of the insulated chambers noted as “Exterior.” The inside of the of TACE module is exposed to the interior of the other chamber noted as “Interior”. In this configuration, the only non-insulated connection between the two chambers is the TACE module itself. Because the TACE module is the only connection, thermal energy must pass through the module and the flow can be measured and characterized. For the module as a whole or for individual components. The chambers and TACE module are instrumented with an arrangement of thermocouples to record the thermal inputs and describe the thermal transfer from the exterior to the interior chambers and across the TACE MVP module.

The hotbox enclosure was designed and fabricated to contain one TACE MVP module within the insulated test panel frame (fig. 6). Chamber wall construction is comprised of 203.2mm(8in) thick expanded polystyrene foam insulation 32kg/m^3(2lb/ft^3). Panel joints used adhesive mastic to create a complete sealed surface and eliminate the need for mechanical fasteners to support a consistent insulation value and all interior seams were filled to limit air infiltration. A 950w enclosure heater with integrated fan was placed within the exterior chamber side of the hotbox enclosure which provided the thermal load on the exterior surface of the TACE MVP module. It was determined that the built-in thermostat for the enclosure heater had an inadequate level of precision and adjustability during initial trials. The heater was then improved to receive a PID controller and

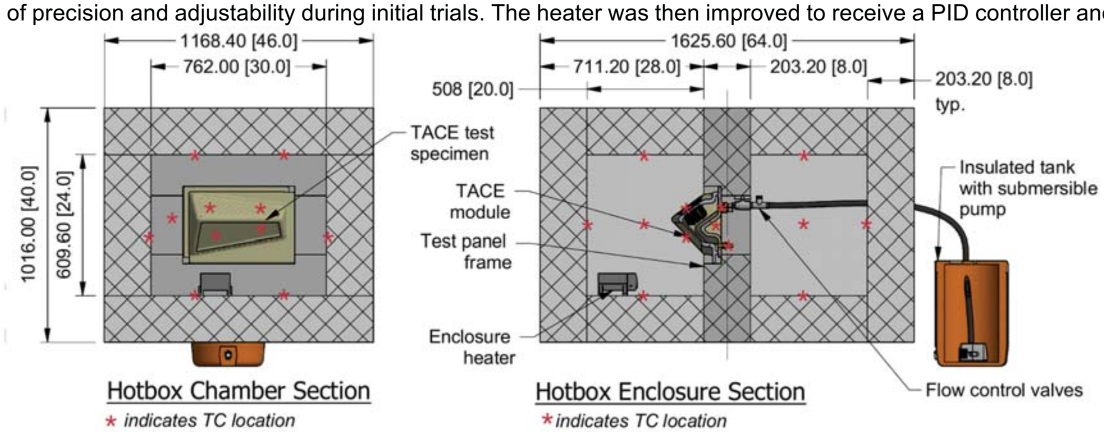

Figure 6 - Test chamber assembly

T-type thermocouple that provided for an accurate control of the temperature and therefore energy that was applied into the system. The thermocouple used to modulate the heater energy was placed adjacent and above the TACE MVP module on the test panel surface.

The thermal conditions in the hotbox enclosure were observed and recorded with a 16 channel DAQ system equipped with a 16-channel extension unit for a total of 32 thermocouple channels. The DAQ system was manufactured by Measurement Computing, models (USB-2416-4AO and AI-EXP32). Data was recorded using the Measurement Computing DAQAMI data acquisition software. The data sampled rate was set for 1 measurement per second per thermocouple using T-type thermocouples. For the calibration experiment, there were 28 total thermocouples distributed throughout the experimental setup: (8) distributed across the interior surfaces of the "interior" and "exterior" chambers, (1) ambient condition, (1) submersed in water tank, (4) distributed across interior and exterior faces of the TACE tile, (1) at each water inlet and outlet port.

The active thermal of the TACE MVP design includes a thermal mass transfer plumbing loop, and instrumentation. The TACE MVPs used for testing has ports on the interior component of the TACE module for inlet and outlet of the working fluid and additional ports which serve as instrumentation ports for thermocouples. The inlet and outlet ports were fitted with ball valves to modulate the flowrates and are used for servicing experimental set up. The working fluid is circulated at flow rates (identified above) through the insulated piping into the insulated storage tank. The total volume of working fluid in the system is 9.46 liters (2.5gal) of water. The working fluid volume of the TACE MVP module was 4.74 liters (1.25 gal).

Three testing rounds were conducted to develop the comparison with the simulation framework. Throughout each test run, relative starting temperature, set-point temperature, ramp time, soak time, and fluid volume were maintained as consistent. The only variable used to create the ramp profiles was the flowrate of the working fluid. The tested flow rates of the experimental setup were identical to the simulation framework: static/no-flow, 0.625LPM(0.165GPM) low flow, and 2.5LPM(0.66GPM) high flow. The control valves were adjusted in order to achieve the designated testing flowrate.

At the start of the experiment, both hot (exterior) and cold (interior) chambers were at a steady state near equilibrium ambient temperature with no discernable flow. The pre-defined ramp temperature and soak temperature profile began with convective airflow coming from the enclosure heater. The set temperature for the hot side of the chamber was set at 60°C (140° F); the ramp time was 38 minutes; the soak time was 80 minutes. Once the ramp time was achieved, the heater was turned off. The thermocouples continued to take readings until both sides of the chamber reached a new steady state, based on how much energy was put into the test chamber.

1.7 RESULTS AND DISCUSSION: PHYSICAL MODEL

The data collected from physical experiments was compiled and directly compared to data generated in parallel Modelica simulations. Instrumentation points of particular interest are working fluid inlet and outlet temperatures as well as tile face (interior and exterior) surface temperatures. The data that was logged from the hotbox enclosure when the TACE MVP was fitted with the energy transfer component with medium pin length 29.34mm (1.15in) with the 0.625LPM (0.GPM) flowrate was compared to the Modelica Calibration model that was modified with the calibration data from the CFD and steady state model.

The temperatures of the outward facing surfaces of the Modelica systems model of the exterior and interior components was compared to the measured data logged from the hotbox chamber experiment. These temperature ranges appear to match in quantity and ramp profile as shown in Figure 7.

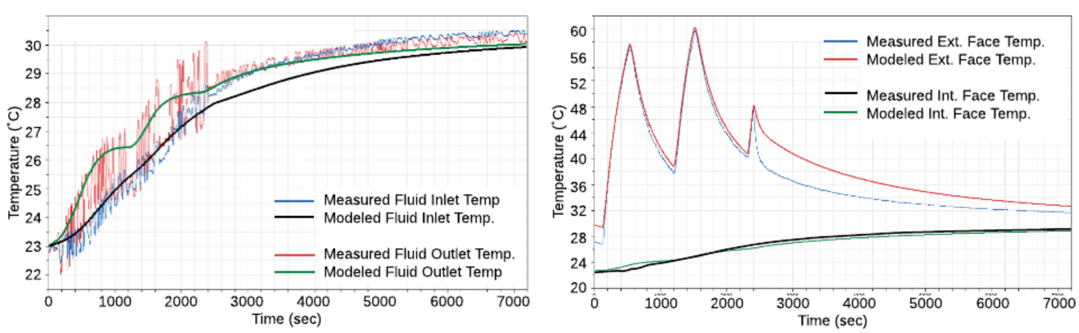

Figure 7 - Comparison of fluid inlet temperatures (Left) and comparison of tile face temperatures (right)

The working fluid outlet temperature of Modelica Module Model showed more movement due to the high temperature peaks in the surface on the exterior component temperature than the hotbox chamber experiment. As expected, the higher peaks of the outlet port working fluid temperature for the model corresponds to the temperature peaks on the surface of the exterior component. While a significant amount of noise was recorded in the working fluid temperature as show in Figure 7, the peaks in temperature can be noted, though not to the quantity or clarity of the Modelica Module Model results. Modifications (e.g., adding more mass to the model, changing surface areas, etc.) to the Modelica Module Model were implemented in an attempt to better align with the lower peaks of the experiment results. No modification developed a better fit curve to than the one shown in Figure 7.

CONCLUSION

While the focus of this paper is on developing the calibrated simulation framework and not co-simulation with EnergyPlus, the TACE system has been compiled and co-simulated with EnergyPlus to generate comparative EUI results for various TACE system configurations. Initial analysis runs demonstrate a significant reduction in EUI when compared to existing traditional envelope systems, and smaller reductions in EUI when compared to a typical ASHRAE curtain wall system (fig. 8). While these initial results do not show significant performance improvements compared to an ASHRAE curtain wall, it should be noted that this was an initial calibration test and not considered an optimized TACE system design.

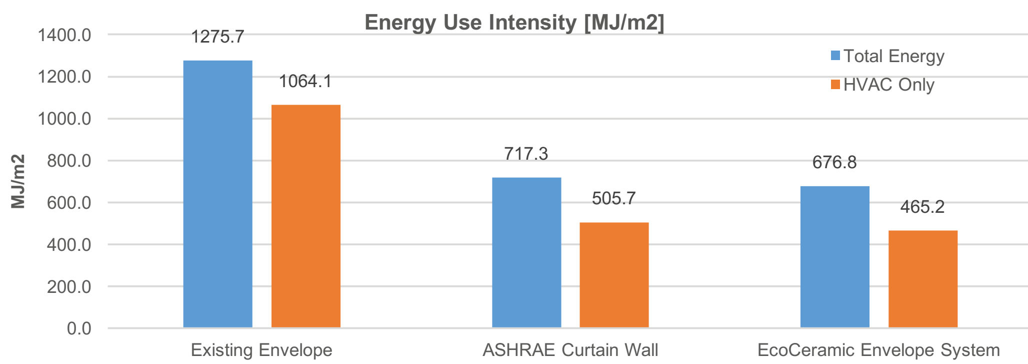

Figure 8 - Energy Use Intensity (EUI) for building envelope system types

Future development of the TACE system should include efforts to improve the accuracy of fit curves between the experimental ramp profile and simulated data. Additional comparisons are being evaluated that examine more discreet and isolated variables of the TACE. However, the combination of CFD analysis, physical testing and simulation in Modelica demonstrated here do successfully make up a calibrated simulation framework that can be used as a design tool to characterize TACE system efficacy and its impact on overall building energy consumption. Future TACE development will focus on a parametric model that accounts for changes in design and orientation and subsequent performance output and effect on EUI attributed to the TACE system. This methodology of testing and calibration has demonstrated its effectiveness at evaluating the performance of the TACE system and can be applied to development of other dynamic envelope systems.

ACKNOWLEDGEMENTS

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Chris Jarrett

Alexander Houses x 7: Steel Prefab in the Low Desert

Alexander Houses x 7: Steel Prefab in the Low Desert

Chris Jarrett

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ABSTRACT: In an age of increasing globalization, there is a rising need for affordable, livable and humane sub- and non-urban housing. The intent of this research is to uncover the principles, strategies, methods and material means of the Alexander Houses, seven mid-century modern houses in the low desert of the Coachella Valley in California, in an effort to re-establish novel solutions for addressing the need for durable, low-maintenance, economical and inspired housing.

KEYWORDS: Prefabrication, Steel, Housing, Modern

INTRODUCTION

Figure 1: Prefabricated Steel Erection and Construction, Steel Houses, Donald Wexler, 1962

In 1962, architects Donald Wexler and Richard Harrison in collaboration with structural engineer Bernard Perlin of Calcor introduced a novel all-steel system for the prefabrication of thirty-eight 1,400sf (130 sm) affordable houses suitable for a low desert ecology. The planned tract of 38 prefabricated houses was never completed. Shortly after the first seven 'models' were built, the price of steel increased and the builder cancelled the project. During the 1970's and 80's, the all-steel houses were largely forgotten and fell into disrepair. In the 1990's, the houses were rediscovered and in 2001 were granted Class 1 Historic Site status. Through historical research and recent field visits, this paper suggests the Alexander Houses have much to teach us about integrated design, affordability, and construction of modestly-sized, low-cost, low-maintenance, highly durable houses.

1.0 EARLY PREFAB INFLUENCES FROM CHICAGO

1.1 Howard T. Fisher

Howard T. Fisher, FAIA (1903-1979) was born in Chicago, the son of Walter Fisher, Secretary of the Interior under President Taft. A graduate of the Asheville School in North Carolina (1922), Fisher attended Harvard College and then enrolled in the School of Architecture at Harvard University, graduating in 1928.[1] Three years later Fisher opened a solo practice, and in 1932, founded General Housing, Inc., a pioneering firm in the development of prefabricated housing. The firm designed, sold and erected low-cost, high-quality prefabricated homes using mass production methods that integrated design, manufacturing, and marketing of simple houses in a single package.

General Houses, Inc.'s first house was erected in 1933. A typical General Housing steel two-bedroom house cost $4,500 ($110,000 today). Fisher's original patented construction system used pressed-steel panels for walls, roofs, and floors, set on a concrete foundation[2]. After the foundation was cured, a crew of unskilled laborers could put a house together in about two weeks.[3] The houses were composed of a coordinated system of prefabricated steel-framed modular panels, of which there were eight kinds: solid, small window, large window, glass, entrance door, kitchen door, double doors, and a fireplace. All of the panels were four feet wide and all were nine feet high except for the fireplace panel, which was taller. A garage door panel was the same height as the other panels but twice the width. As modules, the panels could be assembled in a wide variety of configurations to suit individual clients and specific sites.[4] General Housing was invited to display two model homes at the 1933 Chicago World's Fair whose theme was "A Century of Progress," celebrating innovations in architecture, science, technology and transportation. Fisher's prefabricated "steel cottages" attracted thousands of visitors.

1.2 Homes of Tomorrow

Figure 2: Promotion, Homes of Tomorrow

Figure 3: General House, Chicago World's Fair, 1933

At the 1933 Chicago World's Fair, twelve model houses demonstrated modern building methods, materials and techniques in the "Homes of Tomorrow" Exposition. The exhibition was one of the most noteworthy exhibits of the Chicago World's Fair, showcasing modern innovations in architecture, design, and building materials. Prefabrication and the use of new building materials were intended to showcase affordable house options to families with limited means. Several architects and firms used the model homes to demonstrate their prefabrication techniques and use of new materials. All but two houses featured flat roofs and at the time were considered "radically contemporary." In one case, Rostone, a type of manufactured masonry composed of limestone, shale and alkali that could be molded into specific shapes and produced in various colors, demonstrated affordable and durable home construction options.

Twelve Houses Showcased in Exhibition

Weiboldt-Rostone House	Armco-Ferro House	General House
Stran-Steel House	House for Brick Manufacturers	Design for Living Home
House of Tomorrow	Florida Tropical House	Cypress Log Cabin
Masonite House	American Forest House	Universal Houses' Country Home

After the exposition ended in 1934, developer Robert Bartlett purchased five of the houses: the Wieboldt-Rostone House, the House of Tomorrow, the Florida Tropical House, the Cypress Log Cabin, and the Armco-Ferro House. He then proceeded to load them on barges and floated them across Lake Michigan to Beverly Shores, Indiana. The five houses continue to reside on the shores of Lake Michigan in what is now called the Century of Progress Architectural District.[5]

1.1 Edmund Lindop

Edmund Lindop (1901-1968) was born in Chicago and like his father worked in the real estate business. Lindop became aware of the work of architect Howard Fisher and his 1930's prefabricated steel house manufacturing company, General Houses, Inc. Hoping to become a developer, Lindop took his "development dreams" and his family to Los Angeles in 1936. Soon thereafter, he acquired a tract of land in the Coachella Valley where he hoped to develop a neighborhood of steel houses.

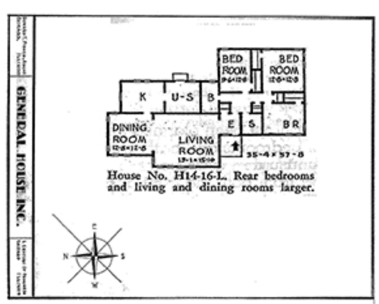

Figure 4: Edmund F. Lindop Residence, Prefabricated Steel House, Howard Fisher, Architect, 1937

Lindop built a single 3 bedroom, 2 bath steel-frame, factory-built model home consisting of 1,750sf (165 sm). On November 20, 1936, an article in The Desert Sun entitled, "Steel House Now Being Erected," described the unveiling:

> "Every part of the house is made by mass production in the factory. The steel frame bolted together and compressed asbestos panels on the outside as well as heat and cold resisting fireproof materials for the roof, form a building that is both earthquake proof and fireproof. Inside walls are of plyboard and both inside and outside walls are finished in any color desired."

But the single-family "model house" was not a financial success. The Lindop family used the model home as a weekend residence until it was sold in 1946 to Charles Stern who commissioned a compatible garage addition to the property in 1947. Beginning in the 1980s the home was owned by Barbara Black, former wife of architect Michael Black. The Lindop House changed hands most recently in 2010.

2.0 THE LOW DESERT

2.1 Context, Climate and Site

Palm Springs, California lies at the foot of Mount San Jacinto, which rises to 10,804 feet (3,293 meters) in the Coachella Valley of southern California, located 100 miles east of Los Angeles. The area was originally inhabited by Cahuilla Indians and known to the Spanish as Agua Caliente or "Hot Water" for its hot springs. By 1872 Palm Springs had become a stage stop between Prescott, AZ and Los Angeles, CA. The dry climate produces 300 days of sunshine and around 4.83 inches (122.7 mm) of rain annually. In 1884 Judge John Guthrie McCallum established the Palm Valley Colony on the site, which later developed as a model desert resort with vast recreation areas for swimming, tennis, golf, hiking, and skiing. Today, the city has a population of approximately 48,000 residents and includes within its boundaries parts of the Agua Caliente Indian reservation.

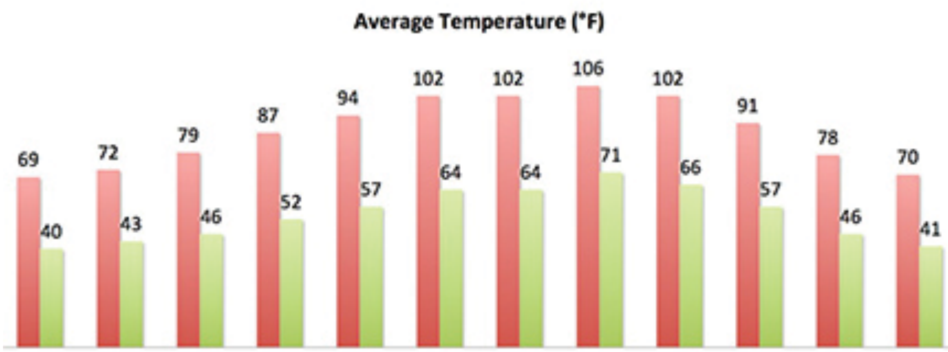

Figure 5: Average Temperatures, High and Low, Palm Springs, CA

The winter months are warm, with a majority of days reaching 70 °F (21 °C) and in January and February days often see temperatures of 80 °F (27 °C) and on occasion reach over 90 °F (32 °C), while, on average, there are 17 nights annually dipping to or below 40 °F (4 °C). Summer often sees daytime temperatures above 110 °F (43 °C) coupled with warm overnight lows remaining above 80 °F (27 °C). The mean annual temperature is 74.6 °F (23.7 °C). There are 180 days with a high reaching 90 °F (32 °C), and 100 °F (38 °C) can be seen on 116 days.

3.0 ARCHITECTS IN THE LOW DESERT

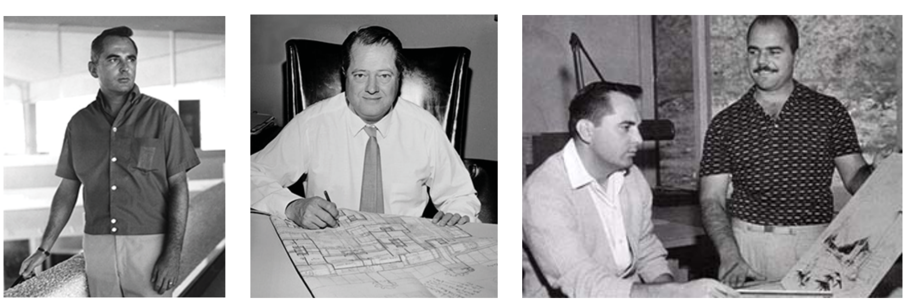

Figure 6: Donald Wexler, William Cody, and Wexler and Harrison

3.1 Donald Wexler

Donald Wexler, FAIA (1926-2012) was born in Sioux Falls, South Dakota. He moved to and was raised in Minneapolis, Minnesota. After serving in the Navy from 1944 to 1946, he attended the University of Minnesota on the G.I. Bill and graduated in 1950 with a degree in architecture. Following graduation, Wexler moved to Los Angeles and worked as a draftsman for Neutra & Alexander. It was here under the tutelage of Richard Neutra that Wexler learned modern design derived from its responsiveness to dynamic environmental, technological, and material conditions. For Wexler, adaptability and flexibility became prominent values inherent in the conception of architectural space, systems, and materials. Working with Neutra & Alexander is where Wexler first gained interest in working with steel framing.[6] Wexler would soon become one of the mid-century pioneers in the exploration of prefabricated all-steel modular design in the low desert. After working for Neutra & Alexander, Wexler took a job with architect William Cody.

At Cody's office, Wexler did the working drawings for a country club in Rancho Mirage. According to Wexler,

> "It was a job with Bill Cody working on Tamarisk Country Club. Once that project was over I didn't want to leave. I just fell in love with the community -- this was in '52. It was a very small community at the time, maybe 7,000 people. It closed down for four months in the summer -- there was nothing here. There were no doctors, no dentists. The first year there was one restaurant open. In the middle of July the safest place in the world to go to sleep would have been in the middle of Palm Canyon Drive at high noon."

3.2. William Cody

William Cody, FAIA (1916-2078) was born in Dayton, Ohio. His mother was an interior designer who had a passion for art and architecture. In 1930, the Cody family moved to Los Angeles and Cody would later enroll in the College of Architecture and Fine Arts at the University of Southern California, graduating with a degree in architecture in 1942. A year later, Cody worked for Kaiser Steel on the design of modular steel institutional buildings. In 1944, Cody worked for Cliff May on his "Pace Setter House," one of many exhibition houses sponsored by House Beautiful that proposed a new "livable modernism" for postwar America. Cody won a commission to design the Del Marcos Hotel in Palm Springs, and shortly thereafter set up practice there in 1950. Working in William Cody's office is where Wexler met Richard Harrison.

3.3 Richard Harrison

Richard Harrison, FAIA (1924-2012) was born in Los Angeles, California. Like Cody, Harrison is an architecture graduate of the University of Southern California. Following graduation and travels to Mexico and Canada, Harrison accepted a job to work for William Cody in Palm Springs, where he met and worked side by side with Donald Wexler.

3.4 Wexler & Harrison

In 1952, Donald Wexler and Richard Harrison formed Wexler & Harrison, an architectural firm that operated through 1961. The office designed schools, banks, offices and houses. The Lilliana Gardens Glass House of 1954 was the first custom house by Wexler & Harrison.[7] Wexler was 28 years old. The distinguishing architectural elements of the house included wood beams that run the length of the house, high windows that flood the space with light and a central atrium filled with cacti and succulents, assuring that famous "indoor-outdoor" feeling.

4.0 STEEL AT WORK

Figure 7: Perlin and Wexler, Steel School, 1958

Figure 8: Perlin Residence, 1960

4.1 Steel Schools

The first steel-framed systems produced by Wexler & Harrison consisted of light-gauge structural steel frame, steel roof decking and insulated wall panels for schools. These elements comprised the basic structural modules which, when bolted to a concrete slab, formed the permanent structure. Since the units were lightweight and structurally independent, they could be relocated. The wall panels were designed in 8-foot modules, allowing flexibility in the placement of doors and windows, and feasibility of expanding the size of the structure. This pre-fabricated modular classroom system was later expanded and used with houses. While there were many factors for building lightweight steel-frame buildings for residential purposes, it was the need to create housing for veterans in the postwar period combined with the desire of the steel industry to break into the residential housing market that eventually made it feasible to produce pre-fabricated modular steel-framed houses on a large scale. As U.S. demand for more than one million new houses each year, wood-frame construction was insufficient to meet the demand. The first steel-framed house attempted by Wexler & Harrison was the Bernard and Adele Perlin Residence of 1959-1960 in Los Angeles.

4.2 Bernard Perlin

Engineer Bernard Perlin was working for Calcor, a Los Angeles-based steel company, and knew of Wexler's steel schools. Perlin commissioned Wexler to design his own steel house on a hillside site in Los Angeles. The single-story, 3,500-square-foot house was almost entirely steel and glass, supported by structural steel panels that also served as walls. Steel beams support the steel roof decking and are used for both structure and cladding. According to Perlin, "There's nothing that's not steel in our house other than the cabinets. It's relatively maintenance free. Pictures are hung using magnets, not tacks. I painted it twice."

4.3 Alexander Houses

The completion of the Perlin residence was followed by a decision to expand the concept to develop a subdivision of thirty-eight single-family steel ‘tract’ houses in Palm Springs.

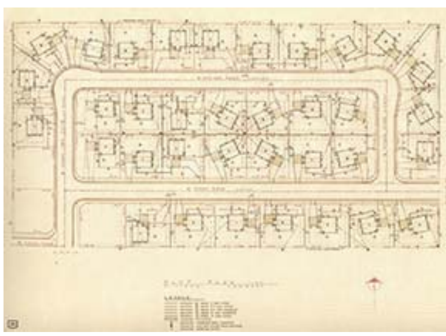

Figure 9: Early Site Plan, 1959

Figure 10: Aerial View, 2017

Originally known as the Calcor Prefabricated Homes, the all-steel houses took one month to build. The tract was to be developed in stages. Between 1961-1962 seven houses were constructed through a joint research program involving Wexler and Harrison, Perlin, a sponsorship by the Columbia-Geneva Division of U.S. Steel, and Alexander Construction Company. The system used light-gauge structural steel and prefabricated panels and flat or folded roofing. U.S. Steel and Bethlehem Steel were hoping to develop new markets for their products, especially in the housing sector. The single-level prefabricated affordable steel houses consisted of floor-to-ceiling windows and glass sliding doors that united indoor and outdoor spaces.

4.4 Rheemetal Steel Home System

The Alexander Houses employed the Rheemetal Steel Home System, including exterior walls, roofs, fascia, and trim. The package was trucked to the site and assembled by the Alexander Construction Company.

Figure 11: Rheemetal Steel Home Construction System

Fewer than 30 days were required to assemble, from breaking ground to completion. The curing of the concrete slab and the interior finishes took more time than the assembly of the metal shell. All rooms featured full-height sliding glass doors that opened onto exterior living spaces and swimming pools. Cantilevered overhangs afforded by the steel construction provided necessary shading.

Figure 12: Prefabricated Steel Erection and Construction, Steel Houses, Donald Wexler, 1962

4.5 Calcor

With U.S. Steel and Bethlehem Steel partially funding the project as part of a concerted effort to expand into the residential market, the wall modules consisted of an outer layer of light-gauge galvanized steel, a hollow core with gypsum board and fiberglass insulation, and drywall.

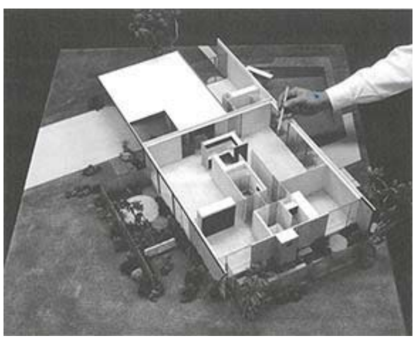

Figure 13: Alexander House, Model

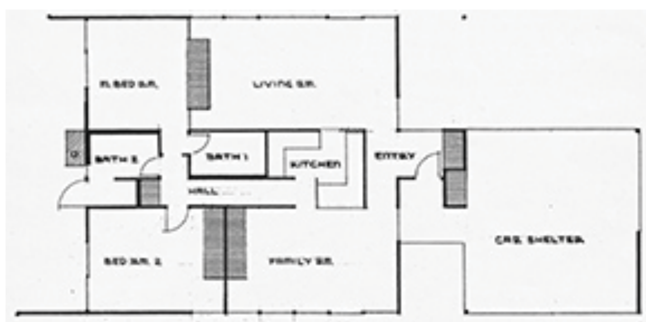

Figure 14: Alexander House, Floor Plan (2 bed, 2 bath)

The 9-by-36-foot central core (kitchen, bathrooms, laundry room, central hallway, and mechanical runs (electrical, ductwork) were prefabricated off-site, trucked to the site, and lowered onto a concrete slab by crane. The outer rooms were assembled around the core using the prefabricated steel panels, which were fit into a track template in the slab, interlocked, and bolted. The roof, also light-gauge steel, was then overlaid and bolted, supported both by the central core and the outer load-bearing steel panels. Each major room featured 8-foot-high sliding and stationary glass panels. Outer structural assembly took 3 days. Calcor's kit of parts used interlocking 16-inch wide steel panels ranging from 18-22 gauge with 3-inch flanges or ribs at each end. The panels, typically spanning 13 feet, were screwed, pop-riveted or bolted together and placed into a steel channel raceway inset into the concrete floor slab to hold the walls. Identical roof panels received steel tabs every three panels to hang ceilings and mechanical runs. Where columns were needed at openings or corners, instead of electing more expensive hot-rolled structural steel, Calcor employed the systems galvanized cold-rolled steel for hollow square tubes with 3/16-inch thick walls. The tubes were also used to drain roof water, which would be prohibited today due to fire rating regulations. Insulation consisted of drywall pieces set into the cavities overlaid with fiberglass batt and an added 1/2-inch thick drywall, which deadened the sound of the light metal building. The exterior walls and factory-built 9-by-36 foot core of the two bathrooms and a kitchen supported the roof, permitting flexible interior configurations. Wexler & Harrison animated the site plan by flipping floor plans and orienting the houses differently. Different roof configurations further individualized the modest orthogonal buildings.

Figure 15: Steel House #1: Construction Photo and Completed House from Simms Road

4.6. Principles, Strategies, Methods and Materials

The experimental Alexander Houses offer numerous advantages to home construction standards and quality measures as compared with more conventional uses of on-site, wood-framed construction with high labor costs, poor and uneven construction quality, low durability, high maintenance and high building depreciation. The manner in which Wexler & Harrison conceived, designed and built the seven all-steel houses hold several valuable characteristics as robust prototypes for the design of future urban and sub-urban housing:

Construction Characteristics	**Design Characteristics**	**Impervious Characteristics**
Pre-engineered Design	Integrated Design	Heat
Off Site Prefabrication	Indoor and Outdoor Relationships	Warping
Quick On Site Erection Time	Daylight and Shade	Rotting
Highly Durable Materials	Adaptable and Flexible	Swelling
Very Low Maintenance	Structure and Form	Termites
Economical, Value Appreciation	Precision and Modest	Fire

But the question remains: If the all-steel prefabricated system has all of these positive characteristics, why haven't more all-steel houses been produced since the mid-60’s? There may be several reasons: 1) profit margins – as demand for wood construction rises, the construction cost drops and profit margins rise; 2) unions – powerful construction unions are typically averse to prefabricated systems in the housing market; 3) new techniques – novel construction techniques are difficult to overturn conventional norms.

5.0 Alexander Houses Today

(photos by C Jarrett)

Steel House #1: 290 E. Simms

Steel House #2: 3125 Sunnyview

Steel House #3: 3133 Sunnyview

Steel House #4: 3165 Sunnyview


Steel House #5: 300 E Molino


Steel House #6: 330 E. Molino


Steel House #7: 3100 Sunnyview

6.0 CONCLUSION

The all-steel Alexander Houses represent an important chapter in the history of American modern architecture. They demonstrate an effort to re-establish novel solutions for addressing the growing need for durable, low-maintenance, economical, low-rise, light-weight, and inspired prefabricated housing. According to author and critic Alan Hess, the steel houses "moved beyond a custom expression of the modern machine to actually incorporate the assembly line processes and mass production that were the essence of modern technology." In 2001, all seven steel houses were registered Class 1 Historic Property status. In 2012, U.S. Department of the Interior recognized Steel House No. 2 in the National Register of Historic Places, making it the first midcentury structure in Palm Springs to be so designated.

In 2000, Donald Wexler sold his firm to WWCOT, based in Southern California, with offices in Riverside, Los Angeles. In 2004, Wexler was named a Fellow of the American Institute of Architects. Five years later, in 2009 Wexler was the subject of a documentary titled *Journeyman Architect: The Life and Work of Donald Wexler*. In 2010, with increasing numbers of mergers and acquisitions during the recession, WWCOT merged with the large mid-west firm DLR Group. In 2015, the DLR Group won the commission to design the new football stadium at UNC Charlotte.

REFERENCES

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[1] Who's Who in America, 40th edition, 1978-1979

[2] The General Houses, Inc. building system was the subject of U.S. patent 1,969,125 issued August 7, 1934.

[3] Fisher's company was considered the "Next Big Thing."

[4] “Our Homes," advertising brochure published by General Houses, Inc., editors J. Eugene Armes, Ruth Fisher, and P. D. Paddock, Chicago 1934. One house built by General Houses was built on the side of a hill, three stories, with the living room on the topmost floor to best enjoy the view.

[5] In 1986, the houses were added to the National Register of Historic Places, collectively known as the “World’s Fair Houses.” They are currently being restored through a partnership between the National Park Service, the Indiana Landmarks Commission and private individuals. It is reported that as visitors passed through the houses during the World’s Fair, many purchased plans of these prefabricated houses and erected the designs in other states.

[6] Neutra’s 1929 Lovell Health House is considered to be the first steel-frame residence in America.

[7] Wexler & Harrison later teamed with Cody to design the 1958 Palm Springs Spa Hotel, and would subsequently be commissioned to design the open-air Palm Springs Airport.

Jori Ann Erdman, George Peter Dodds

Re-Architecting Practice One Project at a Time: Duvall Decker Architects' Addition to Tougaloo College

Re-Architecting Practice: Duvall Decker Architects' Addition to Tougaloo College

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Abstract: *This paper is an excerpt from ongoing research, started singly by George Dodds, University of Tennessee, in 2015, and developed jointly by Dodds and Jori Erdman, Louisiana State University beginning in 2016. It is part of a larger monograph and symposium project with a projected end-date during the 2019-20 academic year.*

The practice of Duvall Decker Architects has been taking shape across two decades in the relative remove of Jackson, Mississippi's Fondren neighborhood. Duvall and Decker have embraced paradigms of the urban south, combining program, materiality, and landscape to create projects subtle and complex in a practice that is innovative in its structure and situ. Their work represents a sea change in convential practice; they are helping to redefine the nature of practice, and the relationship of the individual practice to the collective discipline. The surpluses they provide include regional specificity, socially-charged agendas, and real-time maintenance to ensure a building's salubrity, just-in-time manufacturing facilities, education programs for contractors, and civically-minded project development. To varying degrees, all represent a re-architecting of practice, none of which is explained away by the emergence of digital technology. Our focus is the Bennie G. Thompson Academic & Civil Rights Center at Tougaloo College in Jackson. Along with their innovative re-thinking of public housing (Jackson Housing Authority Mid-City Housing Project), this project highlights themes and strategies common to their oeuvre. For example, Thompson Center is informed by their deep appreciation for a reading of the history of the campus. Varied interpretations of the ubiquitous southern porch, striking site strategies. inventive detailing, and a limited material palette, permeate their work. But it the firm's continued involvement on the site beyond the design and construction of the singular building that bears further study. The work of Duvall Decker represents not simply an expansion of normative practice; it is a re-architecting of practice: a 21st century, multi-valent practice wherein design intersects with clients, culture, and construction, producing works and ways of working that suggest a refiguration of the profession.

> In all that gargantuan paradise of the fourth-rate there is not a single picture gallery worth going into, …or a single public monument that is worth looking at, or a single workshop devoted to the making of beautiful things. …[W]hen you come to critics, musical composers, painters, sculptors, architects and the like—there is not even a bad one between the Potomac mud flats and the Gulf. …In all these fields the South is an awe-inspiring blank.... H. L. Mencken, "The Sahara of the Bozart" *New York Evening Mail* (1917)

> What is true of the geographical elements in building was even more true of the social conditions. Half the misdemeanors of architecture in every age are the result of an attempt to fit rational structures into an irrational social pattern. ...[I]n its larger applications, the quality of architecture is governed by the conventions and ideals of the community: architects will do things in one way when human values are uppermost…. Hence the international style cannot be a mechanical stereotype: it cannot take a form that was beautifully adapted to the geographic and social environment of Birmingham and apply it, without modification to Bombay; it cannot even take a form that was finely adapted to Birmingham and apply it blindly to Montgomery. Louis Mumford, *The Architecture of the South* (1941)

> Architecture as building is always political, because it literally embodies a mixture of state interests and clan interests.... The sliding scale between collective and individual ambitions becomes frozen in structure; architecture is therefore always a snapshot of a political climate." Jack Self, "Does politics have any place in architecture? *The Architectural Review* **(**30 September, 2015)

Preface

Medgar Evers, the regional organizer for the NAACP in Jackson, Mississippi, was shot through the back in the carport of his modest home on Margaret Walker Alexander Drive. He died about an hour later – the first African American ever permitted to perish in one of Jackson's whites-only hospitals. His murder marked that start of what would be a decade of political assassinations and social upheaval in The United States – beginning on a quiet residential Jackson street, and ending in a service corridor of Los Angeles' Ambassador Hotel.

June 05, 2018, marks the 50th anniversary of America's second Kennedy assassination; June 12, the 55th anniversary of the Evers murder. Between the two America lost its 35th president; civil rights volunteers Michael Schwerner, James Chaney and Andrew Goodman; and the two most influential civil rights thinkers of the post-war years: Malcolm X and Martin Luther King, Jr. All but one were murdered in the American South; half in Mississippi. This is not to say the South, or Mississippi for that matter, are alone in this particular criminality. For example, Pennsylvania has long counted a Klu Klux Klan membership far larger than any single southern state, and the countless lynchings of 1919's Red Summer includes sites in Illinois and Indiana as much as southern locales. That said, it would be dishonest to not privilege the role of race in the story of Jackson's Duvall Decker Architects. The matters of color and cultural identity are twin predicates of a worldview onto a regional stage in which their work is a local agency for positive change and engaged criticality.

Unlike Memphis, Tennessee, which has yet to fully recover from, or make restitution for, Dr. Martin Luther King, Jr.'s murder,[1] Jackson has memorialized Mr. Evers' murder in several ways; their international airport carries his name and the site of his execution is now the Medgar Evers Home Museum, restored to its 1963-state by Anne Duvall, of Duvall Decker Architects (operated under the aegis of Tougaloo College). More recently, Jackson is now home to the Mississippi Civil Rights Museum. Ironically, the opening of the museum, attended by Congresswoman Bennie G. Thompson, itself was cause for additional civil unrest.[2]

1.0 Architect, Re-architect, Re-architecting

The terms "architect" and "architecture" have been increasingly nettlesome things to nail down with meaningful specificity at least since The Enlightenment. Yet, they remain among the most useful metaphors in the English language. Although legally protected professional appellations, they are perhaps two of the most plastic and promiscuous words in the contemporary topical press.

Architects and architecture are everywhere. Software has an architecture. Cities have an architecture. Organizations have an architecture. And all of these have "architects" in charge of organizing, designing, and directing production. Even wars have "architects"—not the Albert Speers of the world, but rather the generals and upper echelon who choose the strategies, tactics, and end states of warfare. It's not surprising then to arrive at the verbing of "architect," as in, "to architect" a thing. Nor ought we be surprised to learn that the most common use of this term is not in the practice of architecture, nor is it in the lexicon of most architects; rather, one finds it amidst the opaque landscape of software engineering.
Bloomberg.com describes the UK-based Everware-cbdi International as "a research company, [that] provides service oriented architecture and component-based development services". Their key company slogans are: "*Architecture* can drive delivery," and "*Agile Provisioning* Architecture Results". They've branded their core service: "Re-architecting". They explain, to "re-architect" a thing is "to provide greater agility." The goal of Re-architecting is to create "fine-grained architecture [that] enables: optimal scalability and performance; wider range of deployment options; and wider range of deployment option."

From their office in Jackson's Fondren neighborhood, the principals of Duvall Decker embrace paradigms particular to this southern site, responding to programmatic, material, tectonic, and landscape strategies. While their work is embedded in specific situations, the manner in which they have worked to re-architect their practice, are not perforce limited to this region alone. Rather, their work is a signpost of sorts, signaling a sea change common to a core group of contemporary practices that rigorously interrogate and challenge the received boundaries of practice, the academy, and the discipline.

The surpluses they provide include: territorial precision owing to long-term cultural studies; socially-charged agendas from work in the local culture and politics; real-time building maintenance to ensure their building's salubrity over time; detailed analysis to control costs and raise production quality; hands-on education programs for local contractors whose inadequate materials and methods disclose a building culture that has never approached contemporary building methods as craft; and financial development and management of projects to better control the nature, direction, and quantity of their workload. While no single one of these is particularly remarkable, the manner in which Duvall Decker combines this multitude represents a watershed moment in the profession, none of which is explained away by the emergence of digital technology or the groundswell in "alternative" practices.

Can practice be re-architected? Rather than directly answering this question, we aim to explicate through a study of The Bennie G. Thompson Academic & Civil Rights Research Center at Tougaloo College (Fig 1).

This project, the culmination of a series of projects at Tougaloo, highlights fundamental Duvall Decker themes and strategies; it demonstrates ways in which their practice offers new possibilities for architects to expand and question traditional boundaries of the profession. We focus on the specific themes of cultural identity and territorial specificity that are not limited to design tactics and strategies alone; they include architect-client relationships and an almost familial bonds with larger cultural and physical geography in which they work. We maintain that the work of Duvall Decker represents not simply an expansion of practice, but rather a re-architecting of practice: a 21st century multivalent practice wherein design intersects with clients, construction and land in new and often unexpected ways, producing works that potentially redefine the roles, responsibilities, and limits of the profession.

2.0 "Carpetbaggers" and "Scalawags"

Duvall Decker Architects' story is an unlikely tale that's far from finished. The following describes and unpacks the character and nature of a complex and nuanced position, developed across two decades of practice and half again as many years of study.

Fine designers, yet this is not a story about trend-setting design.[3] Their buildings do not look like interstellar birds of prey perched on unwilling hosts. Quite adept at matters of materials and methods, neither is this a story of new or emerging technologies – digital or analog. They do not clad their buildings in skin that follows the sun, nor do their buildings harness desert winds, turning turbines churning out gigwatts of electricity (Fig 2). One must look elsewhere for such things. The recipient of much national press and dozens of design awards, that which is worth learning from Duvall Decker's work resides only partially in the finely designed objects they produce.

Fig 1 Bennie G Thompson Center at Tougaloo College

Fig 2 The Jackson Housing Authority project is constructed of humble materials and methods, yet challenges preconceptions of what affordable housing can look like.

Detail-oriented critical regionalist practices; architect-as-developer; design-build practitioners; civically minded architecture: there is nothing new about any of these. We have seen them before in varied combinations and see them still. Each has its value. Moreover, one can find the usual suspects of super-sized international firms that offer clients a wide-ranging portfolio of services. Duvall Decker, however, is the inverse of the Genslerized Generation. They have marked out their territory of practice by assembling the aggregate of these topical services, and a few more, while maintaining the twin foci of regional specificity and the a carefully researched mapping of the culturally constructed sites within which they dwell and in which they build. The manner in which they combine the quotidian care of the life of the buildings they design; the manner in which their drawings of details become constructed on site; how the practice of civic and institutional architecture can substantially engage the *praxis* of community building, its many challenges notwithstanding; and how, in some cases, commercial projects begin not with an outside developer, but inside the offices of Duvall and Decker themselves.

They understood from the start that their's could be neither a boutique practice for academicians, nor a normative practice of RFP sifting and high-end houses for the *Dwell* set. For their practice to survive, let alone succeed, it required of them a new operational model; they could not get there by local contacts nor design alone. This is the core of their story and perhaps the chief lesson to be learned from what they do.

Roy Decker is native to northern New Jersey, educated at Kent State University. He taught at Temple University in Philadelphia before Dean John McRae, FAIA, at Mississippi State University (MSU) hired him to help remake the Starkville program. Anne Marie Duvall, a native of Humbolt, Tennessee, studied at MSU where she and Decker met. Decker took up residency in Jackson, Mississippi in 1993. He became director of MSU's School of Architecture's urban studio, located in Jackson, in 1995. The two formed a partnership not long after. When Decker established his firm with Duvall, he did something else very much out-of-the-mainstream; he surrendered his tenure at the MSU School of Architecture to devote himself more fully to their practice.

Even though Duvall is from northwestern Tennessee, as a couple they arrived as outsiders and de facto "carpetbaggers" – a term with a complex history. Among its many, less pejorative, definitions is: "northern interlopers intent on measures aimed at democratizing and modernizing the South – civil rights legislation, [and] aid to economic development…".[4] This fits well their intent and what they've achieved to date.

If Duvall Decker assume the role of "northern interlopers," their client's role is that of "Scalawags": a vilification that gained currency during Reconstruction. Among its definitions is "a white Southerner who collaborated with northern Republicans…, often for personal profit…".[5] The inescapable irony is that roughly 80% of their client base are African American leaders in the community or the presidents of Historically Black Colleges and Universities (HBCU), many of whom still have direct connections to the Civil Rights movement of the 1960s: hence, the inverted commas. Among the most politically and culturally complex of their HBCU commissions, and perhaps the most successful architecturally and urbanistically, is Bennie G. Thompson Academic & Civil Rights Center at Tougaloo College.

Having finally realized several significant institutional commissions at Medger Evers' alma mater, Alcorn State University and Tougaloo's Thompson Center among them, they soon identified a problem they had not yet encountered; their buildings, while well-detailed and constructed, nonetheless aged rapidly owing to grossly inadequate building maintenance. In *Maintenance Architecture*, Hillary Sample describes a dilemma common to much high-end architecture.

> Modernism sought to minimize this spectacle of maintenance through technology. The idea was to create a fixed building image that could be maintained by devices like the squeegee, tilt windows, and window-washing rigs rather than by people. Buildings had to be kept in order to preserve their relationship to the photographis of them distributed in books and magazines, to always retain their immediate post-construction imageability. Such an ambition could be achieved only through limiting dependence on a profustion of technological devices and gadgets to keep the building looking as intended.[6]

Duvall Decker's problems, however, were of a very different sort. While they tend to hire the services of Balthazar Korab's protégé Timothy Hursley to photodocument their work, their concern was not about maintaining the gloss of four-color print journalism. Rather, they confronted the more earthly challenge of repairing the daily insult their buildings suffered from institutional building and landscape maintenance crews, careless students, and the occasional irate employee. Moreover, this advanced weathering was hardly limited to their own buildings; it was endemic to the region. Their maintenance company, Dunn Management, slows these vicissitudes while employing and training the unemployed and underemployed and, at the same time, financially supporting their architectural practice.

Once they became stewards of their own buildings, this new "post-occupancy" station point soon underscored the necessity of developing, and in some cases constructing, their own designs vis-à-vis the third leg of their stool – Eldon Development. Indeed, that which makes Duvall Decker worth further study is that, unlike most architectural firms that, during the past 30 years, have consciously distanced themselves from as much liability as possible, Duvall and Decker has moved agressively in the opposite direction. Speaking with The New York Times' Michael Kimmelman on the occasion of the firm's recognition by the New York Architectural League, Duvall explained: "Assuming more risk and responsibility has also given us a stronger voice, upfront, in this community, with politicians and businesspeople…because we have skin in the game."[7]

3.0 Urban South | Global South

It's been well chronicled in daily newspapers, topical magazines, government and NGO reports, that for some time now, the gap (financially and culturally) between the top 1% and the rest of the American population, is at its widest since records on such matters have been kept. The unintended consequences reach across the globe and resonate in virtually all aspects of human endeavor: access to influence, education, advancement, housing, wealth, etc. The list is its own lamentation.

In The United States, for example, between 2009 and 2015, American wealth increased (overall) by 60% while child poverty increased by 60%. Of course, virtually all of that wealth production was limited to a tiny percentage of the 1% income bracket. No less remarkable, "the richest country in the world" has been a world leader in child poverty for far too long, at times alternating that position with Romania. Nowhere in the 48 contiguous states is this more keenly apparent than in the state of Mississippi. Jackson, the state's capitol, has been until late, more the rule than the exception. While the US poverty rates at 12.7% and Mississippi State poverty at 22%, Jackson falls even further behind with a poverty rate of 31%. With an African American population of 80%, it is easy to extrapolate who is most effected by poverty in this community.

Over the course of the past two decades, the practice of Duvall Decker Architects has emerged in the relative remove of the urban south. Urban geographer Seth Schindler has postulated that cities in the global South have particular characteristics that distinguish them from cities in the north including governance that has focused more on territorial transformation than improving the human condition; dynamic energy flows that are irregular; and the materiality of Southern cities is interrelated to political economy (Schindler 2017). For the purposes of our study, we contend that an argument can be made for including the southern US within the Global South, and Jackson, Mississippi in particular. In order to understand the practice of Duvall Decker, one needs to understand the southern urban context within which their practice has evolved. The characteristics provided by Schindler provide this context and are useful in illuminating some aspects of the Duvall Decker practice as both part of the context and resistant to aspects of the context.

Part of the complexity in understanding the work and practice lies in the difficulty of defining the south itself, as addressed by Lori Ryker in her introduction to the monograph on Mockbee Coker:

> The identity of the South builds upon each community's truths and mythologies which are not easily forgotten, while the future moves ahead. In simultaneous acts the present twists back on itself describing the past and pushes forward, leaving tradition without context. … The South is a land of mystery with a historical legacy comprehensible to most through its social and cultural traditions. But it is precisely these traditions and their contradictions which makes the life of a Southerner so difficult to grasp objectively. The difficulty of clearly understanding the South can be seen in the inability to reconcile several contradictory traditions.[8]

The trajectory of Duvall Decker is prefaced by other southern architects including Charles Colbert, one of the first great modernists to work in the South, as well as more contemporaneous practices including Scogin Elam & Bray (now Scogin Elam), Mockbee Coker and Clark Menefee. In the work of Duvall Decker these practices are extended and amplified, changing the nature of architectural practice itself.

4.0 Craft in The Technological Society: Diverging Paths

During the past two generations, the education of architects has largely followed practice rather than informed practice. Since Rem Koolhaas' "research studios" at Harvard's Graduate School of Design, much has been made of architectural firms that have either created their own in-house research enterprises (Kieran Timberlake Architects, Philadelphia), or otherwise aligned themselves with either industry or the academy. Yet, with few exceptions, these operations are either data-driven or applied research. The former – Koolhaas' thematic studios on Lagos and Shopping – or the latter, those at the University of Minnesota and at The University of Pennsylvania's School of Design, represent opposing poles of a spectrum with little in between.[9] While the former tends towards what Alberto Perez-Gomez characterizes as "decorated information," the latter is product driven, aligned with user groups, "real world clients," and industry partners that substantially influence the curriculum. This control comes in two forms: direct – specifying the sorts of projects and/or materials they will sponsor; and indirect – by default – that is by virtue of what thy choose to financially support.

Not since the post-war years has the profession so singularly aligned itself with research in the sciences and directly appropriated the techniques and lexicon of industry, including the military industrial complex. At the same time, as practice and the education of architects has become increasingly technocratic, so too has its research and its researchers. Conversely, while the profession and the discipline raise the stakes of technocratic enterprises, in places such as Jackson, Mississippi – at least the one Duvall and Decker found in 1995 – the quotidian culture of construction was of a different sort.

5.0 Architecture Out of the Shadows: Kin

The Bennie G. Thompson Center is informed by their historical knowledge and profound apprehension of the rich and storied campus. From its founding on the site of a former slave plantation by the American Missionary Association, through its role in the Civil Rights movement, Tougaloo is a multi-layered site – physically and temporally. Duvall Decker infuse these severally in the Thompson Center. First, the development of the project began as a small series of projects and the cultivation of a trusting relationship with the administration of Tougaloo, which is part of the kinship nature of business and politics in the south. Physically, cultural interpretations of the ubiquitous southern porch permeate the Thompson Center, with the porch transformed into a striking, albeit subtle, site strategy with inventive detailing and limited material palette. Finally, their understanding of the project as part of a larger narrative structure of the Civil Rights movement in Jackson informed decisions about space, materials and cladding within and throughout the building.

Southern business relationships often revolve around the oft-cited characteristic of kinship to grow and maintain professional enterprises. Kinship is the anthropological term for a strong tendency to rely on familiarity and sameness and reject those outside of one's group. Strictly speaking, kinship relies on blood relationships, but given the complexity of southern lineages, blood ties are not a delimiting characteristic. Knowing someone, or a business, and feeling comfortable with a common language or shared concerns, as well as affection, create kin-like feelings, which often guide decisions, even business decisions, more than more objective criteria. A strong sense of kinship has been found in both white and black American communities, particularly in the South and throughout the African American diaspora.

It is through patience and a willingness to build trust over time, that Duvall Decker has cultivated relationships with clients that lead to bigger and more significant commissions over time. It is our contention that these relationships grow in part due to the predilection in the deep south for kinship relationship that guides client comfort but is built on the firm's commitment to ethical and conscientious attention to the client in all manner of project. The firm partners work closely with clients and decisions makers to build trust, making them eligible for more work and creating a long list of projects small and large with a committed group of clients, such as the administration at Tougaloo College. Building the trust at Tougaloo has also extended their prospective client base to other HBCU's and minority serving institutions around the state of Mississippi. In fact, Duvall Decker records show that over 90% of their business is from repeat clientele and each client averages at least 6 projects. Their unconventional practice of tapping into kinship relationships is one of the ways in which Duvall Decker taps into and mines the regional culture of the South.

By tracing their relationship with the administration at Tougaloo College, we see a pattern of conscientious attention to the client that is typical of the practice. Initially hired to do facility planning for some historic structures on campus, the firm quickly demonstrated and aptitude and willingness to engage that lead to additional work around the campus including master planning and the design of a student center. The President of Tougaloo, Beverly Wade Hogan, summed it up in an interview with NY Times writer, Michael Kimmelman, "Roy and Anne listen."

Their initial project at Tougaloo was introduced to them through the firm of WFT Architects, where Anne Marie has interned on their renovation of the Medgar Evers House, a property that had been bequeathed to Tougaloo in 1993 by Myrlie Evers. WFT was commissioned to assess and design a renovation to the historic "Mansion," the original plantation house that was part of the property on which Tougaloo was founded in 1869 by the American Missionary Association. As WFT focused primarily on preservation of historic structures, they introduced the nascent firm of Duvall Decker, a committedly modernist firm, to Tougaloo to complete an assessment of the campus library designed by Gunnar Birkerts in late 1960's and constructed in the early 1970's. The library is one of two remaining Birkerts buildings that were part of an ambitious masterplan created by the master architect. Duvall Decker's next project was a reworking of the Birkerts windows in a dormitory that now lies empty. Eventually Duvall Decker worked with WFT to complete an updated master plan for the university that included plans for the Bernie G. Thompson Cultural Center.

6.0 Porch

The porch is well recognized as having specific meaning, resonance and purpose in Southern culture and life. As a mediated (shaded) outdoor space, the porch functioned to raise people out of the dust or mud and bugs and provided a place that was neither intimately private, nor completely exposed, on which to gather. Prior to the develop and widespread distribution of mechanical cooling, one would be hard pressed to find a home anywhere in the south that did not have at least one porch. And the existence and use of a porch was not unique any class or racial distinctions, everyone had one or more. Typically homes incorporated a front porch that was more public for sitting, watching, communing and resting, with a back porch for more of the business of the home. A liminal space, the front porch functioned as a place of gathering for families and communities at large. The porch is so embedded in both the functioning and spirit of the south, that it has become a trope across the narrative and visual arts for the south itself.

At the Thompson Center, Duvall Decker employs the porch trope through the entry sequence. In this case the porch extends well across the front of the building, increasing the opportunities for gathering in the shade and chance meetings with friends (Fig 3 and 4). The space of the porch both welcomes and protects as well as providing shade and depth across the windows of the entry. The materiality of brick and concrete and the detailing are all modern, but the idea is quite old.

Fig 3 Thompson Center porch as shading device.

Fig 4 Thompson Center porch as gathering space.

7.0 Conclusion

Writing in 1941, in *The Architecture of the South*, Louis Mumford observed severally, a fundamental notion that a generation later would go by such names as "Critical Regionalism," and "Critical Architecture." Less than a decade after co-organizing the epoch-making, "Modern Architecture: An International Exhibition," for the Museum of Modern Art, the social critic purposefully distanced himself from his co-curators Henry-Russell Hitchcock and Philip Johnson: "The international style cannot be a mechanical stereotype: it cannot take a form that was beautifully adapted to the geographic and social environment of Birmingham and apply it, without modification to Bombay; it cannot even take a form that was finely adapted to Birmingham and apply it blindly to Montgomery."[10] At the close of the 21st-century's second decade, "criticality" in architectural discourse and among presumptive avant-garde practices, ranks among other walking wounded of post-modern/post-critical/post-Fordist practices. Yet, the agency of Duvall Decker's architecture, the predicate of their re-architecting practice, resides within its ability to establish a critical distance from their subject based on the architect's close readings of the cultural objects they apprehend and re-imagine.

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[1] King was shot on the balcony outside Room 360 of the Lorraine Motel. The Lorraine, now the National Civil Rights Museum, recently restored, is virtually the only architectural or civic marker of any import that memorializes that epoch-changing slaughter in the city. In a recent Op Ed piece in *The New York Times,* Wendi C. Thomas chronicled how Memphis' promininent Loeb family, principally responsible for the need for Dr. King's final travel to Memphis, continues to profit from the same regressive politics and economic repression that prompted the Garbage Collector's Strike in the first place. See, Wendi C. Thomas, "How Memphis Gave Up on Dr. King's Dream," *The New York Times* (April 01, 2018): p. SR1.

[2] Michael D. Shear and Ellen Ann Fentress, "Trump, Rejecting Calls to Stay Away, Speaks at Civil Rights Museum," *The New York Times* (December 10, 2017): p. A 22.

[3] "The architect Billie Tsien was a juror for the Architectural League in New York that just gave the Deckers an Emerging Voices award. 'There's a lot of fashionable work out there,' Ms. Tsien said. 'Anyone who has done public work for nonprofits can appreciate the effort it takes to make even a smidgen of architecture happen.' Michael Kimmelman, "On a Design Mission in Mississippi," *The New York Times* (February 21, 2017): p. C1.

[4] Eric Foner, *Reconstruction: America's Unfinished Revolution 1863–1877* (New York: Harper & Row, 1988): p. 296.

[5] *New Oxford American Dictionary*.

[6] Hillary Sample, *Building Maintenance*, (Cambridge, MA: The MIT Press, 2016): p. 31.

[7] Kimmelman, "On a Design Mission in Mississippi," *Ibid*.

[8] *Lori Ryker, editor, Mockbee Coker: Thought and Process*, (New York: Princeton Architectural Press, 1995) p. 15.

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Edgar Stach

Mies van der Rohe. Space, Material and Detail

Mies van der Rohe
Space, Material and Detail

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Abstract

Ludwig Mies van der Rohe is widely regarded as one of the most influential architects and architectural theorists of the 20th century. His work is unmistakable in its clarity and the rigor with which it embodies the principles of rationalism and functionalism, as well as in its spatial qualities, material expression and detailing. Typical for his style is the clear definition of place, the idea of universal space, the legible logic of the construction and precise detailing. For Mies, technological advances were a driving force of architecture, a spirit of the times that architecture should embrace and express. Above all, clarity and structure, not just in terms of the construction but also in intellectual thought, were for him the only way to create architectural space. Space for Mies was something that continues beyond its physical limits and creates connections between inside and outside.[1]

Keywords: Space, Material, Detail, Universal Space,

1. Mies in Germany

Ludwig Mies van der Rohe was born on March 27, 1886 as the son of a stonemason and building contractor in Aachen. In his father's business, he first learned about the qualities of materials and how to work stone. He also grew to appreciate the value of high quality materials and of craftsmanship. As a singer in the boys' choir, he visited Aachen Cathedral almost daily and knew the Chapel of Charlemagne, remarking years later on his fascination with the way in which stone and mortar was transformed in the structure of the chapel. In his attempt to trace and comprehend its structure and construction lies the beginnings of an idea that would come to manifest itself in his architecture: that architecture is a language with vocabulary and syntax in which the separate parts relate to one another and form a whole.

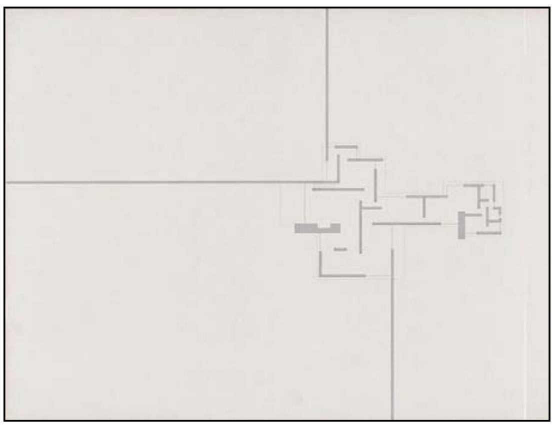
At the age of 15, he began an apprenticeship as a plasterer and developed his talent for drawing on room-sized plaster ornaments in the style of Louis XIV and the Renaissance. In 1904, he changed jobs to work as a draftsman in the architecture office of Albert Schneider where he met an architect from Berlin named Dülow who persuaded him to come to Berlin. Nevertheless, these early years of apprenticeship and his understanding of materials and craftsmanship were to put him in good stead for his later architectural work.

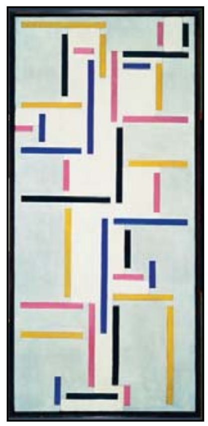
From 1905 onwards, he began working for the architect and furni- ture designer Bruno Paul in Berlin. His first work was a house for the influential professor and philosopher Alois Riehl (Riehl House, 1908) in the reform style, a building style that marked a return to simple forms and regional tradition. From 1908 to 1912, he worked in the office of Peter Behrens where he had the opportunity to advance his professional skills working on larger projects of greater significance including the German Embassy in Saint Petersburg and the AEG Turbine Factory in Berlin. His time in Berlin also marked the beginning of a lifelong intellectual interest in architecture the- ory, and he undertook a detailed study of the work of Karl Friedrich Schinkel.

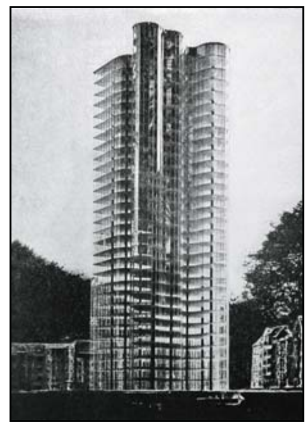
In 1912, Mies opened an atelier of his own and went on to build a series of villas in the neoclassical style until well into the 1920s. Of these, one of the most famous is the so-called Churchill Villa, a hip-roofed villa where Winston Churchill resided during the Potsdam Conference. Mies subscribed to the fundamental belief in a new modern age and saw himself as one of the avant-garde, a protagonist of the 'new age'[2] working tirelessly towards develop- ing a new kind of art appropriate to the modern living conditions of the day.[3] Parallel to his early villas, but in stark contrast to them, he developed five visionary studies designed between 1921 and 1925.

Although none of the five projects[4] were ever realized, mostly because they were highly idealized, they were presented in inter- national exhibitions on modern architecture. To this day, they are regarded as remarkably innovative designs and as the origin of his later work.

Although unrealized, these studies demonstrate his exceptional architectural vision and fundamental attitude to space, material and design. In his design for an office building on the Friedrichstraße in Berlin (1921) he presented a vision of an entirely glazed high-rise with a variable, open floor plan. A second study for a Glass Skyscraper followed in 1922, this time with rounded forms, and in 1923 two further studies for a Concrete Country House and a Concrete Office Building introduced novel concepts for building with the comparatively new composite material the known as ferro-concrete.[5] The office building, with its austere geometric form and wrap-around ribbon windows, can be seen as a precursor to his later high-rise blocks in Chicago. His last study for a Brick Country House in 1924, possibly inspired by a painting by Theo van Doesburg,[6] offers a first glimpse of the open floor plan defined only by freely-placed wall slabs. The concept of continuous space that visually connects inside and outside and allows space to be per- ceived freely according to standpoint was later to be the basis of the Barcelona Pavilion (1929) and Tugendhat House (1930).







Model for a glass skyscraper at Friedrich- straße, Berlin (unrealized). Print, 1921
Brick Country House, project Potsdam-Neu- babelsberg. Ink on illustration board
Theo van Doesburg: Rhythm of a Russian Dance. Oil on canvas, 1918

From the middle of the 1920s, Mies attained international repute as a curator and urban planner of the Werkbund Exhibition and the colony of the Weißenhof Estate, for which he designed four apart- ment buildings using a revolutionary steel skeleton construction with large expanses of glass and flexibly usable living areas. But his big breakthrough came with his designs undertaken in conjunction with the interior architect Lilly Reich[7] for the Villa Tugendhat in Brno in the Czech Republic and the Barcelona Pavilion in Spain. In 1932 Mies took part, together with Le Corbusier, Walter Gropius and J.J.P. Oud, in the 'Modern Architecture'[8] exhibition curated by Philip Johnson and Henry-Russel Hitchcock at the Museum of Modern Art in New York, catapulting him into the limelight in the USA. As work ebbed following the Great Depression in 1929, Mies took over as director of the Bauhaus in Dessau in 1930, concentrat- ing on the academic and theoretical study of architecture. After the seizure of power by the National Socialists in 1933, however, it became increasingly difficult for him to practice as an architect, and in 1938 he followed an invitation to become head of the architec- ture school at the Armor Institute in Chicago, which would later become the Illinois Institute of Technology (IIT).

2. Mies in the USA

Mies' relocation to the USA represents in many different respects a break in his architectural oeuvre. In Europe, Mies was able to build only a comparatively small number of buildings, but had achieved worldwide recognition through this expressionist skyscraper designs, the Brick Country House design and the Barcelona

Pavilion. He was a respected member of the European avant-garde with links to De Stijl and as co-publisher of the magazine *G*.[9]

In the USA, Mies was immediately successful in securing large projects. His spatial concept shifted from that of continuous space (Villa Tugendhat) to the idea of 'universal space' (as epitomized by the New National Gallery) and from the De Stijl-inspired expres- sionism of free forms to the rationalism of constructed symmetry. His European buildings were individual, unique works that cele- brated craftsmanship, while his American works – among them the Seagram Tower office building in New York – achieved archetypal status as ultimate examples of the International Style.

In 1939, Mies founded an office in Chicago and began one year later with plans for the new IIT Campus, for which he realized a total of 15 buildings between 1941 and 1958. Between 1950 and his death in 1969, he completed at least one new project every year. Among the many milestones in his American work are the high-rise apartment buildings at 860–880 Lake Shore Drive (1951) in which Mies employed an all-steel-and-glass construction for the first time, and Crown Hall (1956) – widely regarded as his American masterpiece – where he first created a column-free universal space.

Thirty-six years after his Glass Skyscraper study for Berlin, Mies built his first office high-rise, the Seagram Building in New York. With its sleek elegance and public plaza in front, that continues seamlessly into the glazed lobby, it became the prototype for modern office buildings around the world and influenced American architecture for several decades. For the high-rise apartment building at 2400 Lake View Drive (1963), he developed an aluminum curtain wall construction in which the outer load-bearing framework is set back from the plane of the facade into the interior of the building – a concept that became widespread for all comparable high-rise con- structions. The New National Gallery in Berlin (1968), completed towards the end of his life, represents the pinnacle of his vision for a universal space. In no other building is his concept of space and construction so clearly articulated as in this, the last of his works to be built in his lifetime.

3. Mies and Space

"The building art is man's spatial dialogue with his environment and demonstrates how he asserts himself therein and how he masters it. For this reason, the building art is not merely a technical problem nor a problem of organization or economy. The building art is in reality always the spatial execution of spiritual decisions."[10]

Mies' approach to the design of space can be broadly grouped into four evolutionary stages:

- enclosed space
- continuous space
- free plan[11]
- universal space[12]

During his early years as an architect, the villas he built exhibit a conventional spatial arrangement (enclosed spaces) of separate individual rooms and a polarity between inside and outside. The five studies he undertook from 1921 to 1924 parallel these pre- dominantly traditional-style built projects, however, point to a new kind of spatial thinking.[13]

The first projects to embody Mies' new spatial conceptions were two villas in Krefeld, the Houses Lange and Esters. Unlike his earlier villas in Berlin with their traditional arrangement of rooms and clear delineation of inside and outside, the interiors of these two villas flow dynamically from space to space in a new, modern conception. Moving away from the traditional idea of enclosed rooms, Mies arranged a series of diagonally staggered and offset spaces with progressively larger openings towards the garden. This diagonal sequence subtly interweaves the indoor and outdoor spaces. The ability to appraise several successive spaces simultane- ously served as the basis of a new spatial impression that recalls the idea of the Baroque enfilade. The American architect Philip Johnson described this new spatial perception as continuous space: "Indoors and outdoors are no longer easily defined; they flow into each other."[14]

With the building of the Villa Tugendhat and in particular the Barcelona Pavilion, Mies took his concept of continuous space a step further, composing a single space demarcated by a free com- position of elements.

This ‘free plan’ – a space structured only by free-standing wall planes – was made possible by separating the load-bearing columns from the space-defining elements. The spatial simultaneity and parallel experience of indoor and outdoor spaces, and of the entire spatial continuum, was made possible by conceiving entire facades as glass planes with sliding sections and employing the reflections of the water’s surface and polished natu- ral stone walls.[15]

The architectural historian Siegfried Giedion[16] described this new spatial conception in his book *Space, Time, Architecture*[17] using the new mathematical-physical model of ‘space-time’. Architecture is no longer experienced as individual compositions but through movement in space: the observer moves through an architectural space-time continuum. Beginning with Mies’ buildings in America, in particular his buildings for the IIT Campus, the idea of the free plan shifted to a predominantly symmetrical floor plan geometry. What remained, however, was the separation of load-bearing structure from the space-defining elements – the differentiation between the logic of the construction and the function of spatial arrangement.

The term universal space refers originally solely to the usability of a space and not to its spatial quality. Mies uses it to denote a large, free-spanned space enclosed only by a glass facade. To illustrate this concept, he used a photo of the interior of the Glenn Martin Aircraft Assembly Buildings, designed by Albert Kahn in 1939, as a background for a collage over which he placed a series of free- standing mobile walls and horizontal planes.18 The universal space is the ultimate expression of flexible space and can be modelled or adapted to fit almost any use. The New National Gallery is a mas- terly expression of this spatial concept and is the last of a series of buildings that begun with Crown Hall that are essentially column- less single story hall spaces. The universal space not restricted to a specific function represents an idealized abstraction of free and pure architectural space.

4. Mies and Construction

Mies’ guiding principles in his handling of construction and materi- als can be traced to the following four main principles:

- the search for clarity of construction
- reduction to a few formal elements and simple architectural design
- a constructional logic derived from the material
- the principle of simplicity and continuity between indoors and outdoors

The development of Mies’ constructional logic is that of a gradual shift from stereotomy, i.e. building with load-bearing walls, to tec- tonics, i.e. construction with columns and beams. Stereotomy is the art and craft of masonry construction. Tectonics is defined as the art of construction using linear elements clad or filled in with a light- weight material. Both terms derive from the terminology used by Gottfried Semper in his book The Four Elements of Architecture.19

Where Mies’ early buildings were inspired by Peter Behrens and Hendrik Petrus Berlage[20] and their monolithic wall constructions with articulated openings, Mies’ designs for the Lange and Esters Houses were a hybrid construction comprising load-bearing brick external walls and a skeleton frame of rolled steel profiles. The almost entirely autonomous steel construction made it possible to both construct large window openings linking the interior and garden and to vary the floor plan on each floor.

The construction for Mies was the very basis of the art of building, asserting that “form is not the goal but the result of our work.”[21] His glass skyscrapers, constructed as steel skeleton frame buildings, epitomize his rational style, which he called ‘skin-and-bones-archi- tecture’.[22] Of all his works, Farnsworth House is most exemplary of Mies’ fascination with tectonics, a building that he describes as consisting of “practically nothing".[23] The supporting framework is both the basis and prerequisite for the free plan of the building. The floor and roof planes are held by a series of columns around the perimeter, creating a one-room house that is separated from its surroundings only by glass walls. But for Mies, it was not the con- struction itself that was paramount but the fact that it made it possible for him to realize his concept of a free plan and universal space.

Mies is regarded as a master of precision, and this is particularly evident in his rational organization of an overall building grid. In his brick buildings, Mies was already careful to observe brick dimen- sions and masonry bond patterns. Likewise, his design for the Barcelona Pavilion adheres to a grid system that defines the size of the travertine slabs of the plinth, the wall planes, glass walls and columns. For the pair of apartment blocks at 860 and 880 Lake Shore Drive, a single building grid defines the structure of the two buildings both horizontally and vertically and coordinates the alignment of the travertine paving joints on the plaza, the column grid of the facade all the way down to the stone facing of the lift shafts in the lobby. He also applied the same principle at an urban scale, arranging all the buildings of the IIT Campus in Chicago on a 7.32 × 7.32 m grid (24 × 24 foot).

While Mies applied the principle of modularity to everything from brick masonry to curtain walling for high-rise buildings, he was not interested in the mass production of architecture. For him, every building was unique and not an industrial product. His interest in traditional craftsmanship in the 1920s is very much evident in his designs for the early Berlin villas and in the meticulous brickwork of the Lange and Esters Houses. By the late 1920s, Mies grew increas- ingly interested in using industrially produced materials such as glass and steel. Despite his ongoing interest in modern materials, he was only moderately interested in the industrialization of build- ing. The kind of mass production proposed by Walter Gropius or Le Corbusier was of little interest to him, but the proper use of good-quality materials and good craftsmanship was ever more important. In his own words: "…no design is possible until the materials with which you design are completely understood."

5. Mies and Materials

Mies' declaration that "each material is only what we make of it"[24] describes his fundamental approach to materials. Because his buildings are so rigorously geometric and unadorned, their appear- ance is much more dependent on the careful choice of materials, balanced proportions and meticulously precise detailing. "Each material has its specific characteristics which we must understand if we want to use it".[25] For him, this applies equally to craftsmanship as it does to industrialized technologies, and to combinations of natural materials, such as marble, onyx and travertine, and industri- ally produced products such as chrome, glass, steel and aluminum.

5.1 Brick

> "Architecture starts when you carefully put two bricks together."[26]

Red brick, for Mies, fulfilled two main functions. On the one hand, it relates the material of the building to nature, and on the other, it is an expression of man's rationalism and reason. It is a universally usable material that Mies employed with a timeless quality in all phases of his work: in his early work as a load-bearing wall, then as a facing material and finally as non-load-bearing infill in frame constructions. In his American buildings, brick is used solely as a facing material or as brick infill in a steel skeleton frame structure. The only exception is the Carr Memorial Chapel on the IIT Campus with its monolithic, load-bearing external walls.

5.2 Steel

Mies first made use of a steel skeleton frame in 1927 for the Weißenhof Estate in Stuttgart. From the time of the Barcelona Pavilion and Villa Tugendhat in 1928, steel became Mies' preferred material for the load-bearing structure. The ability to reduce the structure to a few slender columns made it possible to develop designs with a free plan. Mies himself said that the Barcelona Pavilion was the first time he separated the function of the columns from that of the walls. In both projects, he clad the cruciform columns, made of four angle profiles screwed together, with a chrome mantle. Here, he was more interested in dematerializing the columns and their aesthetics than the technical details of their connections. As fascinated as he was with perfecting precise details, he was not at all enamored with the raw industrial aesthet- ics of nuts and bolts. Where possible, he concealed the connec- tions, as seen in Farnsworth House, or he preferred the welding together of steel profiles, such as in the roof construction of the New National Gallery. For the Villa Tugendhat, with its two-story steel frame, the construction is only articulated as free-standing cruciform columns in the main living area, while on the upper level the columns are concealed within the walls for pragmatic reasons. The construction is made visible in an idealized, abstract form. It is not self-serving but serves the room.

Apartment building at 860–880 Lake Shore Drive under construction. The photo shows the structural columns and the non-load-bearing I-beams.

Crown Hall under construction, IIT, Chicago 1955

For the high-rise apartments at 860–880 Lake Shore Drive, Mies employed steel for both the building structure and the facade for the first time. He developed wall and facade systems made of visible steel profiles that made reference to the actual construction but were, as a rule, not part of the actual supporting framework. With their clear forms and functionality, their rational steel frames and curtain walls, the steel skyscrapers in Chicago were a prototype of the modern high-rise block. "Steel," according to Mies, "… is the bones, glass the taut skin over the skeleton."[27]

Mies' concept of universal space, realized as a column-free multi- functional space, was made possible by the wide spans of steel roof constructions. The roof of the New National Gallery is an especially complex engineering feat with a grid of steel members supported on just eight columns. The construction was welded for aesthetic reasons and the thickness of the roof 'slab' is slightly taller towards the outer edges and in the centers to create the optical impression of being completely flat without appearing to sag. The entire roof was assembled at ground level and then hoisted upwards with hydraulic presses to rest on the columns. This was without doubt the most technically complex of Mies' buildings made of steel.

5.3 Glass

The importance of glass as a material for Mies can already be seen in his idealized designs for an office high-rise on the Friedrichstraße and glass skyscraper at the beginning of the 1920s. Its novel construction concept shows the column grid set back from the front plane of the facade and a completely glazed facade membrane. The 'window' as a link to the surroundings and indicator of human scale was replaced by a facade that responds universally to its surroundings and became generalized as an expression of the International Style. "My experiments with a glass model help me along the way and I soon recognized that by employing glass, it is not an effect of light and shadow one wants to achieve but a rich interplay of light reflections."[28]

The dematerialization of the wall and unhindered connection between the interior and the natural surroundings was first realized most convincingly in the Barcelona Pavilion and taken to perfection in the Farnsworth House. The material glass and transparent building skin are an essential part of Mies' architecture. He interpreted transparency[29] in two respects: in the direct sense as a property of light- and air-permeable materials and in a figurative sense as a means of spatial arrangement in which several different spaces can be seen at once.

The most lasting influence on the architecture of offices and work- places was without doubt the development of the curtain wall, first seen in the buildings on Lake Shore Drive and Lake View. The breakthrough for this new suspended facade system, however, came with the Seagram Building in New York (1958). Mies succeeded in applying the highly efficient facade unit as an internal organizational system. The system of grid-based modular facade panels was used as an ordering principle for the adaptive spatial planning, at the time a revolutionary new concept for flexible work- spaces. This also made it possible to incorporate modular installation elements within the building skin, for example office partitions and lighting and ventilation systems. The curtain wall became the new uniform face of the modern city and not only corresponded to the new modern age but also created the conditions for efficiently organizing staff in the universal workplace. Through standardization and categorization, the curtain wall was replicated endlessly, ultimately undermining the role of the designing architect and Mies' idea that each building is unique and site-specific.[30]

Conclusion

For Mies, flexibility and the ongoing development of tried and tested concepts was more important than originality – each new building improved on and perfected his earlier work. Over a period of 60 years, he continued to explore the same primary themes of space, material and detail. His buildings are timeless and have lost nothing of their singular presence. The reconstructed Barcelona Pavilion, the Crown Hall at IIT or the New National Gallery in Berlin are still exemplary in their reduced aesthetics as buildings that demonstrate his architectural philosophy of "less is more".[43]

1 cf. David Spaeth, "Ludwig Mies van der Rohe: A Biographical Essay", in: *Mies Reconsidered: His Career; Legacy, and Disciples*, The Art Institute of Chicago und Rizzoli, New York 1986.
2 The era of architectural modernism began in the 1920s in response to the stylistic pastiche and ballast of the past and as a reaction to the entirely new social structure after the First World War.
3 Fritz Neumeyer, *The Artless Word*: *Mies van der Rohe on the Building Art,* MIT Press, Cambridge (Mass.) 1991.
4 Wolf Tegethoff, *Die Villen und Land- hausprojekte von Mies van der Rohe*, R. Bacht, Essen 1981.
5 The historical development of ferro- concrete construction in the Third Reich began with the registration of a patent by Joseph Monier in 1880. From 1900 onwards the term *Eisenbeton* (iron- reinforced concrete) began to be used, and from 1941 onwards the term *Stahl- beton* (steel-reinforced concrete).
6 The floor plan of the Brick Country House seems heavily influenced in its formal arrangement by the De Stijl artistic movement of the time, especially Theo van Doesburg's painting "Rhythm of a Russian Dance" (1918) to which it bears remarkable similarities.
7 Lilly Reich (1885–1947) collaborated closely with Mies van der Rohe from 1927 onwards up until his emigration in 1938. The tubular steel chair designs for the Weißenhof Estate are attributed to her.
8 The exhibition marked the first time that the International Style was insti- tutionalized and officially recognized.
9 G was a German journal of avant-garde art and architecture that was published at irregular intervals in 1923 and 1924. The title of the journal G derives from the word Gestaltung (design). A total of six issues were published.
10 Mies in a lecture entitled "The Preconditions of Architectural Work" (1928), cited in: Fritz Neumeyer, *The Artless Word*: *Mies van der Rohe on the Building Art,* MIT Press, Cambridge (Mass.) 1991, p. 299.
11 An excellent example is the model house for the Berlin Building Exhibition in 1931. Published in: *Die Form*, no.6 and no.7, 1931.
12 Just two years after the completion of Crown Hall, Mies showed collages of his design for a column-free room with wide-span space-frame structure for the Convention Hall Project, Chicago, Illinois 1954.
13 Interestingly, Mies never adopted Adolf Loos' concept of "Raumplan" in which the height of each room is modulated depending on function and size.
14 Philip Johnson's commentary on the occasion of the first major exhibition on Mies van der Rohe in New York's Museum of Modern Art in 1947. Philip C. Johnson, Mies van der Rohe, New York 1947, p. 30. Cf. also Ulrich Mueller, Raum, Bewegung und Zeit im Werk von Walter Gropius und Ludwig Mies van der Rohe, Akademie Verlag, Berlin 2004, p. 92.
15 Anke Naujokat, "Schichtung, Über- blendung, Collage. Formen und Bedeutung architektonischer Simul- tanität",

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29 Colin Rowe and Robert Slutzky, Transparency, Birkhäuser, Basel, Boston, Berlin 1997.

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31 Max Stemshorn, *Mies und Schinkel – Das Vorbild Schinkels im Werk Mies van der Rohes*, Ernst Wasmuth Verlag, Tübingen 2002.

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34 Ludwig Mies van der Rohe referred to the doctrine of the late classical neoplatonist Aurelius Augustinus, cited in Ulrich Conrads and Peter Neitzke, Bauwelt Fundamente 94, Mensch und Raum: Das Darmstädter Gespräch 1951, revised edition. Vieweg, Braun- schweig 1991, p. 48.

35 Stanford Anderson, Peter Behrens and a New Architecture for the Twentieth Century, MIT Press, Cambridge (Mass.) 2002.

36 The term "rectangle élastique" was coined by the French artist Fernand Léger.

37 Le Corbusier first used the term "plan libre" in 1914 in the schematic construction for the Dom-ino House.

38 Corbusier describes the "promenade architecturale" as a path through a built space through which a sequence of images unfolds for the visitor. See also: Flora Samuel, Le Corbusier and the Architectural Promenade, Birkhäuser, Basel 2010.

39 Le Corbusier developed his color theory "Polychromie Architecturale" in 1931. For him the color scheme of a building was a crucial aspect as important as the plan and section.

40 Le Corbusier defined the principles of his new architecture in 1927 in the pub- lication Les cinq points de l'architecture moderne written by himself and his cousin Pierre Jeanneret.

41 Cf. also Eduard R. Ford, Das Detail in der Architektur der Moderne, Birk- häuser, Basel, Berlin, Boston 1994.

42 In Aircraft (1935), Le Corbusier celebrates the aircraft as the pinnacle of human technological achievement.

43 Although the statement "less is more" is commonly associated with Mies, he originally heard it in Peter Behrens' office. See Detlef Mertens, *Mies*, Phaidon, London 2014.

Bhaswar Mallick

Being Vulnerable: Zaha Hadid in Cincinnati

Being vulnerable: Zaha Hadid in Cincinnati

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ABSTRACT:
The digital turn revolutionizing ways of construing, analyzing and disseminating information has brought the focus on architectural techniques – how they inform, generate and communicate. A globalized world is also increasingly influenced by the same agendas, publications and images, while being mindful of a visual bias, misrepresentation, and overt reliance. As such it is essential now, more than ever before, to define the scope of architectural techniques as an instrument driving the design process and representing positions of architecture and architects in society.

If Zaha Hadid is a relevant architect famous for her typical drawing techniques generating a unique architecture, the realization of Rosenthal Center of Contemporary Arts at Cincinnati established her credibility for realizing in built form the excitement her drawings promised. This paper aims at revealing the ambiguities, triumphs and compromises, that architectural techniques bear witnesses to, through Zaha Hadid's Contemporary Arts Center project.

The research stems from a narrative commentary of the design process, as witnessed through the various drawings, paintings, physical and digital models published in relation to the project. Each of these representations, in each stage were described, and their relations to the immediately previous and later representation commented. As a written account describing the evolution of the design emerged, it was compared with the published objectives of the clients at various stages of the process, and the architect's justifications published after completion. A visit to the building was undertaken, and an account of the experience was compared to the intentions and achievements claimed.

Ethical dilemmas will be revealed in the process that show the vulnerabilities of the Architect and her technique, and strategies that she adopts to accommodate the same. It will show how design processes have an inherent ethical vulnerability, and how Hadid's admittance of the issue and her response to that is instructive.

KEYWORDS: Globalization, Digital turn, Ethics, Instrumentality, Design process.

INTRODUCTION

The digital turn revolutionizing ways of construing, analyzing and disseminating information has brought the focus on architectural techniques – how they inform, generate and communicate. A globalized world is also increasingly influenced by the same agendas, publications and images, while being mindful of a visual bias, misrepresentation, and overt reliance. As such it is essential now, more than ever before, to define the scope of architectural techniques as an instrument driving the design process and representing positions of architecture and architects in society.

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The research stems from a narrative commentary of the design process, as witnessed through the various drawings, paintings, physical and digital models published in relation to the project. Each of these representations, in each of these stages were described, and their relations to the immediately previous and later representation commented upon. As a written account describing the evolution of the design emerged, it was compared with the published objectives of the clients at various stages of the process, and the architect's justifications published after completion. A visit to the building was undertaken, and an account of the experience was compared to the intentions and achievements claimed.

To establish a proper context for this analysis, the circumstances of the initiation of the project, and appointment of Zaha Hadid as its architect would be first discussed, to understand the objectives and vision that the clients and their architect embarked upon with. Thereupon, the design process will be critically analyzed to show the motives, discoveries and compromises that drove its evolution. Dilemmas will be revealed in the process that show the vulnerabilities of the Architect and her technique, and also strategies that she adopts to accommodate the same. Finally, a discussion of the experiential discoveries of a visit to the site would conclude the analysis. It will be shown how design processes have an inherent vulnerability, and how Zaha Hadid's admittance of the issue and her response to that in this project is instructive.

1.1. The Architectural project

The Contemporary Arts Center at Cincinnati was founded by three women in 1939 as 'Modern Art Society', drawing upon the experiences of MOMA, New York. It was initially housed in the Cincinnati Arts Museum, but moved to its first custom-built space – a first for any contemporary art gallery in America – in 1970. Although the new site was in the central business district, being located on the 2nd level, it was cut off from the traffic on the street, with poor access and visibility. Then, in the early 1990s, the institute successfully defended the rights of Cincinnatians to view controversial photographs by Robert Mapplethorpe, which brought it into the public eye like never before. It earned a reputation of encouraging openness to new ideas and different ways of seeing the world. Thus by 1995, the institute could finally raise enough money and have a moral backdrop to search for a building of architectural distinction, located boldly at one of the most prominent intersections in downtown.

A public symposium was organized in 1997, to define a vision for the building. It concluded in aspiring for:

> 'a purposeful expression of ideas about art museums and their public, about urban environments and people who inhabit them, about constructed spaces and human interactions within'
> (Dochantschi 2008).

An architect selection committee was formed and of 300 qualified applicants, 12 were interviewed. Of them, Daniel Leibeskind, Bernard Tschumi and Zaha Hadid were selected as finalists. The finalists were commissioned to produce concept booklets. Hadid responded by redefining exhibition flexibility, by proposing a kit of different sized galleries, independent volumes fitted together in a three-dimensional jigsaw puzzle, hung from a warped concrete plane (Dochantschi 2008). Hadid's initial quest was to release the site from requirements of a box. It was forceful, so as to break the grid, but not with vulgarity. She showed quick sketches, not of a building, but a kind of energy diagrams. The committee found Hadid exciting and indecipherable, while embracing and extending the institute's central view of its relationship with the audience – providing experiences beyond boundaries (Dochantschi 2008). Zaha Hadid was thus chosen as the Architect for the project in 1998.

It is instructive to see how Zaha Hadid, coming across as unassuming, undecided and vulnerable in these initial stages, endeared herself to the committee, for they could relate to the same. Moreover, proposals in the early 90s had been rejected for being situated at the fringes of the downtown, which show that the institute craved for an individual identity, embedded in the heart of the downtown. They aspired to establish themselves as a contrast to elitist art museums, isolated on a hill. Zaha Hadid was herself an outsider in more ways than one, whose work was unapologetically individualistic, yet civic minded. In Hadid's words, the institute would be a place that has the potential to carve out new memories and generate authentic experiences in an age that offers little opportunity for such encounters.

1.2. The Design process

In this section, the design process of Zaha Hadid is discussed, eliciting the ambiguities and dilemmas that feature within. It is opportune to note at this point that the sequence of design discussed henceforth is speculated on the basis of the development of various design elements. These processes do not seem to be defined linearly in time, and often develop simultaneously.

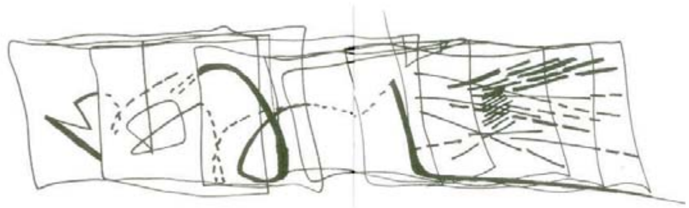

Figure 1: Energy diagram. Source: (Dochantschi 2008)

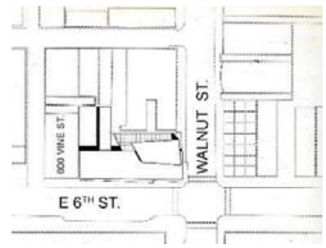

Figure 2: Site plan.

The earliest sketches[1] (Fig. 1) show a sequence of parallel planes, traversed and stitched together by a frolicking line diving in and out of the planes, becoming notional or revealed as it bends and folds – the primal conception of diverse spaces being linked together by a zigzagging circulation path. An acrylic model translates this line as a spiral ramp connecting different floor levels, weaving in and out of an inner wall, while being harbored on a second parallel wall. This ramp strategy can be traced back to the 1992, Guggenheim museum exhibition in New York. Since then, through the many unrealized projects of the 90s, Zaha Hadid can be seen exploring this idea of a spinal, spiral ramp organizing discrete exhibits and spaces into one sweeping experience.

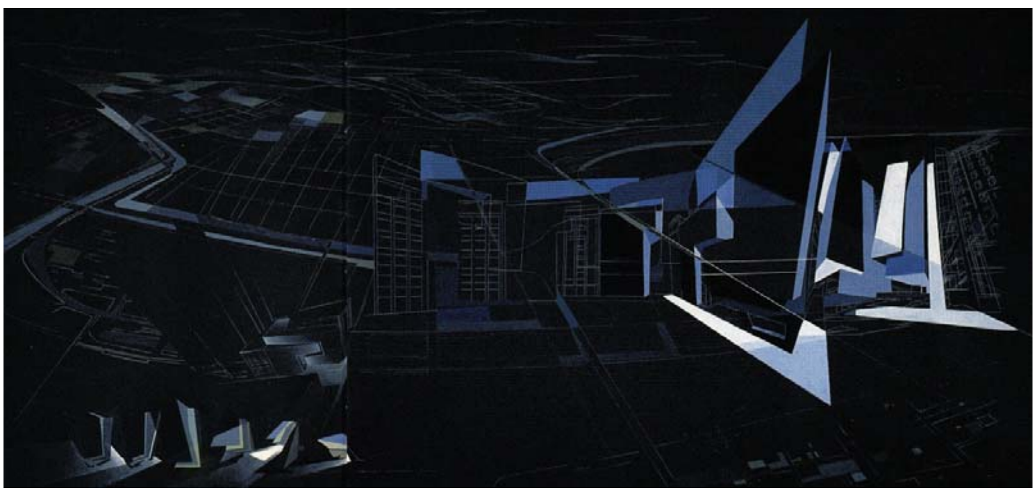

Figure 3: Collage of context. Source: (Dochantschi 2008)

The assimilation of the urban context through fragmentation of the landscape into the site was then explored in a series of Suprematist paintings, which help form the idea of an Urban carpet and define the massing strategy (Fig. 3). Starting off with the immediate context, the height of the Contemporary Arts Center is defined, matching that of the rest of the block, and of those across the street. A collage of paintings shows the drawing of sweeping references from the road networks in the context – the highways sweeping into downtown and energizing the architecture it harbors. The zigzag of the highway to the West, is mimicked by the zigzag of the massing at the Contemporary Arts Center, albeit in two different planes: in plan and in elevation. Zaha interprets the deviations in three dimensions of the massing construct, defining and acknowledging the translation of a two-dimensional road network's geometry into architectural form. The vertically accentuated 'Center at 600 Vine' (Fig. 3) symbolizes a screeching halt to the highway, or an upward shooting up of the highway, manifested by its violent but valiant defying of gravity: defining the skyscraper. This interpretation of the highway sweeping into an expression of exaltation against natural forces, perhaps incites the idea of the Urban carpet, but for being situated in the contrasting axes. In the bottom left portion of the collage, the illuminated 1st level floor plane of the Contemporary Arts Center site marks its presence in the flow of the E 6th street. The white paint strictly adheres to the constraints of the site, and has no indications of sweeping upwards. The roof as seen in this part does not feature an illuminated edge, and the Urban carpet thus, does not yet sweep upwards.

A complimentary mass completes the zigzagging mass, making an interlock, under whose crevice the 1st floor is kept hollow, enticing the public to enter and explore the crystalline caverns it promises to harbor. A muted buffer box between 'Center on 600 Vine' and the Arts Center, feature a grated facade of regular windows indicative of the administrative office space, and the place for back-end functions that are typical of gallery spaces.

A separate sequence of overlapping perspectives, in right end of the collage (Fig. 3), shows the transition from the Walnut street elevation to the E 6th street elevation. The sidewalks are signified as luminous planes. In the Walnut street elevation, the vertical shaft harboring the ramp along the rear wall associates with the luminous sidewalk as components of public circulation, and is similarly rendered luminous. The stoic straight vertical plane of the shaft, while signifying the verticality of the rear wall, also cuts off this new construct from the adjacent older, typical Walnut street façade. As the building object is turned, the perspective is distorted to look at the underbelly of the masses, as seen from the lobby on the 1st level. The marking of the site by a luminous ground plane, conforming to the extents of the site along the E 6th street, can be seen connecting with the luminous vertical circulation shaft in the rear. The sweep of the Urban carpet turning upwards into the rear wall can herein be seen in its conception.

Although the acrylic model had already featured the curvilinear sweeping up of the urban carpet, the reference to the sweeping in highway hint at another inspiration. Moreover, a series of paper models exploring the weave of the ramp, also simultaneously explored the connection between the wall and the street across the base. The curving of the base to form the wall, was modified, rejected and brought back. Whereas the non-linearity of the evolution of the urban carpet, is typical of design development, the drawings evidence the origin of the idea being story-ed in multiple ways. It reveals the architect's dilemma and subsequent efforts, subjugating the multiple inspirations to rather present a story of design conception that makes a more convincing linear argument.

The cascading concrete façade, the jostling volumes and the cavernous massing evidence the inspiration of Magritte's floating rock paintings. But as the following would show again, multiple objectives that were required to be resolved, influenced the design process. Zaha's drawings and models in this phase can be understood as multiple story-making exercises that would assimilate into a seamless fusion. Yet, being true to the AA school's practice of fragmentation and 'social condensers', Hadid can be distinguished for not aiming at definitive solutions. Instead, as if to maintain vitality of these differences, she makes the elements vulnerable. In essence these vulnerabilities are what evidence the tensions, and make the project a dynamic experience – corrupted by, and thus relatable to everyday life's triumphant struggle.

Figure 4: Elevation in Plan

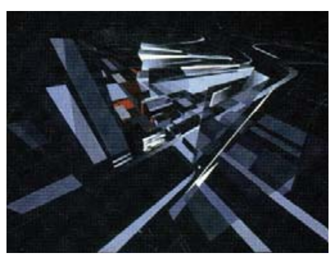

Figure 5: Context to North-East

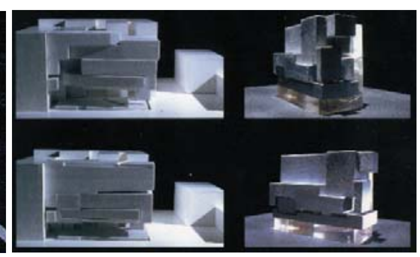

Figure 6: Early massing models.
Source: (Dochantschi 2008)

The next abstract painting (Fig. 4) shows the E 6th street elevation represented in plan, as mid-rise narrow boxes and closed spaces. The perspective distorts and folds as it approaches the Contemporary Arts Center site. The elevation along the E 6th street, by correspondence of the context, is thus depicted as a bunch of discrete narrow midrise boxes. But because the site is restrictively small, similar boxes overlap one another and become a jostling bunch on site. The spinal ramp and the Urban carpet can be seen as the 1st level is revealed, while the other masses float above. The elevation along the E 6th street thus becomes a collage of discrete pure-geometric squarish faces, notional of the plan along the street edge in this context. Further, an overall bird's-eye view shows the context to the North-East (Fig. 5). The connections flowing in from Highway 71 into Cincinnati from the East are accentuated as suggestive parallel spatial volume-flows. The horizontally stacked massing of the Contemporary Arts Center resonates with this interpretation of the context.

The crudest early paper models (Fig. 6) show a stack of volumes segregated by floors. In this, the notion of the Urban carpet and the rear wall are absent. But, in the next model, the crevice of the interlocking, developed in the early paintings, appear as if transforming to a subtle fusion. A ribbon window that seems to originate from the double height space with a glazed façade replaces the complimentary counter mass to the zigzag mass, that now comes together as a ribbon window framed within an opaque volume. Over the next few variations, the overall composition shifts from one with a light corner but a heavy double height volume at the other end, to being centrally balanced in the second variant. This evolution anticipates the ultimate loss of the vertical elements along the E 6th street, for they add or remove weightage to the Urban carpet. Rather, the pure horizontality of the masses eventually reduces the Urban carpet's dominance, making it vulnerable. The 'Center at 600 Vine' anchors one end, while the corner is deprived of a balancing vertical element. Making the Urban carpet vulnerable is essential for it allows the alternate oblique connection of the rear wall with the road intersection to start fostering itself. Finally, an all-red and an all-white acrylic model (Fig. 7) were also made to study the cavernous volumes formed inside, and how the ramp connects through them, even as it clings on to the rear wall. The connections of the stoic back-end service block with the galleries on every level are thus understood.

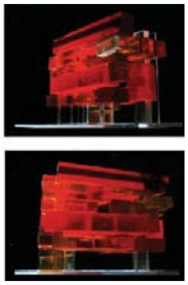

Figure 7: Massing

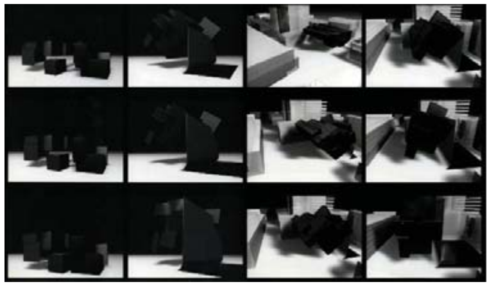

Figure 8: Folding the mass, computer modelling.

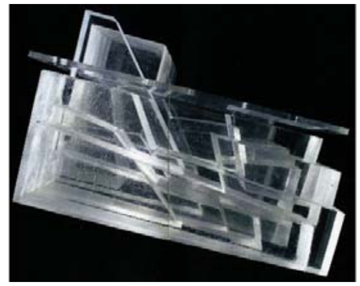

Figure 9: Volumetric study

Computer generated monochrome graphics (Fig. 8) correlate the assembly of fragmented mass elements being tightly packed and the Urban carpet folding upwards to harbor the same. The scale of the constituent pure-geometric blocks empathizes with the small scale buildings of downtown. Two different sequences show this transition, thus evidencing a subtle difference in telling the story. In the first, the carpet is already folded up and the mass turns and aligns itself along it. In the second, the mass stays aligned with the carpet being peeled off, and as the carpet folds, the mass turns with it. Again exploration of different ways of saying, or justifying, a design development indicates the effort to maintain and effect the many objectives and inspirations – multiple ways leading to a fragmented but coherent solution.

Computer generated three dimensional models (Fig. 10) helped visualize walk-throughs along the ramp, exploring views of, and from, the same. The galleries developed a parapet wall at the edge and the floors were terraced, that is, the edge of the floor above receded away from the ramp, allowing generous views of the vertical volume along the rear wall for comprehension of the complexity of the ramp weaving in and out. The drama of the ramp connecting the terraced floors of cavernous gallery spaces, each of different shapes and sizes, was thus explored. The rear wall and structural columns, unforgiving in their verticality, contrast the otherwise varied interior landscape. The parapet along the edges of the ramp resonate with those along the floor edges, transforming the identity of the ramp from being a distinct tool facilitating vertical transport, to becoming the vertically fluid spatial extension of the exhibition floors.

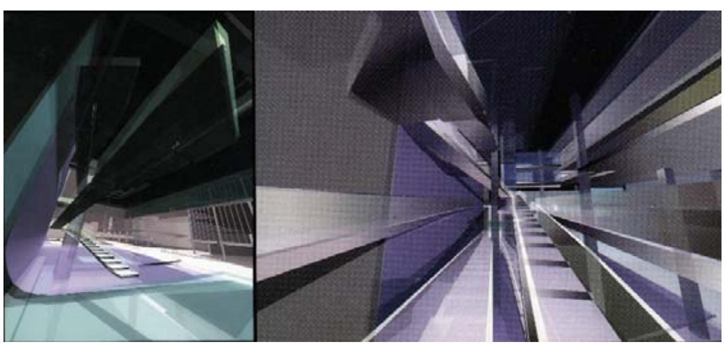

Figure 10: Computer generated walk-through. Source: (Dochantschi 2008)

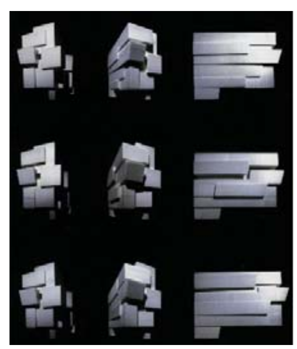

Figure 11: Façade Study.

Finally, a series of foam block models (Fig. 11) were used to refine the proportions and composition of the E 6th street and Walnut street elevations. Cycling through variants, the elements were fragmented in one way and assimilated with another, searching for a balance between dynamism and relatable scalar association with the small scale buildings of downtown Cincinnati.

1.3. The experience on site

The temporality of spaces is an important facet of the CCA project. The rigor to achieve the same may be witnessed in the models and drawings exploring the 'jigsaw puzzle of masses', 'the façade study' and in transparent acrylic 'the void study' (Dochantschi 2008). But only when one travels through these spaces does one realize the invitation of those intimate niches. And only when you embark upon exploring this niche, do you find this interesting door tantalizing you into an even more intimate space, and so on. Each space is uniquely squarish, low ceilinged, double heighted or narrow. There are no windows, and since there are no windows, these characters are the only clues to finding your way back. Only when you are some way into the sequence, this tedious remembering gives way to panic and awareness of entrapment. Then, it is only the artwork that assures and transforms the experience to one of exploration and discovery (Betsky 2009) – typical ideals of contemporary museum design – reimagined.

Another feature that the publications fail to portray is the role of the ramp as provider of 'relief space'—another idiom of contemporary museum architecture. The double flight to each floor is punctuated by the mid-landing (Fig. 6), which invariably is nearest to the only, otherwise unapproachable, curtain wall. So each time one embarks on the spinal ramp, he is taken from the hermetic galleries to a view of the busy urbanity of downtown Cincinnati, and then brought back refreshed. The contrast of 'inside and out' manifests from monochromatic interiors to polychromatic outside and back, from silence to urban noise and back, from abstraction of art to realism of life and back, and so on.

The colors and materiality of the Center are the sole impositions of Zaha's palate unperturbed by the context. There maybe two explanations for this. Firstly, it must be remembered that the process of deconstruction is essentially reductionist. The landscape and the context are stripped off of their materiality for unencumbered fragmentation. As it is, the fragments present a chaotic distorted world, where lack of materiality reduces confusion. The focus essentially is formal. This may be attributed to the loss of information and ignorance of materials in context. Secondly, the project marks a pivotal phase of Zaha Hadid's career, when her colors start deviating from being representative to formally influential. It also is when she goes from being a paper architect to constructing projects in different continents. The concrete 'Urban carpet' does borrow from, and relate to, the concrete pavement all around. But the ramp, which is such a well published element, and one of the exterior masses, feature heat-welded, glass reinforced polyester which is most clumsily executed – as seen in the handrails of the ramp. Such ambiguities and inconsistency in material selection and application indicate an architect finding her material sense, rather than a mature master with an established repertoire.

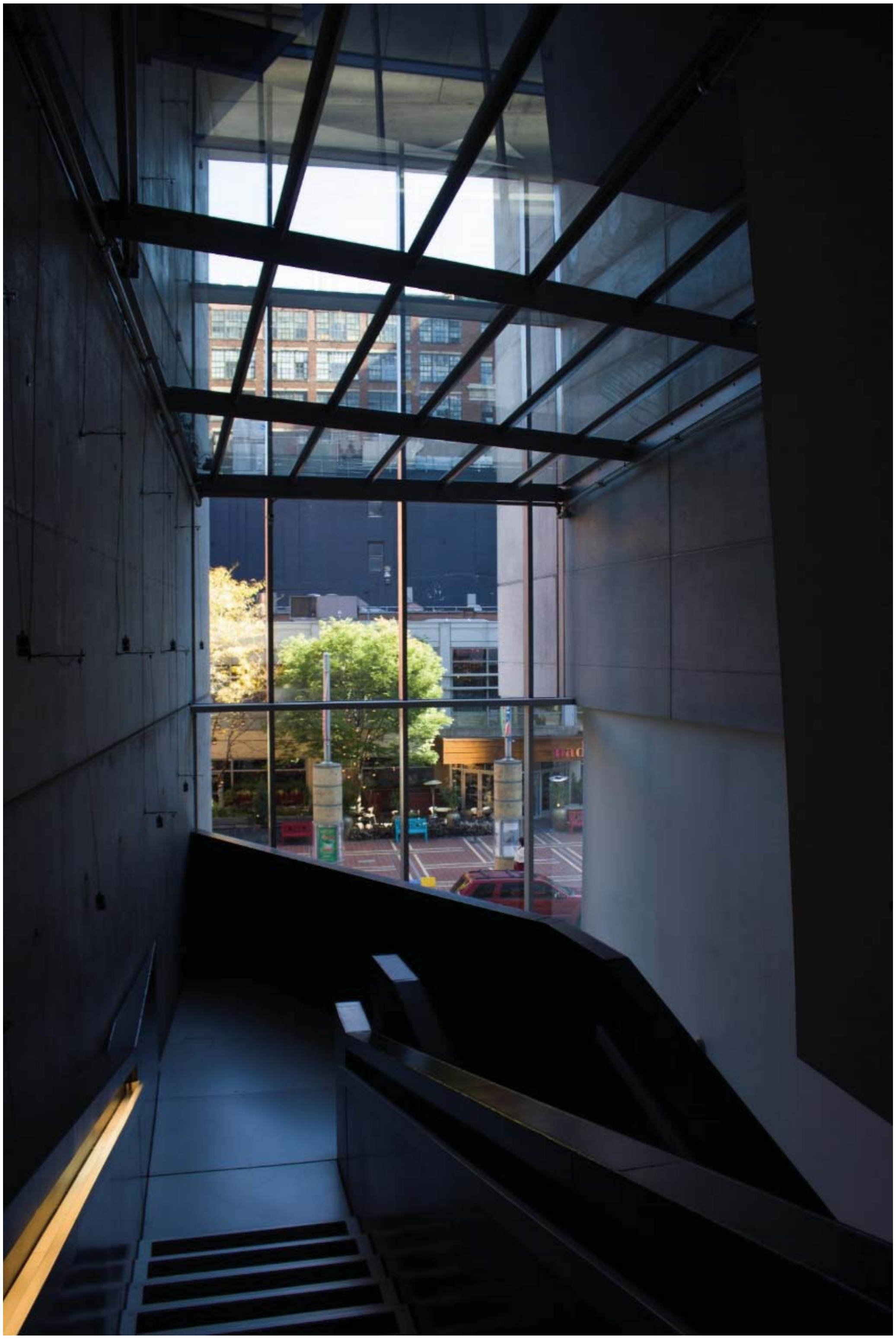

Figure 5: Relief spaces. Source: (Author)

1.4. The Ethical dilemma

The design process as an instrument to achieve aspired and defined objectives, creates a principled narrative. The integrity of an architect is often associated with these principles and how stringently held-fast the modern architect's narrative can remain thus. A principled design process comes across as rational and intelligent. The architectural techniques of the architect thus bear the weight of being this instrument to achieve good design. Yet, according to Dewey, ends, goals or ideas do not arise out of nothing, but develop through action as a method of dealing with a real situation. "End in view" are also instruments to achieve eventual real ends. The techniques of an architect being exploratory leads to discoveries, requiring compromises. The ethical dilemma arrives when the narrative of the process is negotiated as well to retain the moral responsibility of truthful depiction of the situation, environment and present time, all judged by his, or her, adherence to stated principles.

Zaha Hadid's architectural technique is a lesser instrument in construing architecture than her principles of fragmentation, allowing vulnerability. The rebellious language of the Suprematists search for a truth, by daring to portray the individuality of the 'other' is Zaha Hadid's response to the ethical dilemma, portraying contradictions to allow a more truthful reality to emerge.

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ENDNOTES

[1] This is possibly a variant of the energy diagram that the selection committee referred to, exhibited during their first visit to her office.

Jeremy Voorhees

Social Impact: A Case Study in Philadelphia's Newly Minted Redevelopment Metric

Social Impact: A Case Study in Philadelphia's Newly Minted Redevelopment Metric

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ABSTRACT: Although the City of Philadelphia employs a catalogue of legal codes and laws to manage its urban growth, its inclusion of a "Social Impact" metric in a recent project is equally novel and vague. Opportunistically leveraging a prominent and sizable block, the Philadelphia Redevelopment Authority issued a Request for Proposals that required the developers to not only demonstrate how they would benefit the social fabric of the city, but provide metrics in order to do so.

While measuring social impact is fraught with difficulties, it shows a willingness of the city to scrutinize the effect of its architecture on the city as a whole. Over the past decade, Philadelphia has enacted drastic shifts in its urban planning protocols ranging from an overhaul of its zoning maps to a restructuring of property tax evaluation.

This paper will examine the first project to emerge from this process: a mixed use development that includes housing, a chain hotel, and the Equal Justice Center. It will describe the emergence of the social metric, position it among other current planning mechanisms aimed at equitable development, and speculate about its potential impact.

KEYWORDS: Social Impact, Urban Development, Philadelphia Redevelopment

INTRODUCTION

On September 23, 2016, the Philadelphia Redevelopment Authority (PRA) launched its inaugural Request for Proposals featuring a new scoring metric, "Social Impact," for 800-30 Vine Street. The project site was a large undeveloped parcel adjacent to Philadelphia Police Department Headquarters and the historic Chinatown neighborhood. Given the size, significance, and zoning, the PRA strategically leveraged the potential for economic development to test its new scoring metric. Yet the parameters for that metric were not only vague, but intentionally absent. In truth, they asked the proposals themselves to demonstrate "[c]reativity in determining how to quantify these impact(s) and how outcomes are measured and tracked" (Philadelphia Redevelopment Authority 2016, 15).

The inclusion of the "Social Impact" metric signaled a shift in the manner the city dispenses its property and the criteria it chooses to employ. The scoring sheet for the 800 Vine Street RFP allotted 15% of the total evaluation to this new metric, whereas the Project's quality, connection to community, and timeline accounted for a total of 20% (Attachment K). While this percentage is significant, the substance and effect of this addendum is unclear.

The two resulting proposals projected radically different social agendas. One group worked with, and was vocally supported by, the neighboring Philadelphia Chinatown Development Corporation. The second group proposed a headquarters for the scattered network of community legal services organizations, in order to take advantage of the site's proximity to Police Headquarters. The first maintained a 6-story height limit and included a playground and urban farm. The second proposed a 14-story tower, hotel, and well-manicured landscaping. The first sought a systemic relationship between social impact and community while the second consolidated into a single partnership and building. The PRA ultimately selected the second.

The "Social Impact" metric is only the newest way the City of Philadelphia has attempted to support neighborhood stabilization, combat the effects of gentrification, and encourage equitable relationships between public space and private developments. To combat rising property taxes in gentrifying areas, the city began the Longtime Owner Occupants Program (LOOP), providing a tax discount to residents who have lived in their homes for more than 10 years. In another effort, the city apportioned a $100 million dollar bond in May 2017 to restart a program providing repair loans for low- and middle-income homeowners. The aim is to prevent displacement and preserve neighborhoods, but it may also result in 1,000 new jobs and $60-70 million in economic impact. Such overt objectives and clear expectations stand in contrast to the current qualifications of social impact.

However, the majority of these existing devices and programs attempt to stabilize or preserve, making their potential effects more determinate. The “Social Impact” metric is the first to attempt to employ this device speculatively to promote new development.

This paper will outline the emergence of the new “Social Impact” metric to situate it in the context of Philadelphia’s recent urban development agendas. By comparing this metric to the existing host of urban planning mechanisms, it will interrogate the proposed project’s potential contribution to the social fabric of the city.

1.0 THE EMERGENCE OF THE SOCIAL IMPACT METRIC

1.1. Philadelphia 2035 and the Philadelphia Redevelopment Authority

The Philadelphia 2035 plan is a multi-scaled urban plan coordinating infrastructure, sustainability, economic interests, and neighborhood stabilization and development. Adopted initially in 2011, the “Citywide Vision” laid the ground work for subsequent urban initiatives, and the planning process is still unfolding. Following the broad regional agendas initially adopted, district plans are constructed and adopted through community meetings involving relevant stakeholders.

This process marked a significant moment in the city’s planning process. At the same time as Philadelphia 2035 began, the city also significantly revised its zoning map and code (adopted in 2012) and undertook a comprehensive assessment of its property tax system (adopted in 2013). These initiatives came in the immediate aftermath of the Great Recession and in response to the general conditions of disproportionate growth within the city’s disparate neighborhoods.

At the same time, the city began to examine the process by which it sold properties in order to streamline the holdings and protocols of the many city agencies. The city established the Philadelphia Land Bank in 2013 to consolidate the diverse set of lots and buildings owned by various city agencies and departments. However, significant parcels and buildings, including the sale of a number of closed Philadelphia school facilities, were managed by the Philadelphia Redevelopment Authority (PRA). That renewal agency was founded in the heyday of post-World War II federally funded urban planning projects and has been a significant instrument in the city’s development since.

The Philadelphia Redevelopment Authority authored the Request for Proposals for 800 Vine Street.

1.2. Social Impact as Defined by the Request for Proposals

There is little precedent for the inclusion of a “Social Impact” measure in Philadelphia’s Requests for Proposals (RFPs). The Philadelphia Redevelopment Authority gave no clear indication for its inclusion specific to this individual parcel, nor did it announce it as a broader strategy. Within the purview of the PRA’s own protocols, the introduction of the social metric for 800 Vine Street did little to adjust the metrics from previous RFPs aside from changing their weighted impact. The evaluation Criteria outlined in the RFP are:

30% Financial: Bid Price, Financing Plan, Demonstration of Feasibility
20% Project: Concept Design Quality, Alignment with Local Community/Context, Timeline
20% Developer: History of Team Partnership, Track Records of Similar Projects and Partners
15% Social Impact: Measurable Impact, Creativity in Quantifying Impact
15% Economic Opportunity Plan: Minority, Women, Disabled Owned Business Support (AttachmentK)

As the criteria are consistent with previous RFPs, we can assume that while the introduction of such a device was novel, it was not intended to be revolutionary. While the general procedures and criteria of the city’s planning process remained unaffected, the social metric introduced here was meant to leverage the sale of specific parcels already determined to be economically viable enough to afford a modicum of social responsibility.

Though vague, Philadelphia included this definition of Social Impact in its inaugural RFP. The following is the complete description of the Social Impact section included in the *Request for Proposals 800-30 Vine Street*:

> The development team should define the project's social impact within the narrative. Social impact refers to the way that a physical project can have a positive effect on people and communities. Respondents may engage a consultant to assist in developing an approach to impact assessment. Such impact should be described and quantified with relevant metrics (i.e. approximate number of people to be served by the social impact component.) Examples of social impact may include (but are not limited to):
>
> [1] Providing affordable housing within the proposed development.
> [2] Creating or retaining permanent (non-construction) jobs for local, diverse, lower-income individuals, including contribution or participation in job readiness and training programs.
> [3] Providing access to quality Pre-K and afterschool care programs.
> [4] Providing affordable healthy food access, if such access is not currently present in a community.
> [5] Providing opportunities for minority businesses, including flexible lease rates, contracting and supplier opportunities post-construction, and mentorship programs.
> [6] Investment in the local educational unit: public elementary, middle, high school, or community college.
> [7] Investment in proximate community facilities: parks, recreational center, library, health center (13-14).

While the general guidelines suggest that the "physical project can have a positive effect on people and communities," the identification of appropriate responses prioritizes economic concerns. "Providing access to Pre-K and afterschool care programs" and "healthy food access" (examples 3 and 4) have spatial criteria for which a physical project can demonstrate its benefit, other suggestions preface the economic imperatives. For example, both the inclusion of "creating permanent jobs" and "providing opportunities for minority businesses" (examples 2 and 5) are economic directives that consider their social benefit as a consequence. Similarly, the suggestions of investment in local educational and recreational facilities (examples 6 and 7) don't require any specific imperatives or modifications to their own physical project.

However, the suggestions make clear a set of categories for which the social metric could be responsible. Education, health, and recreation are all considered within the purview of a social good. In addition to this, the PRA includes housing in its list of potential responses. However, the inclusion of "affordable" as a qualifier for housing makes clear what kinds of housing the social metric is meant to further.

The intention to make Social Impact a subset of a larger, or simply a more quantifiable, discipline, is characteristic of its development as an assessment metric. Whether understood as part of Economic Impact or Environmental Impact, Social Impact has emerged as an interdisciplinary field frequently relegated to a category within a larger analysis.

1.3. Social Impact as Defined by the International Association for Impact Assessment

Although a thorough literature review is outside the scope of this paper, it is important to note that Social Impact Assessment has been an established process since the 1970s. Sociologist Rabel Burdge describes its emergence in the United States as a larger movement to systematically analyze the environmental impacts of proposed developments.

> In the USA, EIAs [Environmental Impact Analysis] done in the '70s included a socioeconomic component that was intended to be "social impacts" as required under the NEPA (National Environmental Policy Act) legislation. These early EIAs were done by engineers and landscape architects, who gave little attention to, or did not understand what was meant by, "social effects." "Socioeconomic" impacts became a baseline listing of demographic information for a project area…. However, most of the "socioeconomic" data were descriptive of the past—little was done to "project or assess" likely future change to human communities based on the proposed action or its alternatives (Burdge 2003, 85).

In Burdge's view, the social impact of a proposed project was obfuscated by its tethering to economic concerns. Demographic descriptions of existing conditions were substituted for the speculative impact of a project. Yet, as Ana Maria Esteves, Daniel Franks, and Frank Vanclay argue in their paper "Social Impact Assessment: The State of the Art," the role and significance of Social Impact Assessment both developed and gained traction within these economic confines. As a tool to counteract the economic impacts of international developments it became not just a mitigating device to ameliorate social ills, but a pro-active measure to embed social mores within the project's financing:

> International codes and standards, particularly when written into conditions of project financing, have provided an additional driver. The International Finance Corporation's Performance Standards, which have been adopted by some private lenders as the Equator Principles, are an example. The 2006 IFC Performance Standards (a revision of its safeguard policies in place since 1998) require the preparation of environmental and social action plans for all projects (36).

As such, the ability to incorporate social impact metrics not only with planning, but in the conceptualization of the project, makes social impact analysis an ongoing mechanism. This premise is developed clearly within the International Association for Impact Assessment's "Social Impact Assessment: Guidance for assessing and managing the social impacts of projects." They propose that the assessment process begins well before feasibility (starting with the exploration and identification of the project) and continuing not just through construction, but operations, and ultimately the closure of the project.

While not part of the single RFP, Philadelphia has followed many of the larger agendas set forth in the guidance documents by employing community participation in its urban planning initiatives, most notably in Philadelphia 2035, in which neighborhoods aided in the development of individual district plans. Within a number of these districts, including the Central District in which this case study is located, the plan calls for a strategy for maintaining and creating affordable housing.

In Philadelphia, the tension between the economic and social agendas of the city is reified in the form of housing. The inclusion of housing as a specific category of social impact within the RFP reflects the tension about urban growth and community stabilization.

2.0 NEIGHBORHOOD STABILIAZTON INITIATIVES

2.1. The Actual Value Index

In 2014, the city adopted the Actual Values Initiative (AVI) to reassess the values of privately owned properties for tax purposes. The intention of the citywide assessment was to take a comprehensive and equitable valuation in response to substantial variations between the city's assessment and the commercial assessment of a property. Addressing this disparity has been a contentious issue as neighborhoods that have seen an influx of wealthier residents worried their property taxes would increase dramatically. However, in the report by the Pew Charitable Trusts' Philadelphia Research Initiative, *The Actual Value Initiative: Overhauling Property Taxes in Philadelphia*, the group found that there was no effective timetable for assessing property values. The last comprehensive survey had begun in 1983 and was completed in 1989 (12) under the auspices of the Board of Revision of Taxes. As neither the city nor the state had a mandated timetable for appraisals, piecemeal valuations became the norm, resulting in wildly different taxes for relatively similar properties.

The report suggests that the absence of a schedule was compounded by the city's adoption of a fractional assessment system. In this property assessment strategy, rather than estimating the full value of a property and applying a percentage to be tax specific to use type (commercial, residential, etc.), the property is initially evaluated at a predetermined ratio. The shift to the AVI at a time when isolated neighborhoods in the city were growing rapidly fostered suspicion among many long-time residents.

2.2. Longtime Owner Occupant Program

Knowing that longtime residents from neighborhoods that have seen significant recent growth would be disproportionately impacted, the city instituted the Longtime Owner Occupant Program (LOOP). This program continues the work of other city based programs to foster owner occupancy, including the Homestead Exemption (for any Owner-Occupant) and state programs that protect seniors on fixed incomes and other vulnerable populations.

The program began in 2013 (the year the AVI process began) and required that the owner had lived in their home for 10 years. The program still accepts applicants as long as they have owned and lived in their homes since 2003. This protection was enacted specifically to stabilize neighbourhoods in the wake of growth, while at the same time allowing the city to reap the benefits of that growth.

The four criteria for this exemption make this clear. The owner must live in the home (and cannot have more than three residential and one commercial units). The owner's property assessment must have tripled from one year to the next (this is not unusual given the AVI and disparate growth). Finally, there is a cap relative to income and household size. These three parameters clearly identify the intention of the program to maintain the social fabric of residential neighbourhoods that could be clearly disadvantaged by economic development.

In addition to attempting to stabilize neighborhoods through tax initiatives, the city has also attempted to address affordable housing and its future development through zoning.

3.0 SPECTULATIVE AFFORDABLE HOUSING

3.1. The Case of 1 Water Street

In 2015 the Zoning Code established the Mixed Income Housing Bonus which, applied to residential construction, increased allowable floor area and building height in exchange for a percentage of housing units being qualified as affordable or a contribution to the Housing Trust fund. The initiative was applied for the first time to 1 Water Street, a luxury apartment development by PMC Property Group. The inclusion of 25 subsidized apartments garnered an additional 4 floors and 30 units. This project was part of the Central Delaware Overlay, a specific geographic adjustment lobbied for by the Central Delaware Advocacy Group.

In June 2016, PMC asked that they be waived from the agreement to provide affordable housing units. Construction, including the additional stories, had already been completed. For one month, the city argued with the developer and withheld the Certificate of Occupancy, then agreed to a $3.75 million contribution to the Philadelphia's Housing Trust Fund. Matt Ruben, Chair of the Central Delaware Advocacy Group, argued that the city had “won a tremendously important victory for affordable housing.” To be clear, Matt Ruben is the chair of the advocacy group that helped to write the overlay which advocated the public’s right to the waterfront, and after a developer agreed to and then simply rejected the premises of the overlay, he argued that this was a victory. (Ruben 2016)

The premise of Ruben’s argument is that the $3.75 million will do more to construct and sustain affordable housing in Philadelphia than 25 apartments. He contends this is made more evident when the law mandates that these remain “affordable” for only 15 years. In economic terms, he may be correct. However, in geographic terms, his argument is less clear.

The housing bonus itself is part of the Zoning Code and enforced uniformly across the city. The Central Delaware Advocacy group has been lobbying the city and negotiating with developers since its inception.

State and federal funding to support public infrastructure projects, such as capping a two-block area of I-95 to give public access to the water, are concerted strategies to promote development and provide public access to the Delaware River, a significant public amenity.

It is significant to note that the site of 1 Water Street, at the foot of the Benjamin Franklin Bridge, is one block from the Field Operations-designed Race Street Pier, completed less than three years before. Additionally it will be one block north of a newly capped 1-95 park. For each of these recreational and infrastructure projects, the city has contributed $90 million, the Pennsylvania Department of Transportation has contributed $100 million, and the William Penn Foundation has contributed $25 million. This does not account for the planning initiatives funded by the same governmental bodies, nor the countless volunteer hours from advocacy groups, neighborhood councils, and research groups.

The specific indignity of the result is that $190 million of public money, on top of the specific density bonus applied to the building, resulted in no change to the design of 1 Water Street for the public good. One could argue that since the zoning commission had set the acceptable height and density (presumably for the benefit of the public), the city ultimately lost by some social metric.

According to local Pulitzer Prize winning journalist Inga Saffron, who asked PMC officials to comment on the reason for reneging on the original deal, “Officials at PMC could not be reached for comment. Since their substitution proposal became public, they have declined to discuss the reasons for their change of heart.”

Similar to the 1 Water Street Project, the Philadelphia Redevelopment Authority’s RFP for 800 Vine Street serves as a test balloon for a project aimed to leverage economically attractive opportunities to enact social good. However, unlike the density bonus whose trade-offs were explicitly codified, the social impact metric provides less prescriptive mandates.

4.0 INITIAL RESPONSES TO SOCIAL METRIC

4.1. Comparing Parkway and Pennrose

The Pennrose and Parkway responses to the specifics of the RFP are both fundamentally similar and radically different. In addition to the programmatic conditions outlined in the RFP, the SEPTA Regional Rail Tunnel and Broad/Ridge Subway Tunnel cut through the site and there is a set of existing buildings on the southwest corner, producing a limited footprint for potential buildings. Both projects responded by breaking the site into three component buildings addressing the three remaining corners and proposing a mix of parking and green space between them. Both projects include a substantial amount of market rate housing. The Parkway proposal contains 120 condominiums while the Pennrose proposal offers 160 rental units. Both provide approximately 180 parking spaces.

As both projects include considerable housing components, both take advantage of the social impact metric's inclusion of affordable housing and each provides approximately 60 affordable senior units.

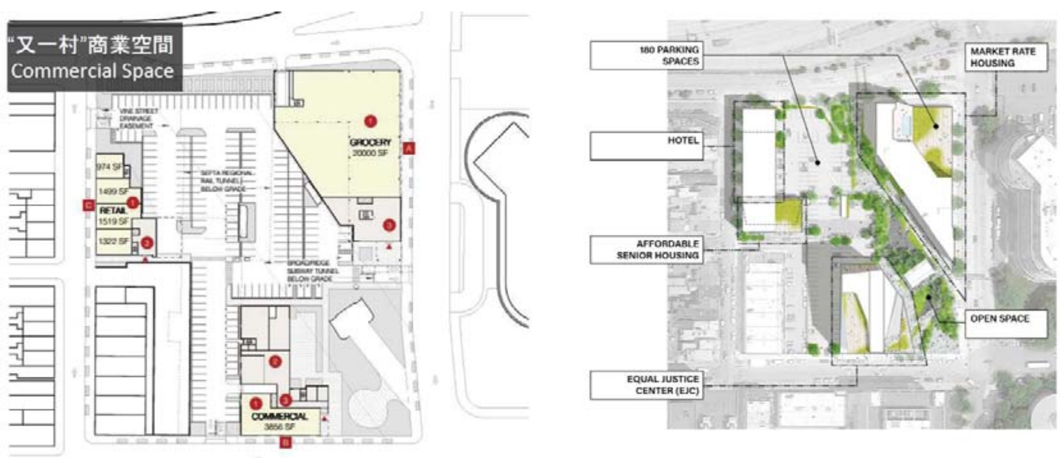

Figure 1: Parkway Plan by Cecil Baker (Left). Pennrose Plan by WRT(Right)

The significant differences emerge in their attempt to qualify the social impact of their proposals.

The Parkway Proposal aligns itself with the local community, Chinatown. As a dense neighborhood located adjacent to Center City, the Philadelphia Chinatown Development Corporation (PCDC) has asked the city to acknowledge their need for more open and recreational spaces. The inclusion of an "Intergenerational Playground" and a 5,000 sq. ft. urban farm are clear attempts to respond to this mandate. The addition of a grocery store is a direct response to the social impact's criteria to provide "affordable healthy food access." This strategy also dovetails with another RFP metric, specific to the project. The RFP provides 20% of its score to this category, and one of its three criteria is "Alignment with Local Community/Context: Strength of the proposal's response to the community and its existing conditions, consideration toward the current residential/commercial market, and potential to be a catalyst for other development." The geographic and social adjacencies to the site are clearly leveraged here to demonstrate the project's potential social impact.

Rather than partnering with a local community, the Pennrose team organized their proposal around a headquarters for the Equal Justice Center (EJC). The EJC was conceived by the Philadelphia Bar Foundation to coordinate the legal aid agencies in the city of Philadelphia. The proposed center would provide a hub to legal aid organizations currently spread across the city and allow a single client to access a number of different agencies in one location. As the site is situated amongst a set of significant civic buildings, including the Philadelphia Police Headquarters, the headquarters would establish the group as a significant actor and give it public presence. The proposal estimates that, "[t]he EJC will serve over 40,000 individuals and low income families annually from the Chinatown community and the City of Philadelphia in one central location easily accessible via public transit” (Pennrose 2017, 19). It also contends that the design will “provide much needed open space, over 30,000 GSF [Gross Square Feet] of beautifully landscaped area extending pedestrian connections from Chinatown, Franklin Square Park, and Independence Mall” (19). While the EJC headquarters occupies the southeastern corner and the market rate housing occupies the northeast, the affordable housing is sandwiched in between the existing building and the proposed Comfort Inn Hotel on the northwestern corner.

Figure 1: Parkway rendering by Cecil Baker (Left). Pennrose rendering by WRT (Right)

The design and imagery associated with the two proposals are equally at odds. The Parkway scheme, designed by Cecil Baker, limits its height to six stories, and adopts a relatively humble palette of colors appropriate to a residential project. The relatively simple forms hold the prominent corners and surround the park. The Pennrose design was produced by Wallace Roberts and Todd (WRT) and features 8-14-story glass prisms surrounded by an immaculate landscape appropriate to a corporate lobby.

The selection of the Pennrose project can be attributed to a number of criteria. Gregory Heller, the Executive director of the PRA, acknowledged “The architecture was ambitious and really set the tone for how Philadelphia wants to develop” (Adelman 2017). The developer, on the other hand, attributed the potential success of the proposal to the EJC, referring to it as “our differentiator.” (Blumgart 2017) Thoai Nguyen, head of the Southeast Asian advocacy group SEAMACC confirmed the significance of the EJC:

> “The tie breaker for me is the Equal Justice Center,” said Nguyen. “In the next four years, and perhaps the next eight, our communities are going to be under attack. The Equal Justice Center to me is a no-brainer [for that reason]. But my very naive question is this: Is it possible that whichever proposal is selected would consider a version of the Equal Justice Center?” (Blumgart 2017)

We might question to what degree the social impact metric actually affected the design, as it seems there is little sacrificed in the name of profit. The building benefits from the zoning density bonus previously described by including affordable housing. The resulting buildings are comprised of a hotel, an office building (occupied by a socially significant client), and an apartment building. Yet, it should be clear that both proposals took seriously the charge that their project should significantly benefit the social fabric of the community and city.

4.2. The Continued Impact of the Social Metric

Since the RFP for 800 Vine Street introduced the social impact metric to the process in the fall of 2016, it has been included only one subsequent RFP to date. That project is much smaller and in a less profitable neighborhood. The RFP provides a clearly defined social scope to demolish an old library and build a new library and affordable housing.

If the Social Impact metric is intended to have continued significance, the Philadelphia Redevelopment Authority should establish appropriate criteria for selecting city owned parcels for the process. The relatively small portion of the city’s land that falls under the PRA’s purview suggests that those parcels that have significant economic value should be leveraged to enact social good.

This should address not only the contemporary value of individual parcels, but the history of the social fabric and public investment of the larger neighborhood. The case of the PMC Group’s attempt to evade the affordable housing agreement makes this clear. Both the past (neighborhoods that have seen their schools and libraries shuttered) and future (districts that have been earmarked for significant public funds) should be accounted for within the Social Impact metric.

CONCLUSION

The City of Philadelphia has attempted to produce equitable metrics for growth, housing, taxes, and other equally complex and contentious topics. The zoning initiative was understood as a 25-year process to account for the changing uses of the city, protect current neighborhoods and citizens, and prepare for future transformations. Land assessments and tax evaluations leveraged the city's recent growth to fund the city's schools, fire departments, and subways, while not discounting those who had lived through the city's decline. While some initiatives provide economic incentive to develop spaces for the public good, like affordable housing, others need to acknowledge the geographic significance of place.

The Social Impact metric could provide a useful device to steer the development of city-owned property and further the public good. While the Philadelphia Redevelopment Authority is only one of the agencies that manages these assets, it is historically one of the most influential. Given the audacity of PMC's test of the city's commitment to the social impact of its projects at 1 Water Street, the city needs to not only affirm its commitment, but develop analytical tools to augment it.

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Samia Rab Kirchner, Farzaneh Soflaei

Mt Auburn Cemetery in Baltimore: Historic Significance and Future Role in Social Sustainability

Historic significance and future role in urban social sustainability

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ABSTRACT: Urban open spaces play a vital role in the social life of city residents. This paper presents a taxonomy of urban spaces and explores the role of cemeteries as an open space that may enhance the social sustainability of neighborhoods. As urban infrastructure, cemeteries provide a resting space for departed citizens and express historical continuity for evolving communities. As superstructure, cemeteries offer spaces for contemplation and chance encounters for the living, contributing to historically-grounded civic identity. Baltimore's Mount Auburn Cemetery was established in 1861 as a rural burial space on farmland outside the city and in time grew into a complex and evolving “City of the Dead”. It is more than a place of rest for the dead and expresses the importance of ritual and ceremony over form and related Euro-American concepts of perpetual maintenance (Jones, 2011). Recognizing its uniqueness as an African American cultural landscape, this paper presents a socially sustainability framework for the revitalization of this privately-owned cemetery into a public memorial park taking into account the full life cycle of urban communities. It also posits the role of universities in developing Partnership and Revitalization Plans through community engagement with varied stakeholders to take care of these resting places and design spaces for meditative contemplation for the living.

KEYWORDS: Social Sustainability, Urban Redevelopment, Urban Open Spaces, Cemeteries, Baltimore

INTRODUCTION

The concept of sustainable development first emerged in the 1980s with the well-known WCED publication Our Common Future (1987), and in response to a growing awareness of the need to balance economic progress with the exploitation of natural resources. The Commission defined sustainable development as “meet(ing) the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). Studies have also shown that positive social interaction is an important element of sustainability that can improve and alter people’s behavior and attitude (Soflaei, 2013 & 2017), as well as improve personal well-being, environmental awareness and care, and aesthetic perception (Warne, 2014). This research focuses on its social pillar (Figure 1) to suggest that future generations should have the same or greater access to shared urban resources for social interaction as inherited by the current generation.

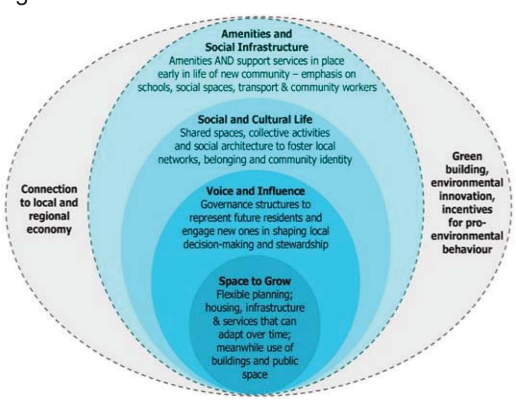

Figure 1. Framework for socially sustainable design (The Young Foundation, 2011)

Examining the case of the Mount Auburn Cemetery in Baltimore, we argue that privately-owned open spaces may be revitalized as public spaces for contemplation and social encounters. Our aim is to understand the Cemetery’s historic significance, document its current state, and chart the most appropriate framework for its revitalization as a Public Memorial Park. We used two research methods: 1) through literature review, we focused on types of spaces that generate most social encounters and identified a research gap in existing strategies that deal with privately owned open spaces in decline where the owners and affected communities are distant, both in time and space; 2) through two surveys, we evaluated the existing condition of the Mount Auburn Cemetery and conducted guided-interviews with stakeholders to understand issues regarding the perpetual care of the cemetery. As conclusion, we propose a socio-spatial framework for revitalizing the Mount Auburn Cemetery as a unique public open space for contemplation and encounters.

1.1. Urban social sustainability

Literature review reveals that definitions of social sustainability in urban context are offered under four theoretical frameworks: 1) Theories that pay more attention to the existing positive conditions of urban life. For instance, Chiu (2002) mentioned that social sustainability relates to the "social norms and conditions" in that any environmental or economic decision must not exceed the community's tolerance for change. In other words, urban sustainability goals are directly related to social acceptability around shared concerns. 2) The main focus in the second framework is on the "measurement", where scholars usually target the positive indicators. According to Colantino (2010) social sustainability themes such as employment and poverty alleviation are increasingly being complemented or replaced by the less measurable concepts like "happiness", social interactions and "sense of place". 3) Scholars have also maintained a "future focus" on the continued improvement of individual "well-being" from the current to the future generations. Barron and Gauntlett (2002) explained that social sustainability occurs when formal and informal processes, systems, structures and relationships actively support the capacity of future generations to create healthy and liveable communities. Socially sustainable communities are equitable, diverse, connected and democratic and provide a good quality of life for citizens. 4) Theories in the fourth framework offer a functionalist understanding of social sustainability as a process of generating cohesion. According to McKenzie (2004), social sustainability is a life-enhancing condition within communities arrived through a process. Examples cited under each of the theoretical frameworks reveal six common characteristics of communities deemed socially sustainable:

1) Demographic diversity
2) Equity in satisfaction of human needs
3) Individual well-being and happiness
4) **Social interaction and mixing (cohesion and inclusion)**
5) Recognizable sense of place (cultural identity)
6) Notable sense of community (place attachment)

The fourth character that relies on social interaction (cohesion and inclusion) is the one most needed in Baltimore; a city with a history of designed segregation. When open spaces are designed to generate cohesive inclusion, their maintenance issues are best addressed when residents in vicinity have a stake as users. While city residents use open spaces in a wide variety of ways (Soflaei, 2014), individuals and groups are much more likely to look after and care for the urban space if they have a positive association or emotion, whether generated by the environment or other people (Warren et al., 2014). This paper investigates the social value of urban cemeteries as an important type of privately-owned urban open space that may be utilized for public social interactions, enhancing neighbourhood sustainability, and the evolving civic identities.

1.2. Social value of urban cemetery as a type of open spaces

Open spaces, like streets and plazas to the water front and parks, are integral to the sustainable life of cities. This paper treats cemeteries as a type of open space that play a vital role in connecting communities across time and space, and enhancing urban civic identity. A cemetery or graveyard is defined as a place, where the remains of deceased people are buried or otherwise interred. The word cemetery, from Greek *κοιμητήριον* means sleeping place (Cantor, 2010), implies the land is specifically designated as a burial ground. There are many different types of cemeteries based on size, function, religion, and location. Early urban cemeteries in occupied US emerged in churchyards but filled quickly and exhibited a haphazard placement of burial markers as sextons tried to squeeze new burials into the remaining space. New burial grounds were established in the early nineteenth century to compensate for lack of space within existing churchyards with burial plots laid out in a grid to replace the chaotic appearance of the churchyard (Mytum, 2004). Cemeteries or burial grounds, have always been a part of the human environment and, as an important type of urban open spaces, have been studied by many architects, landscape designers, and urban planners (Alekshin 1983, Rainville 1999; Yalom and Yalom, 2008; Eggener, 2010; Jones, 2011; Vernon, 2012; Goodrich, 2015). The emergence of the rural or garden cemetery movement in the 1830s gave American cities their first public parks. Initially, urban cemeteries as parks were seen as respite from pollution in urban environments that were rapidly industrializing, providing both a resting place for the departed and encounters with nature for the living. Though originally peripheral, today urban cemeteries are home to wildlife, birds, and plants that are hard to find anywhere else in the urban areas (Worpole, 2003), provide permeable surface that reduces urban storm water flow and mitigates oceanic pollution.

For the African American communities of the US, death in the nineteenth century marked an important social and historical moment and a claim to freedom from slavery (Fletcher, 2014). As the first cemetery in the State of Maryland that is created and operated by the free, fugitive and enslaved member of the African American community, Mount Auburn Cemetery in Baltimore allowed autonomy in death during institutional slavery. It's historic significance as the first place where the African American communities asserted their citizenship should play a vital role in Baltimore's civic identity.

Figure 2. Mount Auburn Cemetery: the oldest African American Cemetery in Baltimore (Kirchner, 2018)

Though originally created as a rural cemetery, Mount Auburn Cemetery is now surrounded by urban neighbourhoods of Westport and Mt. Winans. While the Sharp Street Memorial United Methodist Church has continuous ownership of the Cemetery since its founding in 1807, the Church itself is located 3.7 miles away from the Cemetery and most of the Church Congregation resides outside the city. Maintenance of the Cemetery was a challenge since, until 1997, there were no provisions for "perpetual care". Changes in the demography of the adjacent communities have resulted in the Cemetery's loss of value from the collective memory of its immediate neighbours and the city residents.

2. CASE STUDY: MOUNT AUBURN CEMETERY IN WESTPORT NEIGHBOURHOOD, BALTIMORE, MARYLAND

2.1. Westport neighborhood in Baltimore, Maryland

Westport neighborhood is located in southwest of Baltimore City along the Middle Branch of the Patapsco River with the Gwen Falls stream forming an edge where an iron furnace was set up as roads and railroads lines were introduced to service the Carr and Lowrey Glass works in 1889. Soon after, the Westport power station was established and more people moved into Westport. Once annexed into Baltimore City, Westport rapidly developed into a dense community of row houses. In 1920 the waterfront was set aside exclusively for industrial use and the internal Annapolis road reached its peak as a commercial main street. In 1952 Westport neighborhood was divided with the construction of the Baltimore Washington Parkway, I-295. This event along with the start of industrial and economic decline left Westport in a state of neglect. Economic hardship and the flight of affluent residents to the suburbs allowed for the influx of minority population and low income families into Westport. The introduction of the I-295 highway divided the neighborhood into two parts. While the Westport neighborhood was physically divided into two parts internally, it became accessible externally from two State Highways, easier to get to by car than by foot.

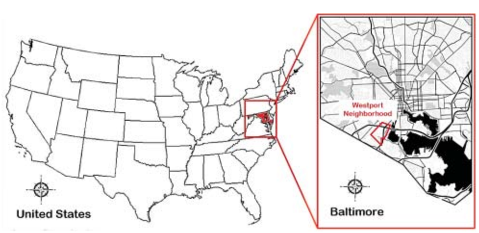

Figure 3. Location of Westport Neighborhood in Baltimore, Maryland

2.2. Mount Auburn Cemetery in Westport neighborhood: A historical overview

Mount Auburn Cemetery is the oldest owned and operated African-American cemetery in the city of Baltimore, founded by the seven Trustees of the Sharp Street Memorial United Methodist Church in 1807, with the official deed signed by Reverend James Peck in 1871. As the first Cemetery in Baltimore where African American people could be buried in dignity, it was originally named "The City of the Dead for Colored People". The name was changed to Mount Auburn Cemetery in 1894. The location and ownership provide a continuing evolution of ethnic history of the African American community in the City of Baltimore, the State of Maryland, and the nation. The Cemetery was incorporated with its urban and rural roots by an Act of the Maryland State

Legislature in 1982, and leased to the Westport Cemetery Corporation for thirty years, ending in May 9, 2012 (Mt Auburn Cemetery Archive). It was designated as a Baltimore City Landmark in 1986 and as a National Register of Historic Place in 2001.

Since 2004, Morgan State University has collaborated with the Sharp Street Church to engage students in visioning the future redevelopment of the 33-acre Cemetery as a treasured landscape. In 2012, after decades of neglect, the DPSCS had partnered with the Church and Morgan to pursue the “clean-up” of the Cemetery by prison inmates. Though the Cemetery remains underutilized as a potential contributor to the image of the city, its grounds are of national significance, as they preserve and sustain history through citizens who experienced slavery and the civil rights movement (Jones, 2011). The rural landscape at the edge of the City is the resting place of generations of Baltimore's African-American community, including historic figures and many unnamed freed and fugitive slaves.

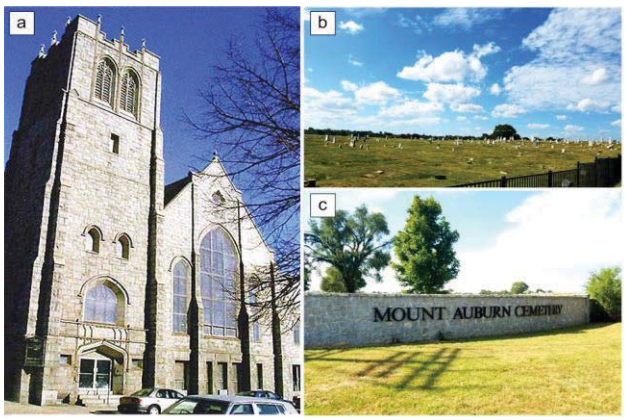

Figure 4. Mount Auburn Cemetery in Baltimore: a) Sharp Street Memorial United Methodist Church owns Mount Auburn Cemetery, b) A panorama view toward Mount Auburn Cemetery from Water view Avenue, and c) Main Gate of Mount Auburn Cemetery in Baltimore.

2.3. Field investigation

Our field investigation of Mount Auburn Cemetery includes both an observational study of its current condition and stakeholder analysis to articulate its historic value and future redevelopment.

2.3.1 Observation: socio-spatial analysis of Mount Auburn Cemetery

In order to revitalize Mount Auburn Cemetery as a significant historic space in Westport community and the City of Baltimore, we first conducted an observational analysis of the socio-spatial characteristics extrapolated from an extensive literature review (Cooper Marcus and Francis, 1990; Whyte, 2001; Francis, 2003; Watson, 2003):

2.3.1.1 Size, and location and neighbourhood context: Mount Auburn Cemetery is located within the city limits of Baltimore accessed by State Highway 295 and Interstate 95. The 32 acres of land it occupied in a polygon shape is permanent home to 55,000 African-American buried here. Originally a rural cemetery, today it is surrounded by housing projects, row homes, commercial, small industrial sites and is the largest open space in Westport.

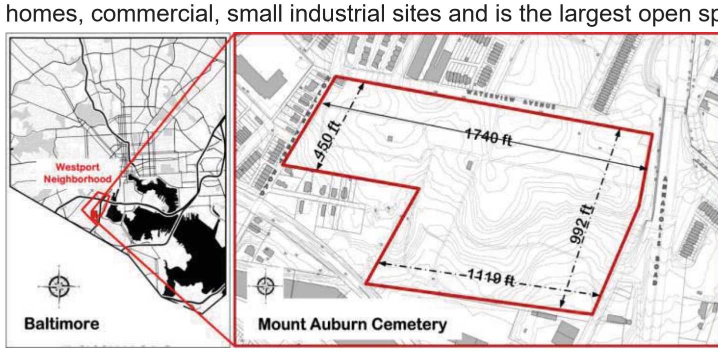

Figure 5. Size and location of Mount Auburn Cemetery

2.3.1.2 Climate, orientation and views: Mount Auburn Cemetery lies within the humid subtropical climate zone (Cfa), based on the Köppen classification, with four distinct seasons. It enjoys a view shed oriented alongside Annapolis Road of a very scenic view toward Hanover Street Bridge on the Baltimore inner harbour. The sight to the harbour warranted the naming of the northern boundary street running parallel the cemetery, Water view Avenue. This view may eventually encompass the Sagamore Development for the Under Armour Headquarters, West Covington on Middle Patapsco River (Figure 6).

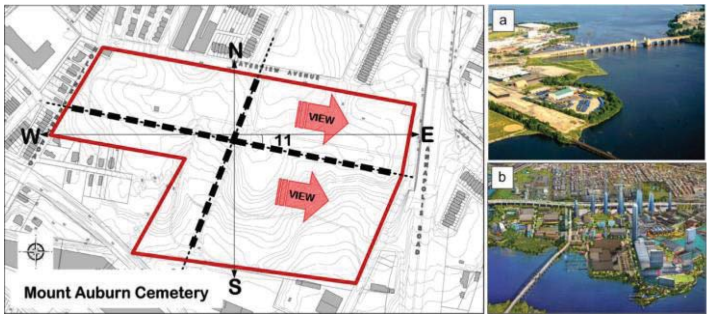

Figure 6. Views of Mount Auburn Cemetery in Baltimore: a) View toward the Hanover Street in the north-east of the site, b) View toward the Under Armour Headquarters in the eastern side of the site

2.3.1.3 **Accessibility and Circulations**: Mount Auburn Cemetery is accessed by Waterview Ave from the North, I-295 and Annapolis Rd from the East, and Hollins Ferry Rd from the West. Access to public transportation includes five bus stops on the northern side of the site and taxicabs that are around, however they stop anywhere on the road that creates traffic problems, and unsafe environment for local residents. Since originally designed as a rural Cemetery, a strong conflict can be observed between vehicles and pedestrians, as the sidewalks and roadways are not clearly separated from each other. There is no crosswalks at key intersections that caused confusion, accidents and unsafe circulation for the visitors (Figure 7). Wayfinding is an issue as the majority of installed signs are not designed properly and do not guide first time drivers and pedestrians to the site. The Mount Auburn Cemetery has a standard ornamental entrance gate, brick and wrought iron half perimeter fence, the remaining fence is chain linked adjacent to the neighboring commercial trucking. There is lack of sufficient crosswalks to serve pedestrian access into the main entrance gate of the cemetery, which causes confusion, accidents and unsafe accessibility for pedestrians. Inside the cemetery, the paths do not lead comprehensively to all zones of the Cemetery, leaving some areas hard to access. While the serene rural landscape provides a respite from the urban chaos of the city, its present condition does not allow for social gathering for events around Easter sunrise for which the Sharp Street Church Congregation visits the Cemetery. Open and covered spaces, as well as additional paths for access are needed, particularly for seniors and disabled persons. In addition, the exit gate is closed and signage opposes directionality making way finding confusing for first time visitors.

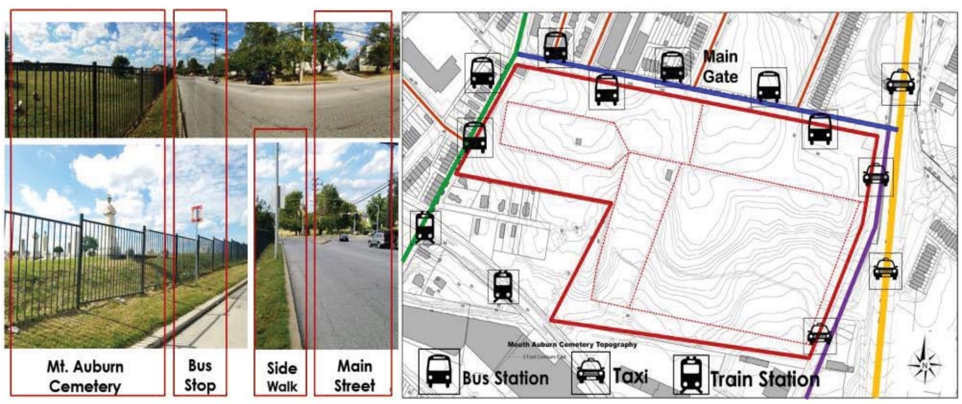

Figure 7. Public transportation and strong conflict between vehicles and pedestrians in Mount Auburn Cemetery in Baltimore

2.3.1.4 **Environment and landscape:** Originally designed as a rural Cemetery over farmland outside the city, Mount Auburn has many features that distinguishes it from urban cemeteries. It contains free flowing unordered distribution of natural elements that include wildflowers, shrubs, bushes and grass. Occasional trees provide shade for groups of burial sites that are individually taken over by grass and weeds. The designed randomness of locating burial sites is intentional and enhances temporality and flexibility. It is a “way to ensure that there will always be room to bury additional family members” (Jones, 2001).

2.3.1.5 **Facilities and equipment:** On 32 acres site of Mount Auburn Cemetery, facilities to provide a comfortable environment protected from harsh climatic do not exist. There is inadequate facilities and furnisher to support gatherings, sitting, drinking water, parking, and spending time to explore this unique landscape.

2.3.1.6 Safety and security: Some dark, dead ends, and in-accessible corners near the residential area were observed in the Mount Auburn Cemetery, and the absence of lighting and lack of security system encourages crime. The quality of signage can be upgraded to clarify the main route and allow visitors to find their way *to the graves inside the* Cemetery.

2.3.1.7 Architecture and construction: With regard to the architectural elements, an old vault still exists near the main gate of the cemetery located on the highest site topography. This is an asset for providing visitors a sense of place and enhance way finding. It is suggested to renovate this ancient vault based on original style to maintain a sense of permanency and heritage, improvement of sense of place (aesthetically, culturally, and historically).

2.3.1.8 Programming, activities and sociability: In addition to the residential communities, the Cemetery has religious structures, educational buildings and green spaces nearby.

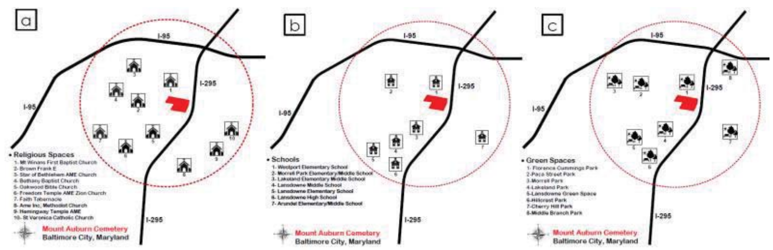

Figure 8: Cemetery Connectivity with: a) Religious Buildings, b) Educational Institutions, c) Green Spaces and Parks

2.3.1.9 Management, operations and maintenance: The owners of the Cemetery no longer live around it, and have not allocated sufficient funds for management and maintenance. An examination would be necessary to best serve the need for repair and/or maintenance of headstone and graves. An estimated $25000 per year for maintenance (http://mountauburn.msa.maryland.gov/) will need a Partnership Plan that engages all stakeholders in the perpetual care of the Cemetery.

2.3.2 Meetings, Interviews and Survey Results:

To further explore the role of Mount Auburn Cemetery in the socially sustainable redevelopment of Westport neighbourhood, we interviewed resident members of the Westport Neighbourhood Association in 2016 as part of the elective Urban Regeneration Studio ARCH403 in the Bachelor of Science in Architecture and Environmental Studies program at Morgan State University. In 2017, we met with Reverend Cary James, the current Pastor of the Sharp Street Memorial United Methodist Church, and in 2018 interviewed the Members of the Church History Committee as well as conducted a survey of the Church Congregation.

2.3.2.1 While the Westport residents honour the Cemetery as a historic site, they also consider it unsafe to walk by or use as an urban respite for contemplation and meditation. Residents in general are willing to volunteer in the efforts to revitalize the Cemetery and help with its perpetual care and upkeep. Their interest centred on ensuring a safe green space in the vicinity of the Elementary School for the health and wellbeing of their children.

Figure 9: Morgan BSAED students engaging the Westport community in Fall 2016

2.3.2.2 The results of the meetings, interviews and surveys conducted with the Sharp Street Church community reveals that most members have been affiliated with the Cemetery through the Church for more than 30 years and have seen with dismay the continued cycles of the Cemetery's decline, periodic efforts at "resurrection" that eventually proceed with neglect. Most visit the Cemetery at least once a year as they reside far away, yet each recognizes its tremendous historic significance to their distant community, to the city, state and the nation.

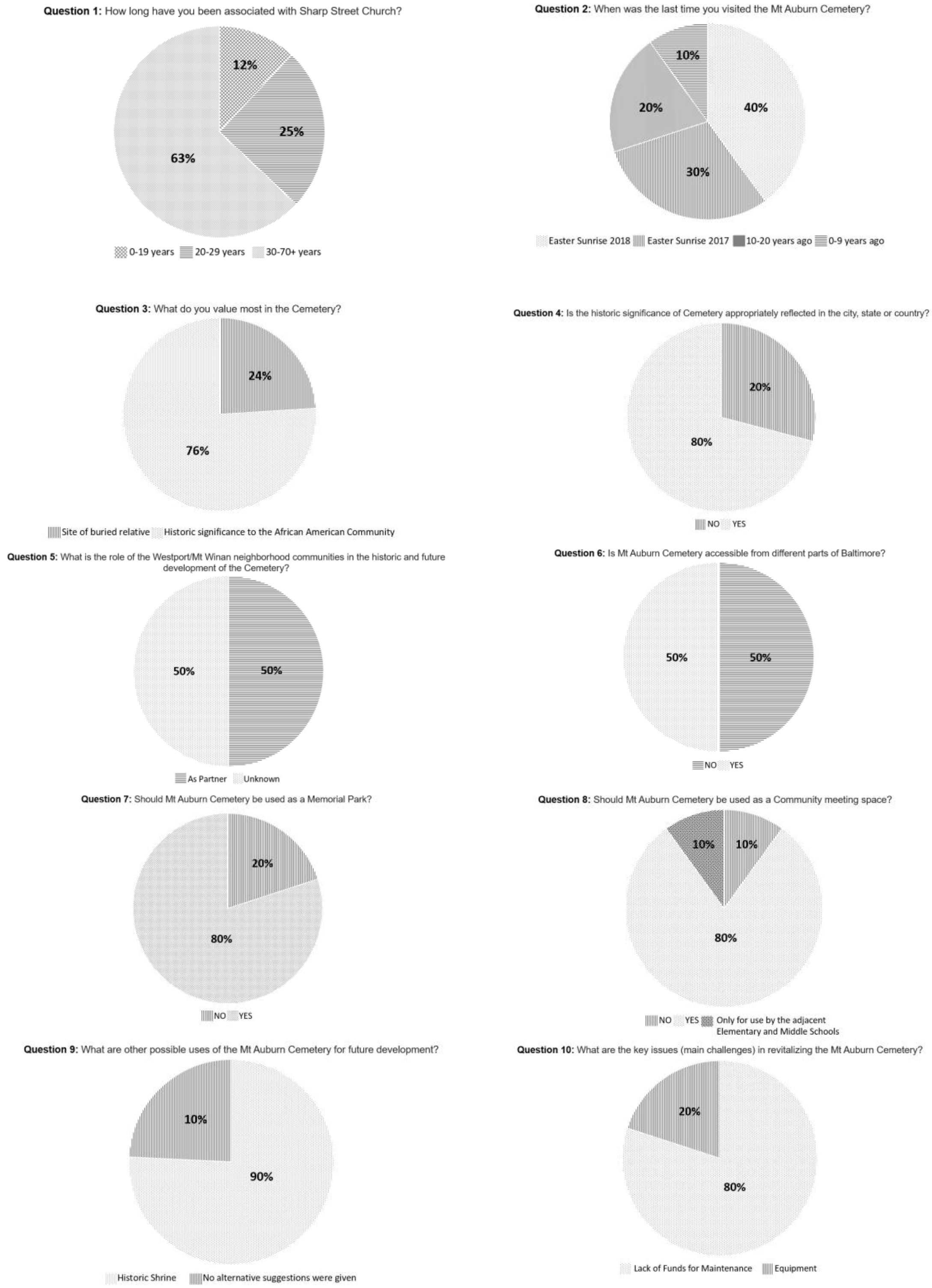

Figure 10: Results of survey conducted in March 2018 with the Sharp Street community

One third of the Church community surveyed suggested reviving the partnership with Morgan State University and the Department of Public Safety and Correctional Services (DPSCS) to train and hire inmates for the continued upkeep of the Cemetery grounds. The operational maintenance of the Cemetery could be sustained through continuation of this partnership and the role of the Morgan State University's Landscape Architecture program could be expanded to provide technical and skills training of the inmates to develop life skills for future jobs. Some Church History Committee Board Members suggested that the visibility of the Church will be enhanced through a sustained partnership with Morgan State University and the Westport Neighbourhood Associations. One member noted that special Bus Tours between the Church and the Cemetery could bridge the distance between the communities and allow Church community to visit the Cemetery more often and engage in social activities generated through the redevelopment of the Cemetery.

CONCLUSION

This paper explored the theoretical and potential impact of socially interactive urban open spaces on sustainable development of neighborhoods. It focused on the potential for revitalizing private rural cemeteries as important open spaces often neglected in urban development, and concludes that:

1. Mount Auburn Cemetery is historically rooted in 150 years of African-American culture and contains a unique landscape that has connected nature with the transforming urban communities. While originally designed as a rural burial grounds, the Cemetery remains the largest pervious green space in the urban neighbourhoods of Westport, with a potential for social enhancement.
2. While the cemetery's historic and present ownership remains with Sharp Street Methodist Church, the neighborhood residents are not directly connected or engaged with the upkeep of the cemetery. The social disconnection between the Sharp Street Congregation and the Westport communities is one of the reasons for the perceived deterioration of the cemetery.
3. Though the Church and the Westport residents have both faced a great social transition, revitalizing the Cemetery as an urban Memorial park through community engagement process will reconnect the Cemetery as a "City of the Dead" to collective memory and enhance civic identity.
4. Morgan State University School of Architecture and Planning has a critical role to play in guiding the Partnership and Revitalization plans for the Mount Auburn Cemetery through community engaged activities with the distinct stakeholders and the Cemetery Board of Trustees.
5. Mount Auburn Cemetery is a place for reflection on the uniqueness of African American cultural landscape in the lives of the city residents contributing to the urban history of the City of Baltimore.

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We thank our colleagues Professors Leon Bridge and Dale Green, Pastor Reverend Cary James Jr., members of the History Committee of the Sharp Street Memorial United Methodist Church, Ms. Dorothy Daugherty, Ms Sara Ford for their valuable time and sharing of archives and space for community engagement activities. We are grateful to Ms. Keisha Allen, Mr. James Allston of the Westport Community and Economic Development Corporation for their support and connecting us to the residents. Lastly, we wish to further the work of Ms. Robin Howard, Associate Director of the James E. Lewis Museum of Art (JELMA), Dr Diane Jones for leading previous collaborative projects on the Mount Auburn Cemetery, and look forward to meeting the Mount Auburn Cemetery Board of Trustees to discuss the next phase of this research project.

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Dustin Graham Albright

Architect Meet Ecologist: A Studio-Based Study of Massive Timber for an Ecological Research Lab

Architect Meet Ecologist: A Studio-Based Study of Massive Timber for an Ecological Research Lab

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ABSTRACT: This paper describes ongoing design research at Clemson University that explores the intersection between massive timber building systems, as leveraged for an academic facility, and topics of sustainable forestry, forest health, and carbon footprint. At the center is a topical design studio course in which students designed a new laboratory for Clemson's Baruch Institute for Coastal Ecologies and Forest Science (BICEFS), in Georgetown, South Carolina. Students were challenged to utilize massive timber building systems, including Cross-Laminated Timber (CLT), while discovering their structural and environmental benefits, and considering the potential impacts of the associated construction on the sensitive site. Additionally, students were required to examine the embodied energies of these timber systems using BIM and available estimation tools. This aspect was of particular interest to BICEFS, as it dovetails with their own research on carbon sequestration. The paper presents selections from the laboratory proposals as well as the carbon footprint data and related methodologies, all while considering the degree to which such questions can be successfully integrated into the design studio. The paper concludes by outlining research objectives for future phases of the project, including more in-depth LCA studies plus embedded monitoring of structural and envelope performance.

KEYWORDS: massive timber, carbon footprint, forest ecologies

INTRODUCTION

In the Fall of 2017, three studio design courses at Clemson University were combined to tackle a challenging service learning project for the Baruch Institute for Coastal Ecologies and Forest Science (BICEFS). In advance of its 50th anniversary, and while facing new infrastructure needs for its future, BICEFS turned to Clemson's School of Architecture for concepts for a new research laboratory, new researcher housing, and site design that tied its small campus together while establishing a framework for smart and environmentally sensitive growth. One critical layer to the project was the integration of timber building systems aimed at minimizing embodied energy and supporting the state's forest products industry. This paper focuses on the laboratory project, the utilization of "massive timber", and the dovetailing of timber construction with BICEFS' own forest research.

1.0 BACKGROUND AND SETTING

1.1. Massive Timber and its Place in South Carolina

In February of 2013, a collection of curious designers, builders, and wood products professionals gathered in Seattle for the U.S. Cross-Laminated Timber[1] (CLT) Symposium and the introduction of the U.S. CLT Handbook, a design guide addressing performance and construction topics associated with these timber panels (Douglas, 2013). Since that time, massive timber construction, using systems like CLT, has slowly begun to take hold in North America. What began with a few noteworthy projects in Canada and the Pacific Northwest has spread with projects in other regions. Moreover, industry R&D efforts contributed to the recognition of CLT in the 2015 International Building Code, and more expansive considerations are currently underway for future editions. However, one constraint on the wider implementation of these technologies has been a stalemate between production and perceived demand. Would-be producers in the U.S. have been slow to invest without solid knowledge of what the market will be, while owners and designers have been reluctant to pursue mass timber solutions without reliable production in their region. Still, a few domestic producers have recently emerged, and new projects are beginning in areas served by these factories. Other enterprising partnerships are positioning themselves to fuel both the demand and supply sides of the equation as developer/designer/fabricator.

Playing a crucial role in the interim period has been a key third player – academic institutions as clients. Schools such as the University of British Columbia, UMass, Georgia Tech, and the University of Arkansas have selected massive timber for new campus projects, thereby providing important case studies for the forest products and building industries. This has been spurred, in part, by vested faculty research interests in the areas of mass timber constructability, structural behavior, thermal performance, and economic and environmental impacts.[2] The marriage of detailed material research, full-scale implementation, and post-construction analysis has contributed to real advancements in the acceptance of these emerging technologies, as well as dynamic and productive interactions across all facets of industry, from designers to manufacturers to code officials and legislators. Drawing from these examples, and motivated to provide a model structure in South Carolina, Clemson University is currently planning a new outdoor recreation center that features CLT construction. As with other institutions, the decision to pursue mass timber was influenced by faculty research interests. In fact, this is the result of four years of discussion between the planning department and Clemson's cross-disciplinary Wood Utilization + Design (WU+D) Institute.

Moreover, the decision to pursue mass timber solutions at Clemson is grounded in their potential to positively impact the state's vital forest economy, and advance its sustainable forestry practices. According to a 2016 USDA report, South Carolina is home to 5.22 million hectares (12.9 million acres) of forested land, representing 63% of its gross area (Forests of SC, 2016). The forest industry contributes over $21 billion annually to the state's economy and represents the most significant manufacturing sector in terms of both jobs and labor income (Economic Contribution, 2017). Within this total, the solid wood products sector (including lumber, plywood, poles, trusses, millwork, etc.) contributes a direct economic output of $2.5 billion. On the supply side, the timber sector accounted for nearly $300 million of direct contribution, while the logging sector, which feeds the mills, accounted for $375 million (Economic Contribution, 2017). These supply numbers, while significant, are still lower than pre-recession numbers from 2006, but they have much room to grow if spurred by new or expanded timber markets. New markets might also prevent the conversion of timberlands to other non-forest uses, such as agriculture or development.

Of the state's forest area, 88% is privately owned, and the overall percentages of hardwoods versus softwoods are 52% to 48%, respectively. Loblolly-shortleaf pine, makes up the predominant species classification, accounting for 44% of all forests, while another Southern Pine variety, longleaf pine, makes up the remaining 4% of softwoods (Forests of SC, 2016). Southern Pine dominates the wood products market throughout the Southeast, and its share stands to increase further if mass timber systems gain a foothold. Southern Pine CLT has been the subject of much research and testing within Clemson's WU+D Institute, and the region's first CLT manufacturer will utilize Southern Pine when it begins operations in late 2018.[3] Considering the potential economic impacts, plus the intersecting research interests of BICEFS and the WU+D Institute, as well as the practical momentum represented by Clemson's planned mass timber recreation center, the studio faculty and the BICEFS director agreed to emphasize mass timber structural systems for the proposed new laboratory.

1.2. BICEFS and its Needs

The Baruch Institute for Coastal Ecologies and Forest Science (BICEFS), located in Georgetown, South Carolina, is one of eight research stations operated by Clemson University's Public Service and Agriculture (PSA) program. BICEFS operates from the historic Hobcaw Barony, which comprises 6,475 peninsular hectares (16,000 acres) between the Winyah Bay and the Atlantic Ocean. Once owned by Wall Street financier, Bernard Baruch, and later his daughter, Belle, the property was ultimately left to a trust in 1964, and the Belle W. Baruch Foundation was established to manage it in perpetuity. According to Belle's wishes, the state colleges and universities of South Carolina were granted access to the property to research and conserve its array of natural ecosystems. Under this agreement, BICEFS was established by Clemson in 1968, with the tripartite research mission of forestry, freshwater wildlife science, and beach stabilization. Over the years, BICEFS' work laid the groundwork for the South Carolina Forestry Commission's best management practices for statewide water and soil protection, among other contributions.

Today, BICEFS consists of ten research faculty, two emeritus faculty, one extension specialist, eight lab staff, plus an array of post-docs and grad students. The numbers swell in the summers with the addition of undergraduate interns. The laboratory work ranges from wildlife sampling to soils to hydrology to biogeochemistry, all revolving around the larger topics of climatic and developmental disturbances and their effects on forest and wetland health. This includes the effects of storm surge salinization on tree growth and carbon sequestration. The property is home to wetland stands of bald cypress and water tupelo, plus dense southern pine forest, portions of which are regularly harvested and replanted. This activity helps fund the Baruch Foundation's ongoing management of the property, and also knits the Hobcaw forests together with the larger South Carolina forest economy.

This institutional history and context were first introduced to the students in the form of a *Request for Proposals* (RFP) document prepared in advance by the Studio faculty, with input from BICEFS director Skip Van Bloem. This RFP also included detailed descriptions of existing facilities, their functions, and their limitations. Existing facilities include an administration and classroom building (completed in 2008), a laboratory building (renovated in 2008), and a residential cottage (completed in 2014) for up to ten guests. To address strategic growth objectives, BICEFS is aiming to double its laboratory space, and add to its housing for interns and other short-term occupants. In addition to lacking in physical lab space, the current laboratory building is also inefficient in its layout, does not easily accommodate dirty-work functions, and lacks adequate workspace for graduate students. In light of these challenges, and under the heading of “Research Support”, BICEFS sought planning and design for a new laboratory facility to consolidate lab functions and storage, plus associated renovations to the existing building. The new facility would need to be situated to optimize workflows, while also respecting specific physical parameters imposed by the site.

An interdisciplinary design studio was formed to respond to these needs and to help articulate other, subtler opportunities – both for the building and its surrounding site. Compelled by the low embodied energy and carbon sequestration offered by timber systems, and the opportunity to connect to BICEFS’ and the Baruch Foundation’s own work in forestry, the decision was made to pursue massive timber structural solutions for the new laboratory building. In so doing, special consideration would be given to the following topics:

- State’s forest industry & potential economic and environmental impacts of mass timber production
- Proper sizing and orientation of proposed CLT panels and other associated framing
- Proper staging of timber panel construction, and potential benefits of shorter construction schedule
- Proper detailing of mass timber systems
- Embodied energy analysis of mass timber solutions

Funded by Clemson PSA and the Wallace F. Pate Foundation (a BICEFS supporter), the ultimate goal of the Studio was to produce a compelling design proposal (e.g. Fig. 1) that would be used to initiate fundraising and later serve as a reference point when the University engages professional design services.

Figure 1: Rendering of winning laboratory proposal. Source: (Anderson, Chan, and Heezen 2017)

1.3. Design Studio Setting

The organization of the Hobcaw Studio and the structure of its calendar were instrumental to the success of the project. Importantly, the Studio was divided into three working sections and was interdisciplinary in nature. A group of 14 architecture students took on the housing needs. This group consisted of eleven senior-level undergraduates and three graduate students in their penultimate semester. Another group of 13 architecture students worked on the research support designs (9 undergrads, 4 grads). Finally, ten senior-level undergraduates in landscape architecture were tasked with site design, acting as special consultants to their architecture colleagues.

Likewise, the project schedule was divided into three phases. For the research support project and its associated site designs, the first phase consisted of background research on timber products and construction, detailed site analysis, programming, and schematic design. Students of both disciplines worked individually during this phase, resulting in thirteen initial design proposals for the new lab and four sets of conceptual site strategies. Following Phase 1, which lasted four weeks, the four most promising lab proposals were selected for advancement, and design teams of varying size were formed around each of these proposals. Moreover, each design team was paired with a landscape architecture student, whose skillsets and early concepts were most complementary.

Phase 2 (5 weeks) involved close collaboration between the disciplines and ended with integrated proposals for proper siting, grading, foundations, ground water management, and front-of-house versus back-of-house functions and circulation. This phase also delved into the selection and design of the massive timber structural elements. Group presentations onsite at BICEFS concluded Phase 2, and provided ample feedback directly from BICEFS faculty, staff and students. Phase 3 (6 weeks) kept the groups intact while focusing on technical resolution, embodied energy analysis, and preparation for final reviews. Following Phase 3, a winning design proposal was selected as the basis for fundraising and future development.

Throughout the course of the project, Dr. Van Bloem acted as our client representative, taking part in each project review, helping winnow down the initial proposals, and helping select the winning design in the end. Additional guidance in the area of mass timber utilization was provided during a studio visit from Tom Chung of Leers Weinzapfel Associates, lead architect of the Olver Design Building at UMass Amherst – the first CLT academic building in the United States. Among other subjects, Mr. Chung addressed the life-cycle benefits of CLT, its precision, and its ease-of-construction. Falling within Phase 3 of the project, he was also able to offer technical advice on topics ranging from floor overhangs to direct panel-to-column connections.

2.0. PRE-DESIGN

2.1. Analysis of Wood Industry

The semester began with a crash course in wood and timber construction, and its broader implications for the state and regional forest industries. The lab design students were divided up to study the three overarching topics of forestry, forest products, and building with wood. This exercise helped paint a complete picture of wood utilization, from growth and harvest, to milling, to design and implementation. In addition to the economic facts described in Section 1.1, students learned about the end-uses of different wood species, the network of logging and milling operations throughout the state, the specific building products manufactured in the region, and the opportunities and challenges of wood construction, including relevant building codes.

All of this helped to lay a foundation for the Studio's later work with massive timber building systems, including CLT and glulam. Students could recognize the path of the lumber used in those products, and the range of potential impacts that mass timber adoption would make at all levels. Within this framework, students noted the importance of sustainable forestry practices and learned about the tenets of certification programs such as those offered by the Forest Stewardship Council (FSC) and the Sustainable Forest Initiative (SFI). Of these two, SFI is the more prevalent in South Carolina. Clemson's own *Experimental Forest* represents 7,082 hectares (17,500 acres) of the state's 483,257 hectares (1.19 million acres) of SFI-certified forests[4]. The total SFI-certified area represents about 9% of the state's overall forestland, up from 0.8% in 2013. This trend is driven by market demand for certified, sustainable wood products, often within the building industry, and stands to continue if mass timber manufacturing finds a foothold in the state.

It was at this stage that students also began learning about the carbon benefits of building with wood when it is sustainably grown and harvested. They learned about the comparatively low levels of embodied energy in wood building products, made lower by the use of recycled wood biofuels for powering the sawmills. Additionally, they learned that trees sequester carbon[5], and that wood products store this carbon throughout their lifespans. Importantly, trees take in CO_2 at differential rates as they age, with the rate diminishing after the tree reaches maturity (Oliver 2014). Therefore, regular and responsible harvesting and replanting serves to maximize the net levels of carbon sequestered in the system. For this reason, a robust market for wood products, including massive timber, is critical for optimizing the total carbon benefits of our forests.

2.2. Site Analysis and Constraints

The Studio made its first site visit to Hobcaw during the second week of the course, and students presented the background research described above. This served the dual purposes of introducing the wood utilization focus to BICEFS personnel, and gathering their feedback on these topics. Conversely, select BICEFS faculty shared from their own research, giving our students a keener understanding of the diverse set of needs to be addressed in the new and renovated laboratory facilities. This was followed by guided visits to various field research locations around the property, from the estuarial marshes to the cypress swamps to the loblolly pine stands, driving home for the students the integrated nature of this work and its relevance to the systemic effects of climate change. It also provided a sense of the rhythms of fieldwork and the cycles of going out from and returning back to the labs. Tours through the existing labs further illustrated these work flows and the value of good circulation, storage, and support, items lacking in the current BICEFS set-up.

For the sake of operational efficiency, and to minimize disturbance and infrastructure, it was clearly important to locate the new research support facility close to the existing lab and the administration building.

In addition to the lessons described above, students were introduced to three very important and specific constraints associated with this immediate building site. The first constraint related to fire separation. During his own presentation to the Studio, the executive director of the Baruch Foundation described the forest management practices on the property, and the importance of prescribed burns, which serve to control the underbrush and thereby safeguard against both wildfires and threatening insects, such as the Southern pine beetle. Given the periodic need for these burns, a firebreak is required to separate the research campus and its buildings from the forest edge to the south. This translates to a clear space of around 15.24m (50ft).

The second constraint had been described in the earlier RFP document, but was elaborated upon in a presentation from the presiding agent of the Fish and Wildlife Service. The red cockaded woodpecker (RCW) is a protected bird species that nests in the cavities of mature longleaf pines. Federally protected since 1970, its coastal habitat was greatly diminished by Hurricane Hugo in 1989 (Williams 2002). Of the remaining RCW clusters on the Hobcaw property, one is located immediately to the northwest and southwest of the BICEFS research campus. The foraging pattern of these close-by RCWs equates to a routine flight path around the western end of the existing lab facility, thereby restricting any new construction and instead relegating it to the area remaining on the east. Moreover, the breeding season of the RCW will limit onsite construction activities to the months of July through March.

The third constraint was described by the BICEFS director when he pointed out a low area east of the lab that is prone to flooding during major rain events. He was able to indicate the approximate flood level from a recent hurricane, making clear the need to address this topic in the proposed building and site designs to follow. Students noted two wetland areas at the boundaries of the site, one constructed and one natural, and began thinking about opportunities to create a comprehensive water management strategy for the campus.

3.0. DESIGNING SOLUTIONS

3.1. Site and Building Planning

Following the predesign analyses, and in light of the specific constraints described above, the students began planning for the new research support facility, its programming, and its specific location and orientation. The most promising solutions from Phase 1 were advanced by the interdisciplinary teams of Phases 2 and 3. Each of the final proposals incorporated a service road along the southern edge to provide for back-of-house access while doubling as a firebreak. Due to the restrictions imposed by the flight path of the RCWs, each of the proposals also elected to site the new building to the east of the existing lab, meaning that each design had to contend with potential flooding at this location. The approaches on this point differed. One group elected to build on the highest ground, immediately adjacent to the existing lab. This dictated a less-than-ideal building orientation resulting in problematic east and west sun exposures that required deeply louvered facades. Another group proposed more extensive grading to reshape the land and build on the resulting plateau. The remaining two groups elected to bridge the new buildings over the flood plane to varying degrees, while locating at the ground level the utilitarian workspaces, locker rooms, and other such functions that could withstand flooding without damage (e.g. Fig. 2). Noting the need to protect wood construction from moisture cycles, the lower levels in these bridging schemes feature combinations of more durable materials, such as reinforced concrete and Cor-Ten steel. All four of the designs proposed some form of on-site water retention, followed by drainage to the natural wetland to the south.

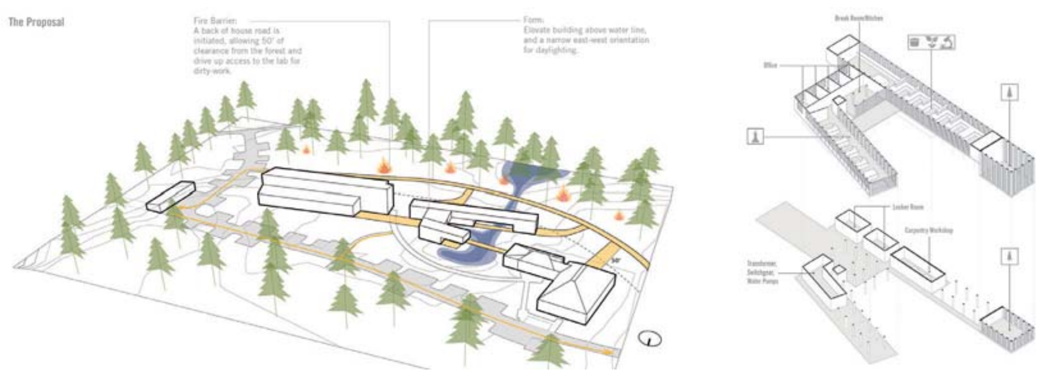

Figure 2: Diagrams of site design strategies and program layout. Source: (Anderson, Chan, and Heezen 2017)

At these early stages, the prospect of mass timber presented two distinct advantages for construction. First, timber offers a very high strength-to-weight ratio, and this lightness supported the notion of structures spanning over the retention area. Additionally, this reduction in weight versus other forms of construction[6], equates to reduced sizing for the building's foundation systems, further minimizing the necessary sitework. This is a common point of emphasis among designers experienced with mass timber projects. The second compelling advantage relates to the constructability of timber panel systems like CLT. The prefabricated nature of these products, paired with easy connections between members, generally equates to accelerated on-site construction schedules. This point is particularly promising for BICEFS, as it must plan around the restrictions imposed by the RCW breeding season. In each of the final design proposals, construction could easily be staged from the south of the site, with efficient panel delivery via the new service road.

3.2. Mass Timber Development

Following the schematic design stages of Phase 1 and early-Phase 2, students progressed into a period of technical development and documentation, including in-depth development of the massive timber building systems. Each of the teams elected to use some combination of CLT panels and glulam framing members. They produced a scaled structural model and accompanying diagrams indicating the placement and relative dimensions of each component in the system. This involved researching span capacities as a function of panel thickness, and also considering the benefits of repeating module sizes, all while making sure that beams and walls were adequately placed to support floor and roof panels. Students also learned that the outer plies of a CLT panel should be oriented to optimize the structural performance in its given role. This meant longitudinally in the direction of span to maximize stiffness of floors and roofs, and vertically for high compression strength in walls. One design team even chose to vary the span direction and sizing of its floor and roof panels in order to most efficiently bridge over the water retention below. In all cases, panel sizes were limited to 3.05m x 18.29m (10ft x 60ft) or less, as this tends to be the upper limit for manufacturers.

From there, students moved into the resolution of the building envelope. Working from case study examples, the design teams interpreted the best strategies for continuous insulating layers and moisture protection. It was at this point that they came to appreciate the additional insulating value of timber itself, which offers an R-value of around 0.55 per cm (1.4 per inch) for softwoods. Each team was required to present detailed wall section drawings articulating the various layers at work in the envelopes. This was also a point that demanded critical analysis of the practical limitations of CLT for this application, namely the durability of exposed floor surfaces. In response, concrete skim coats were specified for laboratory floor surfaces, and recommended separation distances from ground level were observed for any first-story timber components.

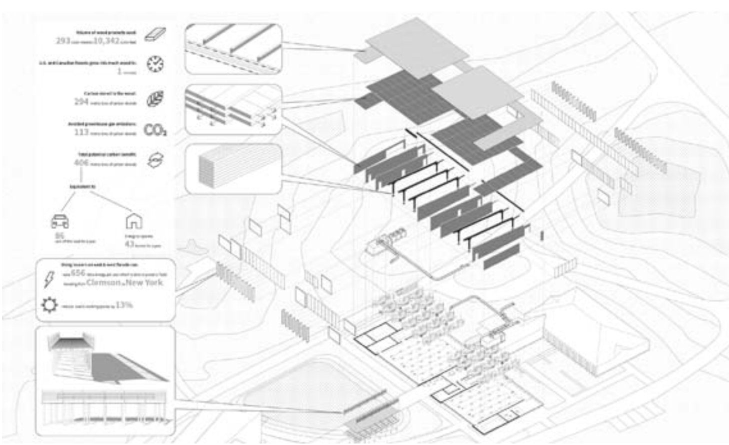

Figure 3: Axonometric diagram articulating timber building system. Source: (Xia, Day, Liang, and Schoonmaker 2017)

3.3. Life Cycle Energy

Building upon the carbon benefits of wood suggested by the background research of Phase 1, students were required in the later stages to estimate the embodied energy of the timber structural systems employed in their design solutions. This served to further cement for them the importance of a full life-cycle understanding of energy, from harvest and manufacturing to transportation and construction – each coming before the operational energy of the completed building to which they were more accustomed. Digital modeling provided an important foundation for these calculations, in that accurate models (e.g. Fig. 3) enabled the quick reporting of member volumes. Three of the four design teams were well-versed enough to use BIM software (in this case, Revit by Autodesk), and could therefore take things a step further through material and assembly definitions. These definitions were essential as the Studio forayed into the use of Tally, a professional life-cycle assessment tool that runs as a plug-in for Revit. This tool was effective for illustrating the myriad factors that go into predictive LCA analyses, and students were asked to make certain baseline assumptions for transportation distances and other inputs. Ultimately, however, Tally required a level of technical understanding of building assemblies that was deeper than what the Studio, and in particular the undergraduates, brought to the table. It was the metaphorical scalpel, when we needed more of a blunt instrument at this stage to study the timber components in isolation. This, when paired with the fast pace of the project and the timeline of deliverables, contributed to a decision to shift directions.

The Studio turned to a simple carbon calculator[7] devised by *WoodWorks*, an education and technical support organization funded by the softwood lumber industry and the U.S. Forest Service. This calculator requires volumetric inputs for lumber and massive timber elements, and area inputs for sheathing. It also allows for the designation of wood species. Outputs include the total mass of CO_2 sequestered, and an estimation of the total greenhouse gas emissions avoided by using timber rather than other conventional structural materials. This GHG estimation utilizes a displacement factor based on building construction type and an array of LCA case studies across materials. It also assumes an end-of-life scenario in which any timber elements would be diverted from landfills and either recycled or used for energy recovery. Table 1 below shows the carbon impact results from the timber structural components of each of the four laboratory design proposals. Wood sheathing, decking, and façade treatments were omitted from these calculations below, though they were included at other points along the way by certain teams.

Table 1: Carbon footprint data for timber superstructures. Source: (Author 2018)

Project Team (conditioned area, m^2)	*Structural Timber Volume, m^3 (ft^3)*	*CO_2 Sequestered, metric tons*	*Total Avoided Greenhouse Gas Emissions[4], metric tons*
Anderson, et al (661)	292 (10,327)	295	114
Rowell, et al (1,372)	450 (15,893)	454	176
Xia, et al (936)	287 (10,139)	290	112
White, et al (1,408)	413 (14,594)	417	161

4.0. FOLLOW-UP RESEARCH

The work described in this paper relative to carbon impact analysis is clearly a rudimentary first step. Having recently completed the central design deliverables for BICEFS, the project team is now poised to delve into a more detailed analysis of the embodied energies and other LCA impacts posed by the selected laboratory proposal. We will turn again to Tally as a tool for this exercise. In so doing, one goal is to redesign the laboratory structure in steel and in concrete and run comparisons against the data generated for massive timber. This will also allow cross-comparison with the initial GHG estimations rendered by the WoodWorks calculator. Moreover, this work would set the table for broader questions, such as: what is the total potential GHG impact (including sequestered carbon) if Clemson University adopted wood and timber systems for all new construction proposed in its master plan? Can the expanding campus begin to act as a carbon sink?

Another area of follow-up research lies further in the future. If BICEFS completes a new research support facility using CLT, then it will be another key structure in the growing list of reference points for mass timber construction. To maximize its impact, it is important to thoroughly document its costs and any lessons from construction. It will also be valuable to monitor the structural and envelope performance over time. Following initial discussions on the matter, BICEFS indicated a keen interest in pursuing wireless sensing to measure moisture, temperature gradients, and structural vibrations. Such monitoring will shed light on the long-term behaviors of mass timber structures, an area for which there is currently little data in North America.

CONCLUSION

In conclusion, the 2017 Hobcaw Studio described in this paper proved to be successful in at least three significant ways, with each having connections to the emphasis on massive timber. First, the interdisciplinary collaboration between students of architecture and students of landscape architecture was critical for developing comprehensive and cohesive design solutions for the sensitive setting. In this regard, the potential advantages of CLT for both weight and construction schedule were understood and appreciated by all involved. The focus on timber also served to effectively attune the students of both disciplines to the larger forest industry and its connections to the ongoing research activities of BICEFS, our “client.”

Second, the project provided students with a new knowledge of embodied energy. The graduate students in the course were already versed in consumptive energy modeling, and were even called upon to use those skills to study the effects of various shading strategies. However, embodied energy and its place in life cycle assessment was largely uncharted territory for the class. The use of quantitative tools, though encumbered by the limitations noted in Section 3.3, effectively grounded and made tangible this aspect of the work.

Finally, the Studio served as a model for combining and balancing a funded service learning project and its associated demands with a material-focused research agenda. This, of course, required front-end support from BICEFS for the topic of mass timber and an acknowledgment of the potential synergies in its use for the new facility. The benefits of service learning scenarios are well understood to include the experiences of working directly with specific clients, their real needs, and their constraints. This was certainly the case with the Hobcaw Studio, and the embedded competition format further drove solutions that were both innovative and responsive to BICEFS' requirements and concerns. Likewise, the depth of emphasis on massive timber systems equally led to a clarity and focus in the work of the Studio. The resulting design products from this unique arrangement were mutually beneficial to BICEFS, as solutions to their institutional needs, and to the course faculty, for whom the work serves as a platform for further research – both in the area of forest industry impacts as well as the deeper material and performance analyses described above.

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ENDNOTES

1 Cross-Laminated Timber is a panelized timber building product, in which the laminated layers of lumber are laid in alternating grain directions to one another. This enhances dimensional stability of the panels.

2 The John W. Olver Design Building (2017) at UMass Amherst was originally designed as a steel building. According to project architect, Tom Chung, the structure was modified to mass timber during the late stages of the design development phase. This decision was driven by the research interests of faculty within the Building and Construction Technology department, one of the multiple disciplines housed in the new facility.

3 IB X-LAM USA, a division of International Beam, will produce CLT out of its new plant in Dothan, Alabama.

4 Notably, the forests on the Hobcaw property are certified within the American Treefarm certification program, which is recognized for SFI chain-of-custody.

5 Carbon accounts for approximately 50% of the dry weight of softwood trees.

6 For reference, Southern Pine has a density of approximately 640 kg/m^3 (40pcf), whereas concrete density, is approximately 2,403 kg/m^3 (150pcf). This is a considerable difference when comparing floor systems.

7 The WoodWorks Carbon Calculator can be found at http://cc.woodworks.org/calculator.php?country=us. A detailed description of the background assumptions and displacement factors is included at http://www.cc.woodworks.org/WW_references_notes.pdf.

Phillip Michael Crosby

Eternal Gardens & Wretched Hives: Representation of Cities in Science Fiction Films

Eternal Gardens & Wretched Hives: Representation of Cities in Science Fiction Films

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ABSTRACT: Cities and the cinema have been inextricably linked ever since Louis Lumière filmed workers leaving his family's factory in 1895. Lumière's cinématographe was smaller and lighter than Thomas Edison's kinematograph, enabling it to be easily moved about the urban environment. This would eventually lead to the development of the "city symphony" genre—epitomized by films like Walter Ruttmann's *Berlin: Die Sinfonie der Großstadt* (1927) and Dziga Vertov's *Man with a Movie Camera* (1929)—which portrays the everyday urban life of rapidly-growing and quickly-changing cities. While these early films examined the city as a subject in itself, more recent films—especially in the science fiction genre—have used cities and urban environments as tools to reinforce the thematic elements of the film.

As perhaps the most influential form of popular culture of the twentieth century, film is one of the primary avenues through which the public is exposed to ideologies of the modern city. Furthermore, recent research has shown that film may strongly influence the opinions and perceptions of an audience. As a result it is essential that scholars of the built environment recognize the role that film plays in developing the cultural understanding of urban spaces. Thus, this paper will examine three common themes from science fiction films that have implications for our understanding of cities—the stratified city, the segregated city, and the synthetic city.[i] Through the analysis of cinematic spaces this paper will show how the ideas of thinkers like Friedrich Engels, Georg Simmel, Mike Davis, Trevor Boddy, Frederic Jameson, David Harvey, Rem Koolhaas, and Charles Waldheim have been disseminated to the public. This paper will also discuss how these films may be used in an academic setting to engage students in discussions of urban issues that can oftentimes be difficult to grasp in the abstract.

KEYWORDS: Film, Cities, Urbanism, Science Fiction, Pedagogy

INTRODUCTION: W**hy science fiction films?**

Despite much recent speculation that the cultural importance of film as a medium is on the wane—WIRED Magazine, for example, has suggested that it has "devolved from Culture-Conquering-Pastime to merely Something to Do When the Wi-Fi's Down"—it remains one of the most accessible and engaging forms of art. The Motion Picture Association of America (MPAA) has shown that the global box office take continues to grow (albeit slowly) year-over-year, reaching $38.6 billion in 2016. Furthermore, the MPAA shows that films reach an enormous audience: more than two-thirds (71%) of the population of the US and Canada—246 million people—went to the cinema at least once in 2016 and the average moviegoer sees more than five films per year. The cinema, thus, remains an important cultural force with immense potential to shape our perceptions of the world around us. In this regard, a growing body of research has shown that narrative forms like film can influence a viewer's perceptions on a variety of topics (e.g. Kolker 1999). Michelle Pautz (2015), for example, has shown that as many as 25% of viewers changed their opinions about the government after watching one of two films: *Argo* (Ben Affleck, 2012) or *Zero Dark Thirty* (Kathryn Bigelow, 2012).

Much of this influence is made possible by the immersive sensorial experience of sitting in a darkened room with an illuminated screen filling a large portion of our vision. Viewers become enmeshed in the world that is being brought to life in front of their eyes, allowing them to be absorbed into the narrative. "If the cinema produces its effect," French psychologist Henri Wallon suggests, "it does so because I identify myself with its images, because I more or less forget myself in what is being displayed on the screen. I am no longer in my own life, I am in the film projected in front of me." (Kracauer, 159) This "suspension of disbelief" was first discussed by Samuel Taylor Coleridge in his *Biographia Literaria,* where he described the need to imbue a story with enough "human interest and semblance of truth" so that readers would lend the story "poetic faith" in accepting the implausible as possible.

British fantasy writer J.R.R. Tolkien, however, suggests that something different is at work in successful fantastical narratives. In his 1947 essay "On Fairy Stories" Tolkien describes how readers will accept the impossible only if the narrative achieves an "inner consistency of reality." In this, Tolkien argues that genre stories must create a "Secondary World" for readers to inhabit. "The moment disbelief arises," Tolkien states, “the spell is broken; the magic, or rather art, has failed. You are then out in the Primary World again, looking at the little abortive Secondary World from outside.” Thus, Tolkien believes that a suspension of disbelief is only necessary if the work of fiction has failed to create a believable world with consistent rules and logics. The creation of a successful “Secondary World” then gives the reader/viewer the possibility of what Tolkien terms “recovery,” or a “regaining of a clear view” of the “Primary World.” Thus, it is our travels through fictitious realms that allows us to “clean our windows” on our views of the real world. It is in this “recovery” that the true power of science fiction films lie. Their implausibilities encourage us to reconsider the conditions of our own world with clearer vision and criticality.

All creative mediums explore powerful recurrent themes, therefore acting as sounding boards for how our society responds, or may respond, to certain cultural forces. Science fiction films, regardless of their fantastical visions, are no different. In recent years science fiction has moved out of the proverbial basement inhabited by Dungeons & Dragons playing geeks and into the limelight of the mainstream. Of the top 50 most popular TV shows as ranked by the Internet Movie Database, 21 come from the sci-fi and fantasy genres, including the massively popular *Stranger Things*, *Game of Thrones,* and *The Walking Dead.* In 2012 *The New Yorker* dedicated an entire issue to science fiction and 2017 brought a massive science fiction exhibition titled *Into the Unknown* to the Barbican. As Patrick Gyger—the curator of the Barbican’s exhibition—explains, the importance of science fiction is that it “helps us read the world we’re in.” (Lambie, 2017) This is echoed by British science fiction author Gareth L. Powell who states that the genre’s role is to offer “plausible futures.” “Good science fiction,” Powell suggests, “looks at the world we know and asks ‘What happens if?’” This search for plausible futures can be incredibly fertile territory for research by architects and urbanists who, of course, are charged with building the *actual* physical environments of our future world.

In addition to offering visions of plausible futures extrapolated out from the current conditions of society, science fiction also provides a territory for exploring the ethical and moral dilemmas associated with a whole range of societal questions. As Powell explains, “Futurologists and philosophers can tell us what the likely outcome of these events will be. But to really understand what living through them will be like, to experience them, you need to put a human face on them.” And it is in putting a human face to these issues that science fiction films in particular play an important role. The power of the cinema is that it allows us to fully inhabit these imaginary worlds for two hours at a time.

1.0. THE STRATIFIED CITY

1.1. Fritz Lang’s *Metropolis*

Any discussion of science fiction films and urbanism must begin with Fritz Lang’s 1927 film *Metropolis*. The film depicts a future in which the city of Metropolis is deeply divided. The wealthy live in tall towers on the surface of the Earth and idle their time away in the beautiful Eternal Gardens. Meanwhile, the workers who operate the machinery that keeps the city running live in quarters far below ground. Lang’s vision for the film was inspired by his visit to America, and specifically Manhattan, in October 1924 for the premiere of his film *Die Nibelungen.* He described his arrival in New York via cruise liner, saying “I looked into the streets—the glaring lights and the tall buildings—and there I conceived *Metropolis*.” (Minden & Bachmann 2000, 4-5) He would later expand upon his American experience in a travelogue for the German film journal *Film-Kurier*, stating:

> [Where is] the film about one of these Babylons of stone calling themselves American cities? The sight of Neuyork [sic] alone should be enough to turn this beacon of beauty into the center of a film. … Streets that are shafts full of light, full of turning, swirling, spinning light that is like a testimony to happy life. And above them, sky-high over the cars and trams appear towers in blue and gold, in white and purple, torn by spotlights from the dark of night. Advertisements reach even higher, up to the stars, topping even their light and brightness, alive in ever different variations. … Neuyork by day is the definition of sobriety, nevertheless fascinating by its movement. Neuyork by night is of such beauty that, if one experienced nothing but the arrival in the harbor at night, one would still have an unforgettable impression for one’s whole life.

This description of course calls to mind the futuristic imagery of *Metropolis* (Fig. 1), but also that of the countless films that it has influenced: *Blade Runner, Star Wars, The Fifth Element, Minority Report, Brazil*, and many more.

Metropolis is perhaps the first film to “map ideological values and/or class structure onto the urban structure of upper and lower worlds”—a technique that will become a common trope in science fiction films. (Mennel 2008, 7) The vertical city that Lang portrays in the film makes references to the real-life conditions brought about by the Haussmannization of Paris—the modern city par excellence—as well as the futuristic visions of Antonio Sant’Elia’s *La Citta Nuova* and Le Corbusier’s *Ville Radieuse.* Perhaps more interestingly, the vertical city of *Metropolis* can also be understood as a representation of the *horizontally* disassociated city described by Frederick Engels in *The Condition of the Working Class in England*. As described by Engels, Manchester consists of "unmixed working-people's quarters, stretching like a girdle… around the commercial district. Outside, beyond this girdle, live the upper and middle bourgeoisie, the middle bourgeoisie in regularly laid out streets in the vicinity of the working quarters…, the upper bourgeoisie in remoter villas with gardens." In addition to this physical embodiment of the Marxist critique of the capitalist metropolis the film also gives life to Marxist themes of social stratification and class struggle in a way that gives viewers an accessible way to enter into these complex issues. According to Anton Kaes (2010), "From the start *Metropolis* establishes a nexus between urban space, mechanical movement, and the technical apparatus of moving pictures. Lang uses compositional principles of abstract film to convey the dynamics of the big city and the literalize the precise and unflagging automatism."

The automatism of the workers in Metropolis offers viewers an illustration of both what György Lukács has termed "reification" and what Georg Simmel (2002) has described as the "blasé attitude." This is seen particularly clearly in the shift change scene during which the workers march rhythmically through an underground tunnel whilst avoiding eye contact with their fellow men. The workers here are successfully dehumanized—transformed into mere cogs of the machines that they operate. The alienation caused by this reification into *things* rather than fully-fledge *people* is highlighted by the blank expressions on their downturned faces as they shuffle along from one part of their miserable existence to another. This can be read as a broader critique of the "mutual reserve and indifference" that Simmel identified as a natural outcome of the "bodily closeness and lack of space" of the modern metropolis." Thus, according to Simmel, the modern city dweller (like the subterranean worker of *Metropolis*) "never feels as lonely and deserted as in this metropolitan crush of persons." Furthermore, the rebellion of the workers in the film can be understood as a response to what Simmel called "the resistance of the individual to being leveled, swallowed up in the social-technological mechanism."

Figure 1: (L) Fritz Lang's depiction of Metropolis; (R) Ridley Scott's depiction of Los Angeles in *Blade Runner*

1.2. Ridley Scott's *Blade Runner*

Ridley Scott's 1982 film *Blade Runner*—which tells the story of an ex-cop charged with tracking down several android "replicants" in Los Angeles of 2019—has many things in common with *Metropolis*: flying cars, tall towers, robots that appear to be human, and a marginalized underclass. Scott is particularly well known for using the urban environment as a tool for reinforcing the themes of his films. "If there are seven characters in a film," Scott says, "I treat the environment as the eighth character—or the first. After all, that's the proscenium within which everything will function." (Sammon 1996, 93) However, the Marxist themes that can be seen in *Metropolis* are much less overt in *Blade Runner* despite the fact that Scott describes the world of *Blade Runner* as a "tangible future" in which "the poor get poorer and the wealthy get wealthier." (Peary 2005, 49) Nonetheless, the film still depicts a highly stratified society where the dank and crowded environment of the street level of the city is populated by an ethnic majority while the clean and crisp towers are inhabited by a wealthy, white minority. Meanwhile, the most fortunate of all have relocated to the "golden land of opportunity and adventure" of the off-world colonies, which are depicted as utopias (although the truth of their conditions may be drastically different) in the ever-present advertisements that pervade the urban environment of the film's version of 2019 Los Angeles. (Fig. 1)

2.0. THE SEGREGATED CITY

2.1. John Carpenter's *Escape from New York*

John Carpenter's 1981 film *Escape from New York* is set in a world ravaged by World War III. The voice-over narration of the film's opening credits sets the scene:

> In 1988 the crime rate of the United States rises 400 percent. The once great city of New York becomes

> the one maximum security prison for the entire country. A fifty foot containment wall is erected along the New Jersey shoreline, across the Harlem River, and down along the Brooklyn shoreline. It completely surrounds Manhattan island. All bridges and waterways are mined. The United States Police Force, like an army, is encamped around the island. There are no guards inside the prison: only prisoners and the world's they have made. The rules are simple. Once you go in, you don't come out.

As Carpenter describes in his commentary to the DVD release of the film, the original script was written in the mid-1970s amidst the Watergate scandal and responds to fears of a police state and a general cynicism about the presidency. By the time film was released in 1981, Carpenter suggests, the film offered a commentary on the anxieties of the Iran Hostage Crisis, the growing greed of the world, and the frequent presence of violence in the streets: "It seems to me that *Escape* attends to all of those things. It's kind of America in a way, put into the future. And it's both our fears and what we would like to have happen."

For urban theorist Mike Davis, *Escape from New York* is one of several films that have been "more realistic—and politically perceptive—in representing the hardening urban landscape" than most contemporary urban theory. For Davis the Manhattan Island Prison of *Escape from New York* can be understood as the (il)logical conclusion of the "militarization of city life" that he sees as "increasingly visible everywhere in the built environment of the 1990s." (Davis, 1992, 154-155) In his 1992 essay "Fortress Los Angeles: The Militarization of Urban Space," Davis describes the "spatial apartheid" wrought by the redevelopment of downtown Los Angeles—including the Crocker Center, the Bonaventure Hotel, the World Trade Center, and others. While other cities have created gentrified zones that exploit their downtown's historic buildings (e.g. Faneuil Market in Boston and Ghirardelli Square in San Francisco), Davis believes that Los Angeles has taken things a step further, creating a "strategy [that] may be summarized as a double repression: to obliterate all connection with Downtown's past and to prevent any dynamic association with the non-Anglo urbanism of its future." Davis suggest that this is indicative of a "national movement toward 'defensible' urban centers" that provide space for white, upper-middle-class gentrifiers while physically severing the rejuvenated upscale city center from surrounding ethnic communities.

Nan Ellin (1996) has expanded this idea of "defensive urbanism" to include the proliferation of master-planned communities and gated communities that turn their backs to their surroundings—creating enclaves of socio-economic and racial homogeneity. While definitive numbers are difficult to determine, in their book *Fortress America* Edward J. Blakely and Mary Gail Snyder suggest that between 6 and 9 million Americans live in gated communities. The negative societal implications of this segregation have been extensively studied by sociologists and anthropologists (e.g. Low 2001, Blakely and Snyder 1997, and Marcuse 1997). A 2007 report on urban safety from the United Nations Human Settlements Program states: "One of the most noted changes in urban space over the last two decades has been the growth of private urban space in the form of gated communities." The report goes on to note that the impacts of these developments include "an increasing polarization of urban space and segregation between urban poor and middle- and upper-income groups." The extreme case of Buenos Aires is highlighted by the report, which shows that by 2000 there were about 500,000 people living in 434 private communities encompassing "an area of 323 square kilometers, or an area 1.6 times larger than the downtown federal capital area, which houses 3 million people."

Figure 2: (L) Manhattan Island Prison in *Escape from New York*; (R) The island of Seahaven in *The Truman Show*

2.2. Peter Weir's *The Truman Show*

If *Escape from New York* was, as suggested by Mike Davis, an "extrapolation from the present" of the 1970s and 80s in which many downtowns were in ruins, Peter Weir's 2008 film *The Truman Show* offers an interesting update to these themes. Rather than the more typical post-apocalyptic hellscape of most science fiction films, *The Truman Show* is set in the artificially-perfect town of Seahaven, which was famously portrayed by the iconic New Urbanist town of Seaside, Florida. At the time the popular press and urban scholars were divided over the film's depiction of New Urbanist ideas with advocates of New Urbanism suggesting that the film was a critique of the alienating effects of suburbs and modern town planning and critics suggesting that the film offered a "devilish send up of New Urbanism's preening self-righteousness." (Steuteville, Kroloff)

However, the discussion of the role of New Urbanism in the film is largely a distraction that diverts attention away from *The Truman Show*'s critique of the carceral spaces of the contemporary city, which is perhaps all the more biting because of its neo-traditional packaging. While audiences may have difficulty placing themselves in the post-apocalyptic world of *Escape from New York* they have no trouble imagining themselves in the idyllic surroundings of Seahaven/Seaside. Nonetheless, both films take place on islands that have been shut off from the outside world, suggesting a critique of both the psychological isolation of the experience of the contemporary city as well as the physical fracturing of the urban fabric. (Fig. 2) In the film the visionary television producer Christof (played by Ed Harris) suggests that the world that he created for Truman is no different than the real world outside his artificial bubble: "There's no more truth out there than in the world I created for you. Same lies. Same deceit. But in my world, you have nothing to fear." Christof's suggestion that the world he has created for Truman is safe from malice can be seen to have a direct analog in Trevor Boddy's conception of the "analogous city" of pedestrian skyways and underground concourses that have proliferated around the world—including Minneapolis's Skyway, Calgary's Plus15, Chicago's Pedway, and Houston's The Tunnel.

This "analogous city" is perhaps best exemplified by John Portman's city within a city: Peachtree Center in Atlanta, Georgia. Boddy (1992) points out that these pedestrian networks "seem benign at first" as they are "promoted as devices to beat the environmental extremes of heat, cold, or humidity that make conventional streets unbearable." However, he goes on to suggest that they are anything but "value-free extensions of the existing urban realm" because they "provide a filtered version of the experience of cities, a simulation of urbanity" that serves to "accelerate a stratification of race and class." In this way the analogous city is very similar to the idealized urban realm of *The Truman Show's* Seahaven, which serves as the literal backdrop for Truman Burbank's (played by Jim Carrey) life. Rem Koolhaas (1995) similarly points out that Portman's famous atria became "container[s] of artificiality that allows its occupants to avoid daylight forever—a hermetic interior, sealed against the real." These hermetic interiors have been harshly criticized by scholars like Frederic Jameson and Edward Soja who have both discussed the disorienting effects of Portman's Bonaventure Hotel in Los Angeles, California. In fact Jameson (1997) could very easily have been describing the artificial reality of Seahaven in *The Truman Show* when he suggested that "the Bonaventure aspires to be a total space, a complete world, a kind of miniature city. ... In this sense, then, ideally the mini-city of Portman's Bonaventure ought not to have entrances at all, since the entryway is always the seam that links the building to the rest of the city that surrounds it: for it does not wish to be a part of the city, but rather its equivalent and its replacement or substitute."

3.0. THE SYNTHETIC CITY

Perhaps one of the oldest tropes in works of Western fiction stems from the nature-culture divide that developed in the 16th and 17th centuries as European thinkers began to conceive of themselves as something set apart from nature, thus rendering the natural world as something to be observed, analyzed, and studied. This conceptualization of the natural world as an "other" derives in various ways out of the writings of Jean-Jacques Rousseau—who viewed culture as a corrupting influence on humankind's natural innocence. The result is that in Western literature and film cities are very often conceived of as synthetic sites of evil and corrupting influences set within the framework of a more pure and moral natural world. This dichotomy is present in countless science fiction films. It can be seen in the extinction of all signs of non-human life from the world of *Blade Runner* in which all things that appear to be animals—including Tyrell's owl and Zhora's snake—are revealed to be robotic "animoids." Joe Dante's 1984 film *Gremlins* illustrates this dichotomy through the corruption of the cute and cuddly Mogwai named Gizmo into a gang of reptilian Gremlins after his adoptive family fails to follow the three simple rules for his care. The eventual result is that Gizmo's original Chinese caretaker (playing the clichéd role of the innocent, non-Western, noble savage) reclaims the Mogwai while chastising the family for their ignorance stating, "You do with Mogwai what your society has done with all of nature's gifts. You do not understand. You are not ready." It can even be seen in the animated children's film *Wall-E* (Andrew Stanton, 2008) in which the corrupt human society that has abandoned Earth underneath piles of trash is redeemed after the titular trash-collecting robot discovers a tiny plant that represents the return of the healing power of nature to the world.

3.1. *Star Wars* and Landscape Urbanism

Film critic Leo Braudy (1998) goes so far as to identify a "metagenre" of films that embody an "urge to nature as a response to moral and cultural disarray" and that "assert the need for a reconnection to what is vital in nature in order that we might escape from the dilemmas history has forced upon us." He makes reference to how "the natural world of the cuddly Ewoks is to be destroyed by the Death Star" in *Return of the Jedi* and suggests that the original Star Wars trilogy are some of the earliest examples of this "metagenre." However, Braudy's analysis relies upon a common reading of the Star Wars saga, which suggests that cities are evil, corrupting influences. The most famous example of this is Obi-Wan Kenobi's description of Mos Eisley spaceport on Luke Skywalker's home planet of Tatooine as a "wretched hive of scum and villainy." Mark Lamster similarly suggests that the settings of *Star Wars* "are neatly divided into the natural and the man-made, and coded to their inhabitants' stations in the moral universe of the series: the innocent Rebel Alliance is time and again pictured amidst the natural world, while the evil Empire is fascistically resplendent in its technological terrors."

Figure 3: (L) Theed, the capital city of Naboo from *Revenge of the Sith*; (R) Aldera, the capital city of Alderaan from *Revenge of the Sith*

However, a closer look at the cities of the Star Wars universe reveals something more nuanced. While Coruscant, the capital of the Galactic Empire and the seat of the ultimate evil of Emperor Palpatine, is a planet-wide city rendered as an urban hellscape in which all traces of nature have been extinguished (and an on-screen portrayal of Constatin Doxiadis's Ecumenopolis), the cities that are associated with the heroes of the universe offer a vision of lush urban fabrics that are wholly integrated with their natural surroundings. Perhaps the best on-screen example of George Lucas's model of urbanism from the eight theatrical releases of the Star Wars franchise is Theed—the capital city of Naboo and home to Padmé Amidala, the eventual mother of Luke Skywalker and Leia Organa. The domed architecture of the Theed Royal Palace is integrated into a massive cliff replete with waterfalls and offering sweeping views of the surrounding verdant plains of grass. (Fig. 3) The design of the palace complex was inspired by Frank Lloyd Wright's Marin County Civic Center (the setting for Lucas's first feature film, *THX-1138*) which itself features sky-blue domes and is nestled into its valley site. Other cities associated with the heroes of the Rebellion are similarly integrated with nature. Aldera, the capital city of the ill-fated planet of Alderaan and the adoptive home of Leia Organa, can be seen as fully integrated into its mountainous terrain in *Revenge of the Sith* (Fig. 3). Similarly, Coronet City, the capital of Corellia and home of Han Solo, which has yet to appear on screen but has been featured in numerous video games and comic books, is also depicted as being integrated with its verdant surroundings.

George Lucas's admiration for Frank Lloyd Wright is well known (one of the rooms at Skywalker Ranch has a Wright theme) and therefore his Broadacre City may be an obvious point of reference for Lucas's approach to urbanism. However, given his hiring of Chinese architect Ma Yansong of MAD Architects for the design of The Lucas Museum of Narrative Art there is perhaps an opportunity to introduce the more contemporary ideas of landscape urbanism in to the discussion of cities within the *Star Wars* universe.[ii] According to Ma, his work strives to "construct an urban environment that embodies both the convenience of the modern city and the ancient Eastern affinity for the natural world." (Ma 2015) The cities of Theed and Aldera can be viewed as on-screen analogs to large-scale landscape urbanist projects like Ma's Nanjing Zendai Himalayas Center or Michael van Valkenburg Associate's masterplan for the Lower Don Lands in Toronto in which "the social program was recognized as important as the ecological one" and a "large new meandering riverfront park becomes the centerpiece of a new mixed-use neighborhood." (MVVA) This, according to Charles Waldheim offers an approach to cities that "rather than offering an exception to the structure of the city or planning for its dissolution, aligns with the return to the project of city making associated with contemporary service, creative, and culture economies." (Waldheim 2016, 5) After all, the *Star Wars* saga as a whole is all about the balance between the light and the dark.

CONCLUSION

What the analysis of each of these films illustrates is that there is an enormous potential for using the medium of film as a tool for analyzing the conditions of the contemporary city and for providing a starting point for conversations of complex urban issues. The Tolkienian "recovery" that we experience as we turn our attention back to the real world after experiencing a fictitious secondary world allows us to view both the successes and failures of today's urban world in a new light.

Furthermore, the use of films in the classroom, particularly mainstream blockbusters like *Star Wars*, has enormous potential for engaging students in a new way. First and foremost it enables them to see a variety of representations of urban environments presented on the big screen. The screening of films in a classroom setting enables students to gain a greater insight into many complex urban issues that can be difficult to fully comprehend when experienced as abstract ideas in texts and drawings. Film in general, but especially films in the sci-fi genre, push these ideas and ideologies to their logical (or illogical) ends by creating fictitious spaces that we can enter into for two hours at a time. Secondly, it suggests alternatives to traditional professional practice by illustrating the important roles played by architects and other designers in creating the settings of our popular visual culture. Finally, and perhaps most importantly, it teaches them to be more aware of the built environment in both real life and in various media of entertainment including film, television, video games, and more.

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ENDNOTES

[i] The films selected for case studies in this paper have been selected from a list of the "100 best sci-fi movies" compiled by *Time Out London*, which brought together dozens of authors, filmmakers, critics, scientists, and other experts to determine the most influential films of the genre. While there are many other films that could be cited in reference to the themes of this paper, I have limited myself to those included on this list because of their potential for greater societal impact than more obscure films. Furthermore, this research relies on a synoptic approach that examines the ramifications of an array of disciplines on the reception of urban ideas by both the design disciplines and the general public.

[ii] George Lucas's drawn-out search for a site for his museum offers some insight into his urbanistic preferences. All of the proposals for the museum—including sites in San Francisco, Chicago, and Los Angeles (where it is now under construction)—have illustrated a careful integration between the architecture and landscape architecture, much like the home cities of the heroes in the *Star Wars* films.

Liyang Ding

A Preliminary Study of the Architektonischer Garten as a Post-perspectival Concept

A Preliminary Study of the *Architektonischer Garten* as a Post-perspectival Concept

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ABSTRACT: This paper examines the concept of *architektonischer Garten*, an understudied idea that came to define early modern architecture. Presented as a brief examination of its historical transformation from a garden design approach to a spatial configuration model, this paper reinterprets the history of this concept with a focus on the relationship between the man, the house, and its surrounding gardens. Starting from offering a long-overdue definition of the *architektonischer Garten* concept, this paper explains the formation and development of this concept by studying the corresponding contribution of Hermann Muthesius and Mies van der Rohe, arguing that the sense of space evoked by the *architektonischer Garten* is, through offering a self-exceeding mode of experience, “circumstantial” and “holistic.” Further, the *architektonischer Garten* can be understood as the key spatial concept that characterized the post-perspectival age, by virtue of our perception of spatial depth, capable of forming an integral whole consists of the perceiving subject and the perceived world, which includes both indoor space and outdoor topography.

KEYWORDS: Architectonic Garden, Space, Hermann Muthesius, Mies van der Rohe, Perspective

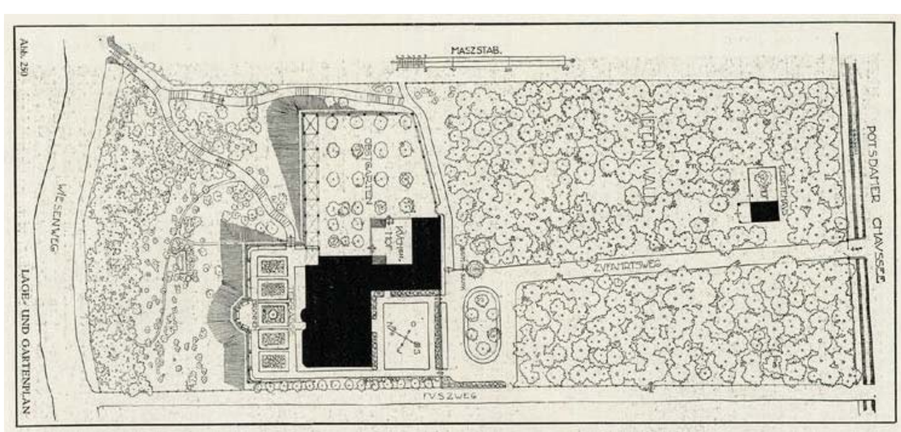
1.0 *Architektonischer Garten* as a Garden Design Approach

The German term “*architektonischer Garten*” (architectonic garden) first appeared in Hermann Muthesius’s *Das englische Haus* (1904-5), a three-volume treatise of the *Landhaus* (country house) design in England during the late 19th century (Muthesius 1904-5, Bd. I: 210, 216; Bd. II: 86, 96, 99). While discussing the relationship between the house and its surrounding gardens, Muthesius (1861-1927) asserted:

> The English garden is no longer the landscape garden familiar to us under this name (landscape garden), but in those cases where artistic considerations play a part, it is a formal garden laid out essentially along geometric or — if one prefers it — architectural lines: in short, a garden that does not seek to imitate nature but which stands in a close artistic relationship to the house (Muthesius 1904-5, Bd. I: 210; Muthesius, 2007, vol. 1: 210).

This idea is to some extent self-explanatory by referring to Muthesius’s design of his own house (1906): (Fig. 1)

> … In his own house he (Muthesius) realized his ideas of surrounding the building with a series of individual, geometrically designed garden rooms, linked to the house with a pergola … Although this new style was initiated by architects, it was soon



> adopted by a new generation of garden designers … they called themselves *Gartenarchitekten* (garden architects) in order to set themselves apart from the landscape gardening tradition of the previous century (Stiles, 222).

Figure 1: Hermann Muthesius, Site and Garden Plan, Muthesius House, Nikolassee (1906). Source: (Muthesius 1912, 166).

Similar to read Muthesius's writing and design, there are also two ways to formulate the proper definition of the concept of *architektonischer Garten*: descriptive and prescriptive, or, in other words, from a way of viewing it as the outcome of design process and from a way of viewing it as a goal of garden design. From the first perspective, a preliminary definition of the *architektonischer Garten* can be outlined as follows: the *architektonischer Garten* can be seen as the geometric room-like spaces for outdoor activities that programmatically and perceptually connect to their adjacent indoor rooms from within. Meanwhile, we can also arrive at a slightly different definition if we see it as a garden design approach: (1) to see the surrounding garden as the outdoor extension of the indoor space; (2) to design the garden in conformity with the way of organizing indoor rooms; and (3) to designate each outdoor room in accordance with the function of its adjoining indoor one.

Muthesius's related description, his own house design manifestation, a descriptive definition, and prescriptive design principles, I believe, are sufficient to understand the first stage of the development of the *architektonischer Garten* concept. As a garden design approach, this concept reflected Muthesius's conviction that: (1) the *architektonischer Garten* constituted a critique of the practice of setting a villa in a picturesque garden, proffering an escape route from historical culture and a path to restoring authenticity to German life and building; (2) the *architektonischer Garten* is an indispensable component of English country house; in other words, the house is only validated by its associated garden (Muthesius 2007, vol. 2: 82).

2.0 *Architektonischer Garten* as a Spatial Concept

Now, I want to turn to Mies van der Rohe (1886-1969), who, according to Barry Bergdoll, developed the *architektonischer Garten* idea into a specific model of spatial configuration (Bergdoll 2001, 66-105). Bergdoll argued that both Muthesius and Mies sought a sense of fusion of interior and exterior in spatial composition. In particular, Mies's early Berlin projects seemed to transcend the categorical distinction between the building and the landscape; he treated the order of building as if it is part of the landscape (Leatherbarrow 2009, 280). Mies's pre-WWI work — such as the Riehl House (1907), Perls House (1911-2), Wolf House (1926), Esters & Lange House (1927-30), and the Tugendhat House (1928-30) — constantly employed multiple *architektonischer Garten* devices, namely, deliberately framed landscape views, exedra bench tied to certain vantage points, and vine-covered pergola as emblems of the harmonious unity of house and garden. Calling for a tight spatial interweaving relationship between interior space and exterior garden, all of these treatments were exploited by Karl Friedrich Schinkel (1781-1841) and Peter Joseph Lenné (1789-1866), clearly emulated by Mies, and documented by Muthesius (Muthesius 1910, 50-1). (Fig. 2) What is even more evident is that, while teaching at the Bauhaus in the 30s, Mies developed his court-house concept, where rooms and gardens were integrated as if the later became small outdoor "rooms" defined by perimeter walls that mark the boundary between the house and the city. (Fig. 3)

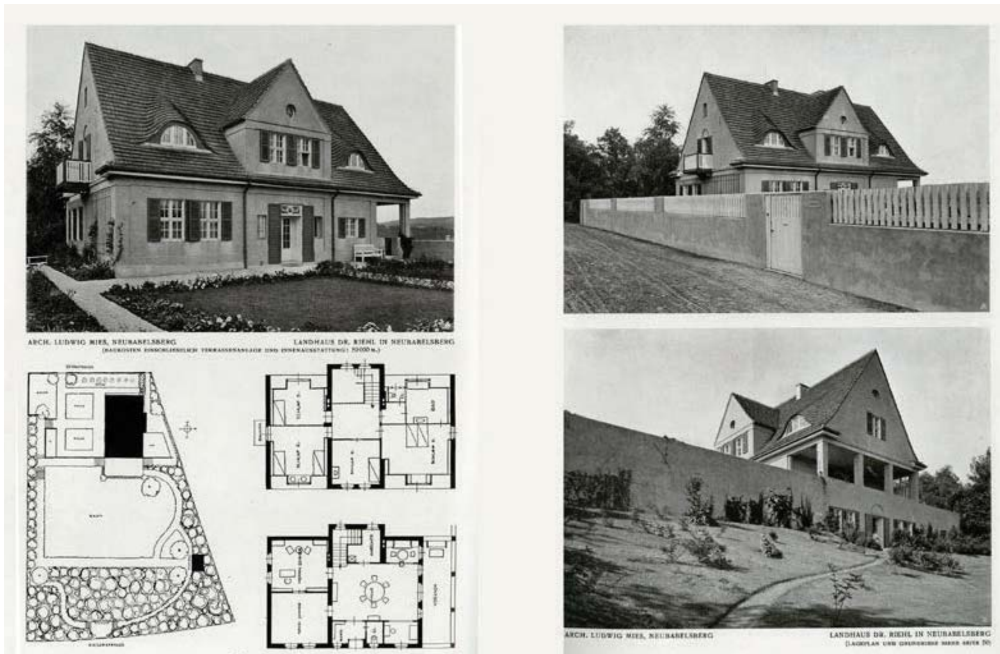


Figure 2: Ludwig Mies van der Rohe, Riehl House, Neubabelsberg (1907) Source: (Muthesius 1910, 50-51).

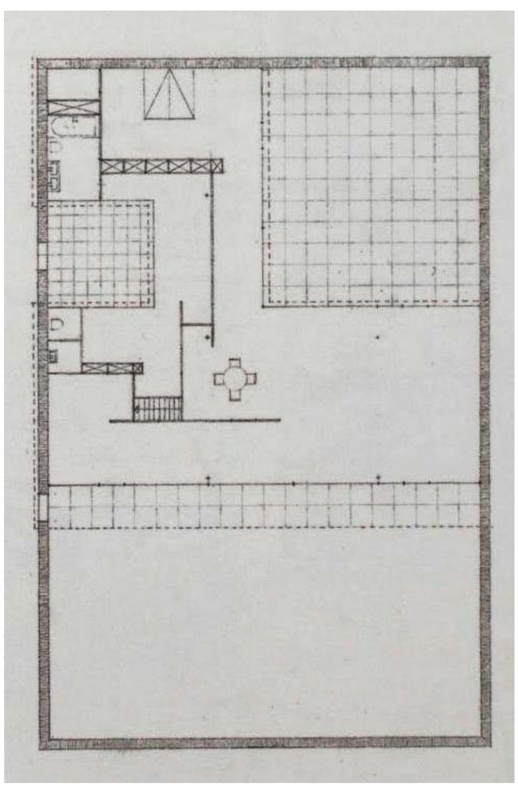


Figure 3: Ludwig Mies van der Rohe, Plan with furniture layout, Hubbe Court-House (1934-5) Source: (Riley Bergdoll 2001, 295).

Furthermore, the *architektonischer Garten* idea for both Muthesius and Mies embodied a philosophical consideration. First, Muthesius had seemingly assigned disparate features to two integral elements of the *Landhaus* — the house and the garden. He argued that, on one hand, the "irregularity" and "freedom" were essential characteristics of the house; its garden had to be "formal" or "architectural," on the other. Seemingly contradictory, the "free" interior plan and the "formal" exterior garden should nonetheless be considered as two coherent aspects of the central feature of English "free architecture." Explaining what he understood as the essence of English country house, in *Das englische Haus*, Muthesius wrote:

> All that can be done here is to record the basic features of its development by concentrating on what might be termed its *inner organism*, as expressed above all in the design of its floor plan. Only those aspects will be singled out that are of relevance to the house's present form (Muthesius 2007, vol. 1: 12).

Thus the central feature of English "free" architecture and also the main thesis of Muthesius's book was the *inneren Organismus* (inner organicism) (Posener 1989, ix). Muthesius in his later book *Landhaus and Garten* re-emphasized this idea:

> If the house is combined with the garden as a unity, then this can only be the case with a regular garden. The palace [historicist villa] and grassy lawn are no artistic unity. If the house is architecture, then the garden must also be architecture. And if one takes the word "architecture" in its most general terms, so that it encompasses human creation and design in all its forms, then garden design must belong to architecture by necessity which is appropriate to human design in all forms is the rhythmic, and regular. Regularity and rhythm are found in the most primitive ornament of the wild just as in the art of advanced culture… the same fundamental principles that underlie the house, the same *organic* relation of the parts to one another, the same unity of the single elements into a harmonious whole … must also govern the garden … in order to save the house from the decadence into which it had fallen in the nineteenth century, and to stamp it once again with the mark of artistic unity … garden and house are a unity, they characteristics should be infused with the same spirit. (Muthesius, 1910, xxix-xxv).

According to Muthesius, English country house had developed the "organic" characteristic as "inside to outside," a higher essence that governed both house and garden than that of the banal imitation of nature, which allied his attack on the naturalistic tradition of landscape design with the critique of historical style in architecture. Rather than "display," Muthesius advocated for a middle class focused on family and healthful living. A similar idea can be identified evidently in Mies's terms. While being asked about his idea of the role of nature with respect to the buildings, he answered with reference to his Farnsworth House:

> Nature, too, shall live its own life. We must beware not to disrupt it with the color of our houses and interior fittings. Yet we should attempt to bring nature, houses, and human beings together into a higher unity. If you view nature through the glass walls of the Farnsworth House, it gains a more profound significance than if viewed from outside. This way more is said about nature — it becomes a part of a larger whole (Norberg-Schulz 1958, 339).

This claim can be seen as a response to the contention that garden design was not a major focus for Mies (Beneš 1998, 133; Schulze 1985, 22-3). Mies, indeed, showed no particular interest in garden design per se; rather, he viewed building and landscape as integral parts of "a higher unity." It is therefore safe to say that modern living for both Muthesius and Mies concerned both interior and exterior spaces, and both of which were integrated into an "organic" whole — a new and all-encompassing mode of human situation.

Now, to understand the "inner organicism" or "higher unity" expressed respectively in Mies and Muthesius's terms, it is decisive first to acknowledge the *architektonischer Garten* concept contains an extended connotation of a spatial conception. Because the most notable feature of spatial conception is that it puts the perceiving subject into the center of consideration. And this sense of "higher unity" that Mies was implicitly referring to, I argue, can be understood as a new sense of space that articulates the reciprocal relationship between the subject and the architectural setting.

The notion of space has a double character: physical and nonphysical (Straus 1966, 3-4; Jammer 1969; Merleau-Ponty 1962; Morris 2004). Apart from its physical property, the experience and sense of space from the first-person point of view — known as spatiality — is the central concern of spatial creation in architecture. Based on the up-to-date understanding of human spatial perception, our experience of space depends on people and object in space appearing, perceiving, and moving in depth — the central feature of spatiality (Morris 2004, 2). Due to the limited space of this paper, I have to explicate this philosophical aspect of the understanding of this mode of human situation on another occasion. Nevertheless, to put it in a relatable way, the sense of depth is nothing like the dimension of height and breadth that are seen as equivalent in an abstract, isotropic, and homogeneous space. Nor is it the perception that buildings allow people to "see through things" or to perceive space as "many-sided and dynamic," with an intent to exhibit "the interiors and exteriors of objects simultaneously." (Giedion 1941, 493, 521). Rather, this depth perception is a "trans-substantial" *medium* that mediates the perceiving subject and the outside world (Merleau-Ponty 1945, 159; Straus 1996). In short, it is depth perception — which functions as "first dimension" of spatiality, as the *medium* that integrates the subject and the outside world, and as the central structure — that makes this new "higher" sense of space possible.

At this point, a further question needs to be raised: were there examples, in early modern architecture, that accommodated a similar spatial experience over static, frontal, or axial spatial experience, say, putting painterly images on display? My answer is "yes." And they are the works that were intended to evoke the "lived," dynamic space by a compression or in-stabilization, rather than amplification or stabilization of the "dead," static depth effect in the perspectival spatial construction. This manipulation of our depth perception resulted from multiple architectural devices and treatments, such as the concealment of ground surface, thwarting any extended view in only one direction, devising a series of non-aligned, transverse walls that limit visual expansion, projecting a transition zone that avoids an abrupt shift to the outside, etc. Above all, it should first and foremost consent the primacy of our temporal experience from the first-person point of view, with the aim to produce a *surplus* of structured views or a *self-exceeding* mode of architectural setting.

Many scholars have observed that Mies intended his buildings, especially his Berlin projects designed between 1923 and 1933, to offer more scenes than they were meant to provide (Constant 1990; Quetglas 1988; Evans 1990; Leatherbarrow 2009, 280-1). Most evidently in his projects such as the Brick Country House (1923), the Esters & Lange Houses, the Barcelona Pavilion (1929), and Tugendhat House, Mies devised a spatial composition that continually offers to experience both unexpected and familiar situations, thus turning the viewer into an "ambulant observer." (Evans 1990, 63). As a result, in contrast to experience an axial construction of space where depth — presented as the "third dimension" — can be grasped instantaneously or to experience individual architectural settings in an orderly sequence, the spaces created in these projects were conceived in a way that one was forced to experience "all" of architectural settings "at once." Put differently, this particular sense of space requires a perceptual apprehension that simultaneously "maximizes" and "minimizes" the built environment as a holistic entity. It seems that what constitutes the margin of perceptual concentration always exceeds the expectations of that momentary focus; there is always "more" as the subject moves in space, despite this "more" of the immediate experience is not the "same" experience, arisen by the given architectural setting, of the temporally extended present either before or after, the perceptual act that is retained in our consciousness. This lived experience of space, according to Merleau-Ponty, "runs from my perceptual field itself, so to speak, which draws along in its wake its own horizon of retentions, and bites into the future with its protentions. (Merleau-Ponty 1962, 371)

3.0 *Architektonischer Garten* as a Post-perspectival Concept

Given the emphasis on the primacy of human perception of space, it would be natural to view building and garden both as, rather than stylistic forms with mere technological and aesthetic values, arts of man-made space that are parts of an all-embracing topography. What's more, depth perception, because of its primordial role in structuring our spatial experience, performs as the *medium* through which a building, its adjoining garden, the surrounding topography, and the perceiving subject are integrated. In light of this, by virtue of depth, everything becomes part of a special wholeness in perception (Casey 1991). The most striking consequence of this understanding is that this reciprocal, holistic entity that comprises both subject and object indicates objects such as architectural and garden elements are no longer "outside me," but rather I am "in things," and everything is "in things." Therefore, the sense of space that people perceive in the *Gartenarchitektur*, such as Mies's Berlin projects and court-house schemes, is essentially "circumstantial" and "holistic."

It seems that there emerged a new "unknown" space in early modern architecture that was exemplified the "circumstantial," "holistic" sense. Then, how shall we understand this "unknown" spatial configuration? My tentative answer to this question is this: rather than challenging the hitherto clear, dualistic relationship between indoor space and its immediate vicinity, the central concern of this "unknown" spatial configuration, ever since Muthesius's *architektonischer Garten* concept, was not about the relationship between inside and outside, but rather, as I would like to call it, "outside of outside." In fact, this matter was less disciplinary (garden design versus architecture) than ontological.

I would like to argue that the organicist motivation that underlay the *architektonischer Garten* idea embodied a paradigm shift in the structure of our consciousness about the world — a shift from a subject-object split to a subject-world fusion. And aiming at a self-world fusion, the *architektonischer Garten* idea initiated by Muthesius and further developed by Mies can therefore be considered as an exemplary spatial concept that characterized the post-perspectival space. And this post-perspectival space in its genuine sense, I argue, does not just defy pictorial representation or signify exclusively material reality; it, rather, transcends the scientific framework upon which classic linear perspective was built. The key to understanding post-perspectival space is this: it embodies an attempt to suspend the subject-object split that underlies the scientific epistemological tradition, a division between the perceiving subject and the perceived world resulted from the presuppositions of the modern Galilean scientific and Cartesian philosophical and epistemological tradition (Johnson 1996). Considering post-perspectival space in a genuine sense should therefore indicate a liberation, rather than mere negation of scientific perspective. By "liberation," I mean that we have to do away not only from the perspective tradition but also from its central structure that makes perspective possible. That is to say, our focus should be the space as we experience it, before we objectify it through mathematical, geometric, or scientific means. Thus post-perspective space is not the objectified space that would be measured by the surveyor, geometer, or scientist, but the perceived space as we experience it before we objectify it. David Morris, a philosopher who developed Merleau-Ponty's philosophy of spatiality, called this kind of spatial perception "lived space." (Morris 2004)

To repeat myself, the lived experience of space — "lived space" — should become the central concern of the post-perspectival architectural creation. To evoke and enhance "lived space" depends on the perceiving subject and the perceived object in architectural topography appearing, perceiving, and moving in depth, the "primordial dimension" of spatiality, or the central structure that makes spatiality possible.

4.0 Conclusion

To sum up, the development of the *architektonischer Garten* concept has been through two stages, both contributing to modern architecture. First, as a design approach for the country house garden, the *architektonischer Garten* concept physically and perceptually created a close correlation between the indoor room and the adjoining outdoor garden, foreshadowing the fusion of domestic life and natural living as a goal for German *Hausgartenreform*. Second, as a model of spatial configuration, the *architektonischer Garten* idea was intended to provoke a new kind of spatiality, in which the depth perception, by virtue of its role as the central structure of the spatial experience, functions as *medium* that integrates a building, its adjoining garden, the surrounding topography, and of course the perceiving subject. Considering this new spatial characteristic in association with the paradigm shift of the structure of our consciousness about the world, it is evident that the emergence and development of *architektonischer Garten* concept embodied the transition of human consciousness of the world from perspectival (static, dualistic) to post-perspectival (circumstantial, holistic). Thus far the still-persistent understanding of modern spatial conception that characterized modern architecture is nevertheless in need of timely revision. The study of the *architektonischer Garten* concept presented in this paper can be seen as a start point for this task.

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Hayri Dortdivanlioglu

The Diagram in Continuum: From Inscription to Generation of Form in Architecture

The Diagram in Continuum: from inscription to generation of form in architecture

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ABSTRACT: The modern concept of the diagram has evolved in various disciplines and professions in terms of both inscriptive and performative mediums since the 1950's. As a powerful abstract concept, the diagram shows dichotomous characteristics; while the inscriptive mode of the diagram is seen as representational, concrete, and reductive, the performative mode of the diagram is seen as generative, abstract, and proliferative. This paper compares the production and the role of the diagram respectively in representative and generative mediums to give an insight into how diagrams embody these dichotomous modes. To do so, first, it studies the concept of the diagram in the works of two French philosophers: Bruno Latour and Gilles Deleuze. On the one hand, for Latour, the inscriptive aspect of the diagram becomes prominent as a tool to render scientific processes or objects onto an abstract representation, which acts as a concrete, irrefutable, and referential object. On the other hand, the Deleuzian concept of the diagram is not representational or visual at all, but it is still real. According to Deleuze, diagrams are sets of relations of forces that define virtuality of assemblages as a space of possibilities. The modern concept of diagrams in the realm of architecture has evolved in between this dichotomy. After giving insights into the contrasting concepts of the diagram, this paper studies three different approaches to the diagram in architectural praxes: Analytical diagram in Sejima's works, textual diagram in Eisenman's works, and material diagram in Spuybroek's works. This paper identifies these three praxes as intermediary stages in between Latour's and Deleuze's concepts of the diagram. In conclusion, it shows the dichotomy of the diagram as a continuum in architectural praxes, characterized at one end by the inscriptive mode and at the other end by the performative mode of the diagram.

KEYWORDS: Architecture, Diagram, Form, Representation, Generation

INTRODUCTION

Diagramming plays a prominent role as both a form of representation and a process in sciences, philosophy and design. Despite its significant position in each field, the discourse of diagram has been multivocal; every field re-defined the concept of the diagram to serve its own agenda. The abundance of different approaches to the diagram complicates its understanding and provides vague definitions. In his article "What is a Diagram anyway?", Anthony Vidler offers an overviewing answer to the crucial question. Vidler traces the meaning of the diagram step by step from open ended dictionary definition to the philosophical definition by Deleuze (Vidler 2006). The twenty-third volume of *Any* journal on "Diagram Work" provides a large collection of articles evaluating the concept of the diagram specifically in art and architecture. The contributors including Stan Allen, Robert Somol, Peter Eisenman, Manuel DeLanda, and Greg Lynn, emphasize the generative characteristics of the diagram from their own perspectives (Davidson 1998). In the more recent publication "The Diagrams of Architecture", editor Mark Garcia collects a larger variety of works on the diagram. Besides architectural concepts of the diagram, the reader offers various conceptual approaches to the diagram in other fields including sciences, art, landscape design and urban planning (Garcia 2010). According to Garcia, the problem with the broad definitions of the diagram is that "it dilutes the meaning of the term to the extent where it begins to decompose and collapse into even more general and unhelpfully vague concepts such as form, system, schema, space, structure, simulation, process, pattern, suggestion, analogy, influence and inspiration." (Garcia 2010, 23). Among all these conceptual differences, the gap between the definition of the diagram has never been larger than the one between the concepts of the diagram in sciences and that in philosophy. The conceptual difference of the diagram in sciences and in philosophy displays a dichotomous relationship. At the one end, sciences promote the inscriptive aspect of the diagram as a visual tool to render scientific processes or objects onto an abstract representation, which acts as a concrete, irrefutable, and referential object, at the other end, philosophy emphasizes the performative aspect of the diagram as an 'abstract machine', which generates genuine creations. While the scientific concept of the diagram is physical, concrete, representative and inscriptive, the philosophical concept of the diagram is incorporeal, abstract, generative and performative (Fig. 1).

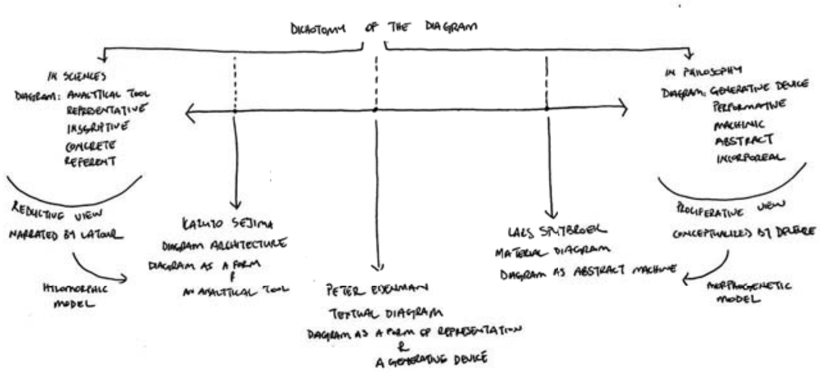

Figure 1: Diagram of dichotomy of the diagram. Source: (Author 2018)

The dichotomous characteristics of the diagram can be comprehended better in the works of two French philosophers: Bruno Latour and Gilles Deleuze. Latour, as one of the leading figures of science studies, describes the role of the diagram in scientific studies rather than offering his own theory or concept of the diagram. What is important for the purpose of this work is that in the article "Circulating Reference" Latour describes the diagram as an irrefutable scientific reference that represents dynamics of scientific objects. Latour narrates how the scientists constructed the diagram gradually through scientific process and claimed it as a concrete representation of their findings in an expedition in the Amazon Forest that he participated as an observer of science in action. Based on his observations during the expedition, the diagram, according to Latour, becomes a constructed visual representation of the dynamics of the Amazon Forest (Latour, 1999). On the other hand, the Deleuzian concept of diagrams is not representational or visual at all. According to Deleuze, diagrams are sets of relations of forces that define virtuality of assemblages as a space of possibilities. He identifies diagrams as abstract machines underlying actualized form. He argues that "the diagrammatic or abstract machine does not function to represent, even something real, but rather constructs a real that is yet to come" (Deleuze 2005, 142). Therefore, while the diagram in sciences becomes a concrete, constructed representation of the real, in philosophy the diagram itself becomes real and gains abstract, generative characteristics. Architecture, which benefits from both representational and generative characteristics of the diagram, produces its own approaches to the diagram influenced by the scientific and the philosophical concepts. While architecture utilize the diagram as a form of representation to rationalize its design decisions, it also conceives the diagram as a generative device to produce novel forms. But how does architecture manage to hold these two dichotomous modes concurrently?

This paper aims at giving insights into the diagrammatic concepts in architecture. It questions the ways that architecture utilizes both the representative and generative characters of the diagram. To answer this question, in the first part, it studies thoroughly the dichotomy of the diagram in sciences and philosophy through the works of Latour and Deleuze. After defining the two ends of the dichotomy, it seeks in-between positions that architecture benefits from both inscriptive and performative modes of the diagram. In this search, three main architects and their praxes become prominent: Kazuyo Sejima and her diagram architecture, Peter Eisenman and his textual diagrams, and, finally, Lars Spuybroek and his material diagrams. Because each of these three names takes a certain position in between the scientific and philosophical dichotomy of the diagram. Toyo Ito names Sejima's architecture as 'diagram architecture' in which "a building is ultimately the equivalent of the diagram of the space used to abstractedly describe the mundane activities presupposed by the structure" (Ito 1996, 18). There is a one to one correspondence between the diagram and the resultant form of Sejima's architecture. The representative character of the diagram gains significance as a tool for Sejima to generate her architecture. According to Eisenman the diagram is not only a form of representation but also a generative device. He conceives the diagram as a series of surfaces on which there are infinite possibilities to write and re-write. Thus, the diagram is constantly regenerated through multiple series of traces on every surface, however, the diagram still does not have an agency to generate by itself. It requires an external condition in the process as a generative or transformative agent. In the material experiments influenced by Frei Otto, Spuybroek fully utilizes the generative agency of the diagram through its machining properties, which operate on both extensive and intensive properties of matter. His material diagrams produce form and structure during reconfiguring qualitative and quantitative properties of matter in flow (Spuybroek 2008). In the second part, this paper will focus on these three in-between diagrammatic approaches and define their positions in relation to two sides of the dichotomy. As a result of its investigation, this paper states that the dichotomy of the diagram should be seen as a continuum in architecture, characterized by the concrete, reductive, representative modes at the one end, and by the abstract, proliferative, generative modes at the other end.

1.0 DICHOTOMY OF THE DIAGRAM IN SCIENCE AND PHILOSOPY

1.1. Inscriptive mode of the diagram in science

The diagram has become prominent for the sciences not only as a representation tool to manage the scientific processes but also as a reference material to enhance the validity of the scientific findings. Hyungmin Pai claims that the diagram emerges within the scientific realm due to the clear subject-object dichotomy. He says, "the diagram emerged as a necessary mechanism for the subject to control its object of knowledge. The diagram is an essentially modern mode of representation" (Pai 2010, p.65). In the article 'Circulating Reference', Latour explains the ways that the scientific practice utilizes the diagram as a representation tool to control its object of study (Latour 1999). He joins a field trip to Amazon forest with the scientists whose aim is to find out whether the forest is advancing over savanna or it is retreating. Latour is not one of these scientists, in fact he is the observer of the scientists in action. His aim is not to observe the forest-savanna transition but rather to study the dynamics of the scientific practice. Throughout his observations the role of the diagram significantly stands out as the representation of the object of study in the scientific process. He states that "if a picture is worth a thousand words, a map, […]; it does not resemble anything. For Latour, "it does more than resemble. It takes the place of the original situation" (Latour 1999, 67). Without the pre-constructed map of the forest, it is not possible for scientists to handle the enormous scale and complexity of the forest.

According to Latour, the diagram is a constructed invention which allows discovery of unseen through conversion of the world into signs (Latour 2010, 67). The diagram is constructed by the scientists by transferring concrete world onto geometrical forms through marking and tracing. It is invented by the scientists, it would have never appeared without their efforts. It is a tool for discovery because it reveals what is not seen but known. Latour adds, "the diagram not only redistributes the temporal flux and inverts the hierarchical order of space, it reveals to us features that previously were invisible even though they were literally under the feet of our pedologists" (Latour 2010, 65). What enables such discovery is the abstract construction of the original situation through conversion of the concrete matter into geometrical forms by reducing complex networks into signs which is then compressed and marked on the diagram. By the help of the conventional coding of judgements, forms, tags, and words, the scientists construct the diagram as a referential material, through several stages. It carries out standardized way of representation. It acts as a concrete, irrefutable, and referential object. Here, Latour points out another significant aspect of the diagram to verify the validity of the scientific findings. The world is represented on a paper. It is still physical, and it is still as concrete as the original situation but it is not real, rather it is the representation of real.

1.2. Performative mode of the diagram in philosophy

Deleuzian concept of the diagram, which is heavily influenced by Bergson and Foucault, is central diagrammatic concept in philosophy. Unlike the concrete, physical, representative and inscriptive characteristics of the diagram in sciences, Deleuzian diagram has abstract, incorporeal, generative and performative characteristics. The diagram does not map or represent already existing structures or networks but it instrumentalizes organizational relationships that yet to be realized. Deleuze argues, "an abstract machine itself is not physical or corporeal, and more than it is semiotic, it is diagrammatic. It operates by matter, not by substance, by function, not by form. The diagrammatic or abstract machine does not function to represent, even something real, but rather construct a real that is yet to come, a new type of reality" (Deleuze 2005, 141). In Deleuzian concept the diagram is an abstract machine. According to him, the diagram has machinic characteristic to instrumentalize agencies in assemblages to generate new creations. It specifies the relationship between forces in virtual properties of matter, which are unrealized but still real. It operates through actualization of these virtual properties. The actualized form does not imitate the virtual. It is generated through differentiation whose rules are specified by the diagram. Thus, Deleuzian diagram operates not only in organizational level in which it maps the forces but also in generative level in which it machinize forces to actualize the virtual properties of matter.

Unlike the reductive concepts of the diagram, Deleuzian diagram does not need an external agency to initiate generation. The generative concept of the diagram acts on the intensive properties of the matter. Manuel DeLanda claims that, in Deleuzian philosophy of matter and form, "matter is already pregnant with morphogenetic capabilities, therefore capable of generating form on its own" (DeLanda 1998, 30) Matter itself is an active agent seeking for an order under topological transformations that allows variations of itself. DeLanda explains that the matter that enters into a diagram has only intensive properties in far-from-equilibrium state. The intensive forces in virtual form are in flow, and stabilization of these forces generates the actual form. However, the virtual properties do not disappear, the matter still possesses them. The differences in intensive properties would (re)activate the morphogenetic capacities of matter, and, in the equilibrium state, intensive differences would cancel themselves and actualize the final form. In contrast to the reductive view of the diagram, which always requires an external agent or pre-determined form to become real, Deleuzian diagram always generates novel forms by itself. DeLanda criticizes the hylomorphic view of the diagram as "if the future is already given in the past, if the future is merely that modality of time where previously determined possibilities become realized, then true innovation is impossible" (DeLanda 1998, 30) The strength of the Deleuzian concept of the diagram comes from its capacity to generate genuine forms.

2.0 THE DIAGRAM IN ARCHITECTURE

It has been showed that the concept of the diagram has evolved in two entirely different, if not contrasting, paradigms in sciences and philosophy. While the diagram is perceived as a tool for rationalization of the process and control of the object of study in sciences, it operates as abstract machines to map forces and to generate genuine creations in philosophy. Architecture, which articulates its concepts and creations through rationalizations, benefits from both paradigms. According to Somol the diagram in architecture is fully actualized when the fundamental technique and procedure of architectural knowledge has shifted from drawing to diagram in the second half of the 20th century (Somol 1999, 7). Stan Allen explains the double role of the diagram in architecture as "although diagrams can serve an explanatory function, clarifying form, structure, or program to the designers, and notations map program in time and space, the primary utility of the diagram is as an abstract means of thinking about organization" (Allen 1998, 16). How does architecture manage to control these two dichotomous functions of the diagram concurrently in a single design process? How does architecture link the inscriptive mode with the generative mode of the diagram without colliding two different paradigms? In order to answer these questions, this paper studies three significant diagrammatic praxes to seek for insights into how the means of the diagram are actualized in architectural practices through theories of the diagram. Firstly, it studies diagram architecture of Sejima where, first, the diagram becomes a tool to organize programmatic relations and then it turns into a form to generate the plan. Secondly, it studies textual diagrams of Eisenman, which is conceived as both a generative device and a form of representation. Lastly, it investigates material diagrams of Spuybroek whose generative characteristic is fully actualized through material experiments.

2.1. Analytical Diagram

The modern concept of the diagram has become prominent in the architectural practice since the twentieth century, because, as Stan Allen says, "diagrams are architecture's best means to engage the complexity of real" (Allen 1998, 17). It has been prominently an analytical visual tool for architects to specify relationship between activity and form, and to organize the distribution of architectural program. The diagram enables architecture to represent form and function in an abstract way. Antony Vidler claims that this aspect of the diagram placed the concept of the diagram in a privileged position in the development of modern architecture since it responds at once to "the aesthetics of Rationalism and the authority of Functionalism" (Vidler 2000, 9). Pai argues that "in modern architecture, the diagram has become form, and form has become a diagram" (Pai 2010, 74). Pai's statement recalls Toyo Ito's description of 'diagram architecture', which is an architecture that minimizes "the conversion of a diagram, one which describes how a multitude of functional conditions must be read in spatial terms, into an actual structure" (Ito 1996, 19). He calls Kazuyo Sejima's architecture as a diagram architecture in which "a building is ultimately the equivalent of the diagram of the space used to abstractedly describe the mundane activities presupposed by the structure" (Ito 1996, 18). Sejima brings a unique and simple approach to conversion from diagrammatic stage into architectural stage. For her, the diagram gradually transforms into an architectural plan. She produces spaces and spatial relations at the abstraction level of the diagram. The diagram inscribes architectural form as a necessary outcome of the requirements of the programme.

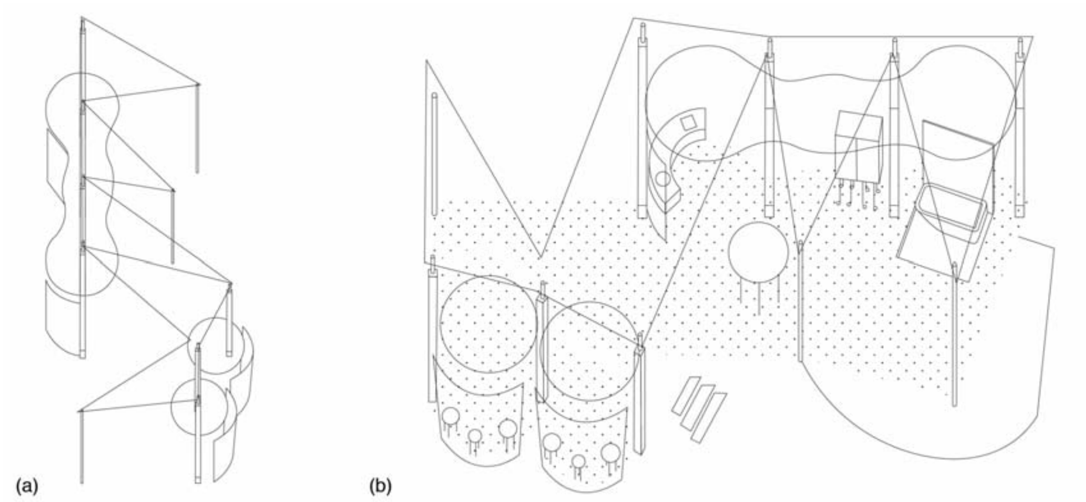

Figure 2: Kazuyo Sejima's diagrams for Platform II House; (a, b) spatial diagrams of the programmatic components. Source: (Images retraced by the author. Original drawings adapted from: "Conversation with Kazuyo Sejima". *El Croquis*, vol. 77. Madrid: EL Croquis, 1996, Image 4, p. 11)

In the conversation with Koji Taki, Sejima defines her design as a continuous process of discovery focused on two stages. In the first stage of the design, she determines the external elements of the project such as demands of the client, condition of the plot, and program. At this stage, she uses diagram as a mere tool to represent the relationships between external elements in abstract geometrical forms. In the second stage of the design, while she continues discovering different relationships between the elements, she visualizes the planning as well (Taki 1996, 6). Sejima produces the first schemes of the plan at these early stages. In the following stages, the structure takes its final form under the influence of the other external factors, which are beyond her control (Taki 1996, 6). In Sejima's architecture, the diagram becomes a translator between function and architectural plan. Ito summarizes Sejima's design process as "she arranges the functional conditions which the building is expected to hold, in a final diagram of space, then she immediately converts that scheme into reality" (Ito 1996, 20). He argues that Sejima's planning bases merely on the diagram of the space (Ito 1996, 20). As in the example of the design of Platform II house, Sejima's diagram of the spatial configuration of the programmatic elements reflects the deconstructivist expression of the final form of the building (Fig. 2). However, Sejima claims, the initial drawing is never actually converted into the structure in the same form as it appears on paper due to the specifications (Taki 1996, 7). The design is initiated by the diagram and then modified by other external factors. In Sejima's architecture, the diagram plays a representational role that inscribes its own form into an architectural form. Like the scientific approaches to the diagram, for Sejima, the diagram, first, performs as a tool to control the relationship between design elements, and then it turns into a physical entity composed of geometrical forms that inscribes the architectural form of the plan. The generative mode of the diagram remains unutilized for Sejima. The building is translated from its function plan through the conversion of diagrammatic form into architectural form.

2.2. Textual Diagram

While Sejima approaches to diagram as a mere inscriptive tool, Eisenman approaches to the diagram from both sides as a form of representation and a generative device. In his seminal essay "Diagram: An Original Scene of Writing", Eisenman influenced by Derrida studies the diagram in relation to text. For him, the diagram is capable of tracing and writing, hence it can be traced and read in architecture (Eisenman 1999). The Diagram becomes textual and performs as analytical and generative device in architecture. While forming his theory, he focuses on the moment when a scheme becomes a diagram and thus more than mere geometry. Unlike the formal resemblance between Sejima's diagram and architecture, Eisenman argues that "there is not necessarily a one-to-one correspondence between the diagram and the resultant form" (Eisenman 1999, 28). The diagram acts as an intermediary in the process of generation of an architecture. The diagram as a generator is not visible in the final form. He defines his approach to the diagram, "as a generative device in a process of design, the diagram is also a form of representation. But unlike traditional forms of representation, the diagram as a generator is a mediation between a palpable object, a real building, and what can be called architecture's interiority" (Eisenman 1999, 27).

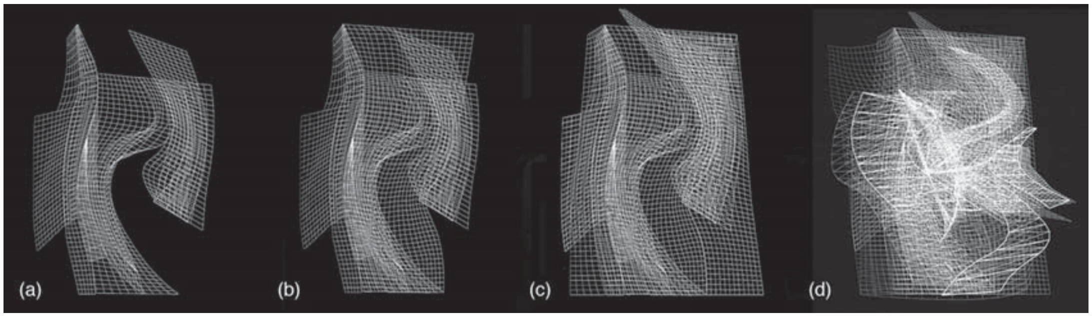

Figure 3: Eisenman's diagrams for Staten Island Institute for arts and Sciences; (a, b, c, d) transformation of grid layers. Source: (Eisenman Architects, New York, 1997-2001. Adapted from: http://www.eisenmanarchitects.com/staten-island.html (accessed March 29, 2018).)

Eisenman's theory of the diagram is heavily influenced by Deleuze as well as Derrida. Even though Derrida did not produce a significant work on the diagram, Eisenman interprets his texts on the mystical writing pad to form his own theory of the diagram. Eisenman asserts that the diagram performs in a similar manner with the mystical writing pad, which consists of multiple levels that allow infinite possibilities to write and re-write on the top surface while it keeps the previous traces on the bottom layer. Like the mystical writing pad, according to Eisenman, "the architectural diagram can be conceived of as a series of surfaces or layers which are both constantly regenerated and at the same time capable of retaining multiple series of traces" (Eisenman 1999, 33). Therefore, the forces can be traced in relation from one layer to another in the diagram like superimposed maps as in the example of Eisenman's Staten Island diagrams (Fig. 3). The conversion from diagrammatic stage to architectural stage is a question for Eisenman as well. Like Sejima's diagrams, his concept of the diagram does not have agency to generate architectural form either. According to Eisenman, in order to actualize the generative agency of the diagram, "an external condition is required in the process, something that will introduce a generative or transformative agent as a final layer in the diagrammatic strata" (Eisenman 1999, 35). The external agent, such as the specific site, the program or the history, can be conceived as another layer of a transparent pattern or screen, which blurs and reveals what has already been traced on the bottom layers. Thus, "the diagram does not generate in or of itself" (Eisenman 1999, 35). The diagram performs as an agency that proliferate a generative and transformative capacity of the design process.

2.3. Material Diagram

Lars Spuybroek criticizes Eisenman for seeing "the diagrammatic capacity of architecture too much as something linguistic, i.e. as metaphysical" (Spuybroek 2010, 280). He argues that in Eisenman's architecture the real has already happened and has always been consumed after the architecture processes it through language and presents its view to the users. Users only re-experience what has already foreseen in the diagram (Spuybroek 2010, 280). As opposed to textual conception of the diagram, Spuybroek advocated his generative view of the diagram for being more sensed and felt rather than read. He positions the diagram between "the-world-imagined and the-world-experienced" (Spuybroek 2010, 279). Spuybroek fully actualizes the generative capacity of the diagram through his material experiments. His philosophical view is heavily influenced by Deleuzian diagram, and his architectural practice is influenced by Frei Otto's material experiments. As Deleuzian philosophy suggests, Spuybroek's diagrams gain machinic properties to actualize the virtual forms through material experiments in which the matter is seen as active agents loaded with morphogenetic capacities. Otto's material experiments on light structures resonate with Spuybroek's material diagrams, which "produce form and structure during reconfiguration. They operate on extensities, and relate the action in space to the perception of space and the construction of space" (Spuybroek 2010, 276). In material diagram, as Kwinter explains, "the virtual is related to the actual, not by transposition - a becoming real - but by transformation through integration, organization, and coordination. The actual does not resemble the virtual; its rule is rather one of difference, innovation, or creation." (Kwinter 1998, 61). Unlike reductive theories of the diagram which always require an external body for creation, the material diagram operates on morphogenetic capacity of the matter through intensity differences. Spuybroek explains this abstract process, in which the intensity differences cease into an organizational singularity while generating actual structures, in two phases: convergence and divergence. Convergence is "a movement of virtualization, in which information is gathered, selected, graphed, or mapped and then organized into a virtual machine. A movement towards quality, order, and organization" and divergence is "a movement of actualization, in which the organizational diagram germinates and becomes formative. A movement towards quantity, matter and structure." (Spuybroek 2010, 273)

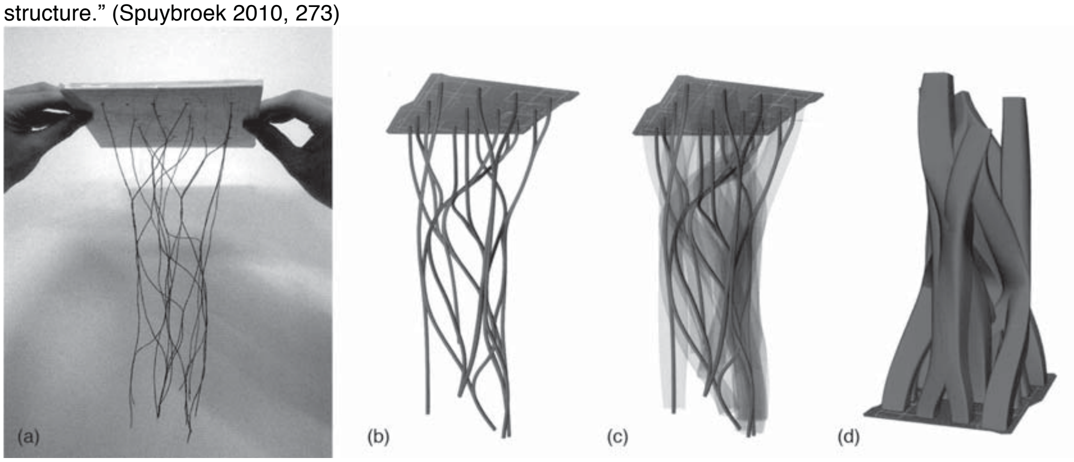

Figure 4: Spuybroek's material diagrams for World Trade Center; (a) wool thread machine out of the water, (b) digital model of the wool threads, (c) digital model of the thickened wool threads, and (d) digital mass model of the tower. Source: (NOX, Lars Spuybroek with Chris Seung-Woo Yoo and Kris Mun, New York, 2001. Adapted from: Lars Spuybroek, NOX: Machining Architecture, New York: Thames & Hudson, 2004, p. 261)

The question of how the convergence phase is connected with the divergence phase becomes the main focus of Spuybroek's material diagrams. They achieve such connection by setting up both phases as empirical machines whose procedures are regulated by organizational rules. Spuybroek lists four stages of machining in design: first stage is "to select a system and create a configuration for the machine based on this selection", the second one is "to mobilize the elements and relations in that system", the third one is where we need "a phase of consolidation to finally make the system" and the final stage results in "an architectural morphology" (Spuybroek 2010, 274). As in the example of Spuybroek's wet string tower diagram, which is inspired by Otto's wool thread diagrams, the strings in the configuration get mobilized by intensive and extensive forces when they are dipped in the water. When the configuration is transferred outside of the liquid medium, the forces acting on and in the strings, settles in and produces the final form (Fig. 4). As Kwinter points out, actualization inflects, combines, and separates elements and leaves nothing untransformed (Kwinter 1998, 23). For Spuybroek, the diagram as a whole is a system of relations in which if one relation changes, the rest changes as well. Spuybroek's material diagrams can be understood as "a continuous unfolding, a progressive differentiation, a gradual increase in information as object takes on form and grows" (Spuybroek 2010, 272). Therefore, Spuybroek offers a concept of diagram whose generative capacity comes from/within the material. Unlike the active role of architect in the diagram concepts of Sejima and Eisenman, architect plays a passive role in the generative process of material diagrams. Architect sets the machine and leaves the form production to the diagram.

CONCLUSION

The conceptual differences between the diagram in sciences and that in philosophy sets the two ends of the dichotomy. At the one end, the diagram is perceived as reduction, a visual tool for representation and inscription; at the other end, it is conceived as proliferation, an abstract machine for generation of genuine creations. Because of the broad definition of the diagram which somehow holds dichotomous approaches in itself, the meaning and the function of the term get ambiguous for several disciplines and professions. Architecture as one of them has produced several concepts and theories of the diagram. Berkel and Bos claims that architecture today approaches to the concept of diagram from a generative view rather than a reductive view. "Diagrams are best known and understood as reductive machines for compression of information. […] But diagrams can also be used as proliferating machines. This is how architecture today interprets their use, thus transforming diagram's conventional significance" (Berkel 1998, 20). This paper showed that even though the generative aspect of the diagram is central to architectural rhetoric, architecture today still benefits from both reductive and proliferative modes of the diagram. It states that the dichotomy of the diagram should be seen as a continuum in architecture where various in-between positions can be described. As Allen points out that while the reductive approaches provide the diagram an explanatory function clarifying form, structure, or program to the designers, the proliferative approaches see the diagram as an abstract means of thinking about organizations (Allen 1998, 16). The diagram serves as both analytical and generative device in the design process. While for some architects the diagram becomes prominent as an analytical too, for some it operates more as a generative device rather than being a mere form of representation.

The three praxes studied in this paper approach to the diagram from conceptually and philosophically different perspectives. They define a gradual transition from one end of the dichotomy to the other. On the one side closer to the scientific view of the diagram, Sejima's design approach utilizes the diagram primarily as an analytical tool to organize the spatial and formal relationship between external forces, such as demands of the client, the site, and the program. There is a clear resemblance between the form of the diagram and the plan of the buildings designed by Sejima. On the other side closer to the philosophical view, the diagram is fully actualized as a generative device by Spuybroek through his material experiments. Unlike Sejima's design processes which are orchestrated by an external agent, Spuybroek's generative processes are actualized in and through the active matter by the machinic forces of the diagram. In the middle of the both view, Eisenman conceptualizes the diagram as a textual device, which functions as both an analytical and a generative tool. He sees the diagram as traces on layered transparent surfaces, on top of which there is infinite possibility to re-trace, re-draw and re-write. Even though, besides works of Sejima, Eisenman and Spuybroek, several other in-between theories and practices of the diagram can be pointed out in architecture, what makes these three significant is that they not only produce their own distinctive diagrammatic concepts but also become frequent references for diagrammatic literature. Sejima, Eisenman and Spuybroek take a certain diagrammatic position within the range of dichotomous modes of the diagram. This study shows that despite the certain dichotomous characteristics of the diagram, architecture achieved to hold concurrently both contrasting concepts of the diagram and utilize them for its own purpose of form generation. Therefore, it asserts that architecture sees the analytical and generative characteristics of the diagram as a continuum rather than a dichotomy.

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Jacklynn Niemiec

Documenting Intent: A Survey of Spatial Models for Indoor Navigation

Documenting Intent: A Survey of Spatial Models for Indoor Navigation

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ABSTRACT: Indoor environments cannot rely on global positioning systems for navigation, which poses a stark contrast to the immediacy and accuracy of positioning and navigation in outdoor environments. The study of indoor navigation has grown in two general topic areas, navigation of indoor space and machine learning of indoor environments. This paper will only review the current research in indoor space navigation and the modes of modeling space for a prescribed route.

Literature reviews of indoor positioning have considered the array of approaches within the network and inertial models, the precision of each approach, and each system's fitness in a mass-market application. Yet, with a significant relationship to the built environment, a review of indoor positioning's impact on the field of architecture and more specifically, its relationship to spatial documentation has yet to be considered.

KEYWORDS: wayfinding, indoor navigation, architectural representation, semantic wayfinding

INTRODUCTION

This paper will review current spatial models and map generation used for indoor navigation and wayfinding. The intent of this review is to provide a relationship of current spatial models to the field of architecture. Recent literature presents a wide range of spatial models for representing the indoor environment. These differences are dependent on several parameters within the building type, program, and users of the environment. The variables surrounding these decisions will be reviewed in concert with the associated spatial model. Unlike outdoor navigation which has a generally common path structure (roads) to follow. Indoor environments vary greatly in size, vertical circulation, use, structure, and complexity. The range of possible indoor spatial configurations has prompted some hybrid approaches in the development of navigable indoor models while others seek a universal approach to defining these spatial models.

The task of indoor navigation requires location, routing, and guidance. (Worboys 2011) The first, location, refers to marking the positions of a start and endpoint. This initial task of navigation requires positioning in space and thus requires an adequate reference system as a *map*. A map, as referred to in navigation systems, could be a two-dimensional plan or three-dimensional model. The derivation and translation of these maps to a legible model for navigation are of interest. Many systems use existing documentation of a space (*a priori)* and derive a spatial model from architectural drawings or models. Other systems have the potential to build their own maps in unknown environments through SLAM (Simultaneous Location and Mapping) technology.

Typically, the *a priori* building information used in indoor navigation models are the floor plans of a building. In architecture, these types of documents are typically in service of communicating tangible information such as scale, material, and assembly for purposes of construction. However, the rise of BIM (Building Information Modelling) and life-cycle considerations in the field of architecture has placed increased value on analysis, building life-cycle, and occupation. Forecasting of use and occupancy within a building can play an important role in the design and should be considered relative to research in indoor navigation and wayfinding. A recent study analyzed occupant behavior and movement to investigate how workspace layout affects communication and team interaction amongst nurses and doctors in an emergency room department of a large urban hospital. The hospital staff's movement, perception, and experience were overlaid onto an existing floor plan to reveal information about communication and use within the existing ER environment and ultimately to provide evidence for future design work. (KieranTimberlake 2017)

There is significant overlap in literature related to indoor navigation and wayfinding in cognitive science, artificial intelligence, architecture, and geo-information science. (Franz et al. 2005) This paper intends to parse out parallel language and dialogues related to spatial models for indoor navigation and communicate the needs and advances of indoor navigation technology in the field of architecture. Leveraging the inherent spatial intelligence of the design process in architecture could yield better responses to human behaviors in navigation. Similarly, understanding and developing spatial models that more closely align with those necessary to foster successful indoor navigation can serve to illuminate architectural intent and help to preserve the qualitative value of spatial experience.

Section one will introduce related vocabulary in the fields of geography and navigations, cognitive theory and architecture. The outlined vocabulary will serve as a bridge between fields and serve as a foundation for the paper. Section two will review graph-based spatial models and the inclusion of spatial information, such as semantics, into navigation systems. The paper will conclude with considerations for future research and applications.

1.0 RELATED VOCABULARY

1.1 Geography and Navigation

Navigation is the ability to plan and execute a goal-directed path. (Gallistel 1990) The term *wayfinding*, while closely linked to navigation, presumes the ability to organize information about the physical environment into a cognitive map. (Passini 1992) Two distinct forms of human navigation are path integration (originally referred to as dead reckoning) and landmark-based navigation.

The *dead reckoning* system of navigation allowed for early explorers to travel over long distances without an exact geographic position or location within a system of coordinates.(Passini 1992) Dead-reckoning relies on the continuous calculation of one’s speed and bearing, incrementally charting this information to create a continuous path made up of individual vectors. (Denny 2012) P*ath integration* and *inertial navigation* are used synonymously with dead reckoning and, similarly, do not rely on landmarks for positioning. The term path integration is often referred to in cognitive science research and literature on the topic considers a human or animal’s ability to return home along the same path without the use of landmarks and emphasizes the cumulative nature of movement. (Ariane S. Etienne 1992)

Landmark navigation relies on visual cues to guide movement to a given location. (Sjolund, Kelly, and McNamara 2018) Two types of visual cues have been identified; geometric and “featural” cues. (Gallistel 1990; Cheng and Newcombe 2005) Geometric cues relate to the overall geometric form of an environment. These cues rely on unique conditions and geometric changes in a space, shape, proportion, corners and spatial axes are examples of geometric cues referenced within a given space. (Gallistel 1990; Cheng and Newcombe 2005) Featural cues as introduced by include non-geometric features such as wall color, elements on walls or objects in space.

Some research has reviewed the overlap of path integration and landmark navigation in human cognition to determine prevalence or weight of one over another in a given wayfinding task. (A. S. Etienne, Maurer, and Séguinot 1996) In addition, the prominence of geometric cues or landmarks within wayfinding scenarios has been considered. (Davies and Peebles 2010)

1.2 Spatial Cognition

Research in spatial cognition relates to the way in which people obtain and implement knowledge about their environment to determine their location and how to find their way to a given destination. (Waller and Nadel 2013) Cognitive Map theory and the term *cognitive map* is widely referenced in wayfinding and navigation literature. The notion of a cognitive map was introduced by (Tolman 1948) as a means of describing an animal’s ability to store spatial information between the point of origin and destination. The term has evolved and since been rooted in the study of human spatial cognition. The landmark study by (O’keefe and Nadel 1978, 86) defines the cognitive map as “a representation of a set of connected places which are systematically related to each other by a group of spatial transformation rules.” These “rules” differentiate the cognitive map from a one to one representation of space and rather, propose it to be a generalization and inference of spatial information beyond the details of a direct experience. (Golledge 1999)

Localization refers to the locating of oneself or objects within a given frame of reference or map. (Kiefer, Giannopoulos, and Raubal 2014) A frame of reference is required to locate or describe the location of objects or oneself in space and a similar condition is required for spatial memory. (Mou and McNamara 2002) Two types of spatial reference systems are considered for understanding spatial cognition. Egocentric reference systems provide location relative to the observer or self, while environmental reference systems use spatial geometry or landmarks to provide a frame of reference.

Typical navigation involves both internal and external cues in combination and studies have tested variables in the “weight” or relative importance of these cues. (Ratliff and Newcombe 2008) Several variables considered in this realm are landmark distance, room size and shape, intrinsic axes, and rotation. (Sjolund, Kelly, and

McNamara 2018) The integration of these cues is the subject of several cue-combination studies that seek to define the priority and optimality of cues in varied environmental conditions. Related work on spatial reorientation, or the process by which one regains their orientation in an environment determined that spatial geometry, or the shape of space, have a greater influence on the reorientation of one's cognitive map within an environment than view-matching. (Keinath et al. 2017)

1.3 Architecture

To distinguish *architecture* from the building, (B. Hillier 2007) states that architecture, "introduces into the creation of buildings an abstract concern for architectural possibility through the principled understanding of form and function. The distinction between architecture and building is of importance to this paper and its relationship to indoor navigation. Literature in indoor navigation and wayfinding almost exclusively reference simplified buildings floor plans.

A *floor plan* represents a horizontal cut through the volume of a building at a given level. Floor plans are typically cut at 3'-0" to 4'-0" above the finish floor of a given level. The floor plan graphically represents solid (wall) and void (space). Floor plans can be viewed as figure and ground; the inverting of which preferences void, or space, over solid forms. The floor plan is a primary tool for organizing space relative to design intent. The underlying structure of a floor plan can reveal inherent spatial patterns such as repetition, rhythm, and sequence. And while grids or other underlying patterns may govern architectural decisions, additional value is seen in the breaking of those rules and the blurring of discrete spaces or rooms. (Plummer 2016)

Spatial organization describes the way in which the spaces of a building are organized, this is typically seen in plan. Common forms of spatial organization are centralized, linear, radial, clustered and grid based. While each underlying organization predicates a natural form of movement through the spaces. (Ching 2014) The term *axis*, in architecture, relates to the organization of space as opposed to the movement through it. Most types of spatial organizations rely upon a single axis or set of axes. The axis of a building or space represents a "symbolic direction" organizing elements or spaces along it and often operates to relate them to a larger context. (Norberg-Schulz 1971, 49) Axes are typically seen in the arrangement of a plan and often correspond with the centerline of a circulation space.

Circulation is a term broadly recognized in the field of architecture as the means of human movement within or around a building. The term circulation was borrowed from physiology and the mechanics of the circulatory system. (Forty 2004) Circulation spaces are commonly considered as hallways or stairways but are not always defined in such narrow ways. (Hertzberger 2000) The boundaries of circulation space can be implied by movement and defined in less material ways, making it common for architects to isolate circulation as a "system" of the building in drawing form to study the space and surfaces of that system independently. Related to circulation, are *paths*, these are described by (Lynch 1960, 47) as "channels along which the observer customarily, occasionally, or potentially moves". However, this modern view of "potential" circulation space was not always such, the term circulation was adopted by the field of architecture late, c. 1850 and was not considered independently before that point. It was found that the word *distribution* preceded circulation, favoring functionality, organization, and rigidity of axes and communication between discrete spaces. (Forty 2004)

Threshold, as used in architectural discourse, relates to transitional spaces in building most typically, doorways or passages. (Boettger 2014) The simplest definition in architecture is "a place or point of entering or beginning". (Ching 2014, 418) In science, threshold refers to the magnitude or intensity that must be exceeded for a certain reaction, phenomenon, result, or condition to occur or be manifested. Both definitions relate to a change, either in place or state. The term threshold is important in the context of indoor navigation because it defines neither here nor there (start or end) as more than a doorway or staircase, more than a connecting element. Thresholds differ from boundaries in that they are spatial and not linear.

Viewshed is commonly used in landscape architecture and architecture to define the extents visible from a given location. A related term, isovist is also referenced in the literature on spatial analysis. "An isovist is the volume of space visible from a given vantage point in space and with respect to an environment." (Benedikt 1979, 47) The concept of isovists and their subsequent representations, isovist or visibility graphs, can provide designers a measurable way to map spatial experience.

The related vocabulary from architecture discussed above is intended to be a reference in reviewing the spatial models discussed in section two. This small cross-section of architectural terms also seeks to provide context to many terms co-opted in the literature on indoor navigation and consider the presented survey of spatial models beyond a building's hallways, doors and rooms and within the broader context of space and architectural intent.

2.0 NAVIGATION AND WAYFINDING

Indoor navigation is a growing field of research yet, a ubiquitous mapping, localization or navigation system for the indoor space has not been implemented. While GPS is widely used for outdoor navigation a primary limitation of it within indoor environments is its signal strength.(Fallah et al. 2013) Additionally, outdoor spaces are easily recognized within Euclidian space or an absolute coordinate system. These coordinates can provide an exact location in outdoor space without relationship to a fixed point or element and distances are measured as absolute dimensions between x1, y1, and x2, y2. Generally, positioning within indoor space is communicated through relative or semantic directions; “you are in Room 201” or “take the second door on your left”. (K.-J. Li 2008)

Indoor navigation systems are also developing in commercial applications. The primary applications being in airports, hospitals, and museums. Additionally, retailers have shown interest in point to point consumer wayfinding and navigation within their distribution centers. Location-based provider, Google Maps launched an indoor navigation system that redraws owner-uploaded floorplans of public buildings and has since published over 10,000 floor plans to their online platform. (Anonymous 2012) Both floor plans and BIM models can serve as strong foundations for spatial models in indoor navigation but are not typically used 1:1 because they have varying styles of partitioning space. (Zlatanova, Liu, and Sithole 2013) The graphic conventions of architectural drawings do not easily translate into a spatial logic required for navigation. The way in which indoor spaces should be visually represented for navigation is a methodological issue that is still under discussion in the field. Some literature in this area suggests the need to identify a set of modeling principles that fit the properties of indoor spaces and to be as “generic as possible” to support different applications and various levels of detail. (X. Li, Claramunt, and Ray 2010)

2.1 Spatial Logic

Graph-based representations topologically organize the structure of an indoor spatial environment. (Franz et al. 2005) Graph-like models can be more appealing as representations because of their flexibility and disassociation with the fixed geometry of space in a floor plan. (Franz et al. 2005) These graph-based spatial models are referenced in cognitive science, architecture, robotics, and navigation. They seem to cross disciplines due to their visual abstraction and ability to represent spatial and non-spatial information. Graph-based models are built on a system of nodes and edges (points and lines) that convey a network of spatial relationships rather than a scaled geometric model. Types of graph-based models include occupancy grids, place graphs, view graphs, access graphs, axial maps, and visibility graphs. (Franz et al. 2005) *A priori* building documentation, typically a floor plan is generally available and used as a basis for design in these studies; though the geometric information is not always evident in the final model.

Connectivity graphs are the most abstract spatial graph based on the definition of spaces and access of one space to another. This type of spatial graph is derived from a floor plan and generates a topological representation of spaces. (Fig. 1) Access graphs provide an additional level of information. For instance, while two spaces are connected, they may not necessarily be accessible in both directions, this would likely be due to security reasons. Both connectivity and access graphs require the definition of unique rooms or spaces to define their relationships. (Jensen, Lu, and Yang 2009)

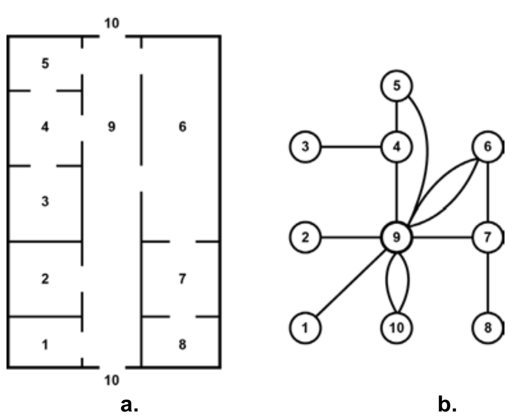

Figure 1: An example of a. base floor plan and associated b. connectivity graph

Occupancy grids were originally proposed in the field of artificial intelligence and are used as a way of representing space for robots to navigate. Space is mapped on a regular grid and each unique cell is connected to its surrounding eight cells. Every cell is assigned a probability value, high values are assigned to cells with more accessible space, while lower values are given to cells containing obstacles. (Moravec and Elfes 1985) When overlaid on a floor plan, the occupancy grid can provide a simple abstract system for navigation while maintaining a relationship to the physical dimensions of a space. In (X. Li, Claramunt, and Ray 2010) the occupancy grid is orthogonal with square cells, the resultant geometry used for navigation is developed through the triangulation of the grid. The connecting lines become edges or paths and the corners of each cell the nodes. The neighboring occupancy values following each move generate the path in a probabilistic method. This model requires a base map (floorplan) of a space and clarity in the definitions of walls, doors, and other access points or obstacles.

Axial maps were developed in the field of architecture and created as a means of representing spatial syntax or the patterns by which different societies develop buildings forms and settlements. (Bill Hillier et al. 1976) Through the use of axial maps, the inherent relationships of social structure are made manifest. This concept presumes that one does not exist without the other and that the relationship is dynamic and changes over time. (Bafna 2003)

Visibility Graphs are built off the idea of an *isovist field.* Isovist fields map the area visible from a given point, while visibility graphs extend that concept to an array of points within a space. By configuring the visibility of all points to one another, the density of lines on the graph define an area as being more visually accessible. Spaces that are more or less visible from nearly all vantage points are made evident. Research in this area has looked as important works of architecture such as the Farnsworth House and Villa Mairea for testing new methods for visibility models. This particular study translates the visibility graph from line to space, using a grid system to show visibility as a field rather than points and vectors The authors also note that the outcomes would be vastly different had they taken into account the view to the outside. (Alasdair Turner et al. 2001) This is rare evidence of context, or view to the outside, being considered within indoor navigation modeling.

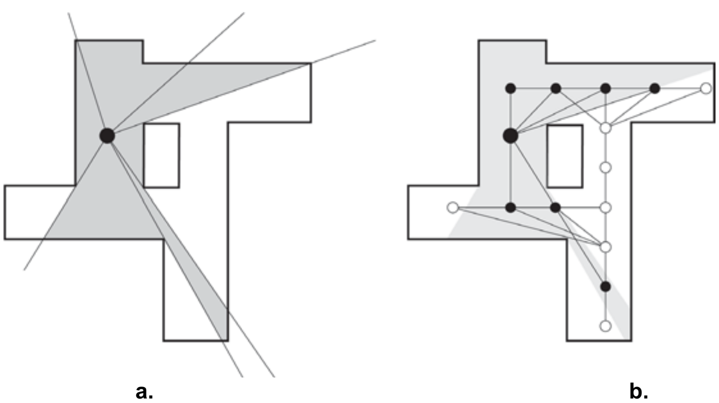

Figure 2: Example of a. isovist field and first-degree b. connectivity graph

Navigation graphs provide the foundation for translating physical space into digital information. The abstraction of spatial information is clearly organized and legible, however, the binary nature of these graphs does little to reveal the continuity of space that relates to the cognitive perception of the environment. Semantic information included in these 2D approaches includes construction elements such as doors, rooms, and stairs that are essential to navigation tasks. (Xiong et al. 2017) Additionally, the role of human behavior is not widely considered and is stated as difficult to approximate in the structural representation of spaces. (X. Li, Claramunt, and Ray 2010)

2.2 Spatial Information

A *semantic map* augments spatial models with descriptive information about physical elements such as walls, floors, and doors that are located in space. (Nüchter and Hertzberg 2008) First introduced within artificial intelligence research, the spatial semantic hierarchy (SSH) is a structuring of spatial information that considers the following information within a space: sensory, control, casual (views), topological (relationships), and metric information. (Kuipers 2000) The SSH is widely referenced in indoor navigation and provides a definition of components within the human cognitive map. Because the original intention of SSH was clear communication between humans and robots, the basis for the structure is inherently embedded in human experience and behavior. Spatial information in this regard encompasses more than physical features. Sensory information could greatly impact metric information as suggested, “two rooms of the same size will feel altogether different if one has natural light and the other is lit artificially … A space with a lot of windows will almost always pull you toward the view, and sometimes it can even feel more like an open balcony facing a vista than an enclosed architectural space..." (Goldberger 2009).

Early research on perception suggested that all perceptual systems “can serve to govern directed locomotion. They are all orienting systems insofar as they can guide the individual to a goal.” (Gibson 1966, 73) Recent work in artificial intelligence and indoor navigation is focused on perceptual systems and understanding the role of semantics and spatial definition in wayfinding. A recent study by (Krūminait\.e and Zlatanova 2014) used Rotterdam Central Station as a model for indoor navigation. This proposed navigation model presumes that human movement is governed by spatial configuration and lines of sight. By quantifying these conditions and assigning a value to various landmarks in the station, the results provide evidence that qualities such as *attractiveness* to a landmark or user *necessity* are beneficial parameters for defined nodes within an indoor environment. Another important point of distinction within this study is its subdivision of a navigable surface. The navigable surfaces of the space are subdivided using Delaunay Triangulation providing a wider array of decision points (nodes) for navigation. This subdivision approach is related to navigation meshes used to simulate movement in crowd dynamics. (Fig. 3) The options available within this subdivision provide choice and variation for potential routes based on a set of parameters.

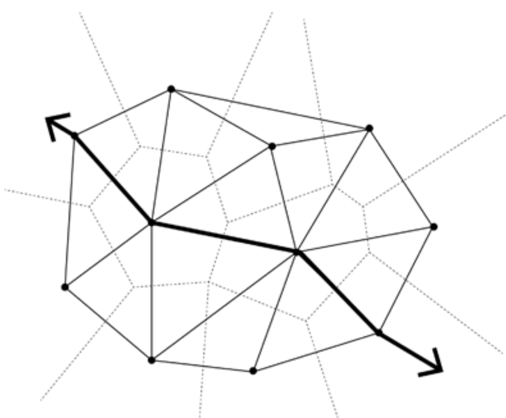

Figure 3: Routing option in spatial subdivision using Delaunay Triangulation

The use of BIM models as a basis for navigable spatial models is growing. (Isikdag, Zlatanova, and Underwood 2013; Xu et al. 2017) Because Building Information Models contain rich data about building components and are three-dimensional, spatial information can be more easily extracted and built upon. Common elements used from BIM for navigation models are: semantic information (levels, element names), properties of building elements (materials, opening direction, exit doors), functional states (obstacles, door open/closed), structural element information (columns, stairs), spatial relationship (hosting of elements), and interoperable geometric representations (exportable format). (Isikdag, Zlatanova, and Underwood 2013)

Additionally, in 2015, the Open Geospatial Consortium (OGC), which is an international voluntary consensus standards organization, introduced “IndoorGML” as a standard for open source models related specifically to indoor navigation. This standard supports a broader language relative to building semantics; defining the following types of space within a model: Anchor Space (entrance), General Space (room), Transition Space (stair or hallway), Connection Space (doorway). An additional type of space, *virtual space,* was proposed in response to these standards and introduced a *threshold* condition or implied space that connects but also differentiates two other spaces without defined edges. (Xiong et al. 2017) A notable distinction in this particular study is the introduction of a building section (vertical cut) to define potential connections between spaces outside of the x and y-axis. Three-dimensional spatial models such as this, use *voxels*, or 3D grids, to identify unique instances in space. Advantages to this cellular division of space can be located through a set of (x,y,z) coordinates and have neighbors, or common boundaries. Much like the occupancy grid, this subdivision of space provides a framework to define the parameters of unique points in space.

3.0 CONCLUSION

The navigation of indoor space is an important topic for architects to gain awareness of. Likewise, developers of spatial models for navigation could benefit from an awareness of architectural design principles. The collection and attribution of experiential data could give needed value to the field of indoor navigation and wayfinding. For example, in building types such as hospitals, using materiality, privacy and light levels as parameters for navigation can promote positive health outcomes. (Huisman et al. 2012)

Architects should also consider seeking new ways of documenting *a priori* building information for purposes of indoor navigation. The sharing of architectural drawings and models with navigation consultants may be on the horizon; developing an architectural convention of intent and analysis for indoor navigation is a viable area of research. The re-drawing of space for indoor navigation is *efficient* but does not place *sufficient* value on design intent or architectural possibility.

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Trends in the Application of CFD for Architectural Design

Trends in the application of CFD for architectural design

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ABSTRACT: This paper is an overview of the trends in the application of Computational Fluid Dynamics (CFD) in architectural design. This paper aims to identify the current trends of CFD-related research in the architectural field and questions how CFD may interact with architectural design practice. To achieve the research objectives, a thorough literature review was conducted with two steps. First, relevant data were collected from journals and conference proceedings. The collected data were categorized according to the detailed topic of literature, such as designing HVAC and building envelope systems, evaluating indoor climates, simulating outdoor airflow, and developing early-stage designs. Based on the developed categories, we studied the trends of the CFD-related paper submissions for the International Building Performance Simulation Association (IBPSA) international conferences from 1997 to 2015. The results showed that the amount of CFD-related research has been constantly growing due to the increase of case-based research, and because the design process itself (including decision-making) has been an active research topic recently. Through in-depth literature review and trend analysis, we found that CFD-related research has been evolving in interaction with architectural design practice, and that the boundary of the research has expanded from evaluation of built environments to include the early stages of design.

KEYWORDS: CFD, architecture, design, application, literature review

1.0. INTRODUCTION

Computational Fluid Dynamics (CFD) is a numerical methodology used to simulate the movement of fluid including airflow. By using partial differential equations, CFD calculates the properties of airflow such as direction, speed, pressure, and temperature. Compared to conventional hand calculation or wind tunnel testing, CFD provides prompt predictions concerning airflow. While CFD has been widely used in aerospace and automotive engineering since the 1970s, it also has a great potential for architectural design. The potential may include structural load testing to include resistance to lateral winds and wind uplift forces, and design for natural ventilation in buildings. Airflow has a direct impact on designing a building form, opening, or space.

The close relationship between architectural design and airflow may explain why airflow diagrams consistently appear in architectural design competitions and discourses. However, some airflow diagrams in architectural design are driven by the architects' intuition, which is often different from reality. For example, the Tjibaou Cultural Center in New Caledonia is a well-known building touted as an ecological design, but researchers proved that the airflow in and around the building was different from the designed path (Wu et al. 2011). Also, Parkinson (2015) reported that Londoners complained to the city about the unintended ground level wind generated by the Walkie Talkie Tower. These papers show that airflow does not behave as predicted in many cases. Airflow is unpredictable because detecting turbulence generated by the wind in interaction with obstacles is a complex process. In other words, intuition may not be sufficient to achieve credible prediction of airflow. Wind tunnel tests can compensate for this problem, but due to their cost and required time, few architectural projects with critical airflow issues include wind tunnel tests.

Utilizing CFD could improve the situation because it offers "meaningful data visualization" which can help architectural designers to make better design decisions (Roudsari and Pak 2014, 3128). Due to its benefits, CFD was introduced in the architectural field in the 1990s (Zhai 2006, 311). In its infancy, CFD-related research in the architectural field focused on numerical methods and mechanical systems. However, the characteristics of architectural design have since been reflected in the research, and accordingly, the research direction has evolved. CFD-related research now has various trends influenced by its interaction with the architectural field.

This paper aims to reveal the current direction of CFD studies in architectural research. Through the review of various research trends, we also question how CFD interacts with architectural design practice. Specifically, we focus on the needs of architectural designers, and the reflection of their needs in CFD-related research. In brief, the objectives of this study can be summarized as follows:

- Reveal the trends in CFD-related studies for architectural research
- Find the interactions between CFD and architectural design practice

To achieve these goals, papers addressing a CFD-related topic published in renowned building research journals and conferences were collected and reviewed in depth to define the categories of major research trends. The categories defined by this process were used to identify the flow of CFD-related research trends in the architectural field.

2.0. BACKGROUND

CFD was introduced in the architectural field in the 1990s, and the number of CFD-related studies has been constantly growing since 1997 (Zhai 2006, 311). The growth implies that researchers recognized the potential of CFD, and thus, an interest in CFD-related topics permeated the architectural field. However, there have been barriers to implementing CFD in architectural practice. Den Hartog, Koutamanis and Luscuere (2000) pointed out the lack of case-based studies that allow architectural designers to be connected with CFD. Their arguments are reminiscent of Nigel Cross' (2006) statement that designers learn when they test solutions in a real-world setting, whereas scientists learn through analytic studies. Since architectural designers are trained to visualize information and produce projects, a case-based approach with visualized data may best speak their language.

The lack of knowledge concerning fluid mechanics principles has been one of the barriers as well. Using CFD requires knowledge of the underlying principles that can be translated into effective procedures. But, concepts in fluid mechanics can be difficult for architectural designers, who are often visually oriented, to understand. Passe and Battaglia pointed out the literature gap between engineering and architectural design; various references on CFD exist, but the existing literature addresses the issue "in a very technical manner" containing "mathematical formulae many architects are ill-equipped to incorporate for lack of knowledge, patience, or time" (2015, 6). To overcome the barriers to implementing CFD in the architectural field, researchers have focused on case-based studies and simulation methods for simplifying the tedious simulation process. Those efforts have become major trends of CFD studies in architectural research. These trends will be discussed further in the Results section of this paper.

3.0. METHODS

Document analysis, also known as content analysis, stems from research "that uses archival materials as data" (Silverman and Patterson 2014, 95). The strengths of this method are the ease of data access and the opportunity for replication. Through the document analysis process, the information in various formats is reduced, reorganized, and interpreted by the researcher. Therefore, document analysis is not a simple review of existing materials, it is a creation of data interconnections and a movement toward "meaningful understanding" (Groat and Wang 2013, 246). Similarly, Okoli and Schabram (2010) asserted that literature review using document analysis methods may become a stand-alone study with new findings or provide an overview of certain topics for other researchers or practitioners.

Using the document analysis method, Zhai (2006) investigated the trends of CFD studies in building research by tracking the number of CFD-related papers presented at the International Building Performance Simulation Association (IBPSA) international conferences from 1985 to 2003. Similarly, Blocken et al. explored outdoor airflow simulations and categorized the literature into four types: "pedestrian wind environment around buildings"; "wind-driven rain on buildings"; "convective heat and mass transfer coefficients at exterior buildings services"; and "air pollutant concentration distributions around buildings" (2009, 489-493). Likewise, document analysis was the main research method of the study presented in this paper. Moreover, the methodology of Zhai and Blocken et al. were referenced to structure our study into data collection, categorization, and data analysis stages.

The data collection was conducted in two steps, defining categories and checking trends. First, we collected literature through search engines including Google Scholar, Science Direct, and Engineering Village. The keywords for the search were "CFD," "Computational Fluid Dynamics," "airflow," and "wind." After selecting papers with titles or abstracts having these keywords, redundant or irrelevant papers were eliminated. An irrelevant paper, here, meant that its methodology did not include CFD. For example, if a paper discussed airflow issues without using CFD, it was eliminated. A thorough literature review was conducted to define categories of CFD-related studies in architectural research. The literature review was summarized with the following categories and subcategories:

- Support for the application of CFD
- Application of CFD
    - HVAC system analysis
    - Indoor climate analysis
    - Outdoor airflow analysis
    - Building envelope analysis
    - Design decision-making process

While Zhai (2006) defined four CFD-relevant trends from 1985 to 2003 focusing on the mechanism of CFD, such as simplification of the CFD interface and development of modeling methods, the categorization above focuses on the application of CFD similar to the literature review by Blocken et al. (2009). This difference in categorization is due to the significant increase of case-based application research after Zhai's studies in 2003, while the mechanism of CFD was the main research topic prior to 2003.

After setting the categories, the second step was checking the trends of the studies based on the categories defined in the first step. The sample of the second step was limited to papers submitted for the International Building Performance Simulation Association (IBPSA) international conferences from 1997 to 2015. Within this boundary, the number of papers that belonged to each category was counted each year to reveal the research trends. The reason for setting this limit to conference proceedings was that conference proceedings are more time-sensitive, thus, they reflect ongoing studies promptly. Although journal articles are often considered more refined versions of these studies, they usually require some time for publication.

The reasons for setting the limit to IBPSA international conferences were: 1) to confine the size of sampling for clarity; 2) to utilize the association's abundant publications and open-source database from 1985. IBPSA is a major association specializing in building simulation. This association holds biannual international conferences that are among the best-known events in the building simulation field (Zhai 2006, 311). Therefore, observing the research topics presented at the IBPSA international conferences can demonstrate the trends of building simulation studies, which include CFD. The reason for limiting the time of publication after 1997 was that there were insufficient data before 1997 since the growth of CFD-related research started in 1997 (Zhai 2006, 311).

4.0. RESULTS AND REFLECTION

The collected papers were categorized into two main streams: support for the application of CFD and the application of CFD in architectural projects. These two streams are explained in section 4.1 and 4.2.

4.1. Support for the application of CFD

Researchers have argued that the complexity of CFD has interrupted the dissemination of the tool in the architectural field and have responded to this problem with various solutions (Passe and Battaglia 2015, Kim 2014, Kaijima et al. 2013, Menacha-B and Glicksman 2008, Broderick and Chen 2001). The solutions can be summarized as: 1) numerical solutions; 2) interface development; 3) creation of guidelines.

Numerical solutions are the traditional type of CFD research focused on equation models. In architectural research, *Chen and Srebric* (2000) simplified the process of CFD by improving Reynolds Averaged Navier-Stokes (RANS) equation models and Large Eddy Simulation (LES) models. Similarly, Zhao et al. (2001) developed a new "zero equation turbulence model" which yields closer calculation results to experiments. With the enhancement of computing power, the numerical research boundary has extended to algorithms and computing systems. Zhang et al. (2010) suggested a prototype mesh generation tool for the CFD simulation of architectural projects; Zuo and Chen (2010) adopted the fast fluid dynamics (FFD) model utilizing the Graphic Processing Unit (GPU) for CFD simulation instead of the existing system based on the Central Processing Unit (CPU). Numerical solutions can reduce simulation time and enhance the simulation accuracy, thus, making CFD more palatable and accessible to architects.

Researchers have also developed various interfaces of CFD that are simplified and graphically oriented for architectural designers. Broderick and Chen developed a software package called Simplified CFD Interface (SCI). The purpose of the software development was to provide a "public domain program that allows architects and building engineers to use CFD without excessive training" (2001, 1). To create a user-friendly tool, the authors emphasized three elements that should be simplified: the settings for the boundary condition, the interface, and the compatibility with architectural graphic software. To achieve these goals, the authors reduced mesh options and set realistic default values for simplifying the boundary-setting process.

The efforts to develop a simplified interface have continued after the publication of the SCI. Malkawi et al. (2005) introduced a platform where CFD, Genetic Algorithm (GA), and visualization are incorporated. Their study adopted an "iterative approach" for supporting the design process (2005, 33). Moreover, Menacha-B and Glicksman developed CoolVent software that required only "bulk characteristics" of the building and allowed users to adjust the boundary conditions according to the type of the target site (2008, 133). In a similar context, Kajima et al. (2013) developed a toolkit for the visualization of CFD. In the toolkit, the authors attempted to connect CFD and architectural design software. Likewise, the Autodesk company released a built-in CFD feature in Revit software (Kfouri 2012).

Setting the best practice guidelines for CFD is also a solution suggested by researchers (Tominaga et al. 2008, Franke et al. 2010, Kim 2014, Den Hartog, Koutamanis, and Luscuere 2000, Schmid and Burrell 2004). Hartog et al. introduced CFD as a "new technique in building design" (2000, 165). After stating various possibilities for using CFD for indoor climate analysis, the authors explained each step of the simulation. Also, Schmid and Burrell (2004) explained basic information about CFD and described the procedure of the simulation with an example project. Both of these articles allowed readers to see the simulation procedure from a non-expert's perspective, thus, the articles could serve as CFD guidelines for architectural designers.

Expanding the range of CFD application, Tominaga et al. (2008) suggested a CFD guideline for simulations at the urban scale, which was adopted by the Architectural Institute of Japan (AIJ). Similarly, Franke et al. proposed a guideline for the simulation of urban environments, particularly for "micro-scale obstacle-accommodating meteorological models" (2010, 1). On the other hand, Kim (2014) used a qualitative approach to set up a CFD guideline specifically for architectural designers by utilizing Star-CCM+ software. Kim pointed out the lack of qualitative research on CFD and emphasized the necessity of guidelines enabling architectural designers to easily apply CFD in their projects. His immersive case studies demonstrated how the knowledge gained through literature review could be applied to real-world projects.

The literature in this stream shows that CFD-related studies in architectural research tend to consider the characteristics of the architectural design. For example, Broderick and Chen (2001) set the default values for the simulation to mitigate the uncertainty of the early-design stage. Malkawi et al. (2005) observed the iterations in the architectural design process and adopted an iterative approach for their algorithm. All these efforts demonstrate how the features of architectural design can be reflected in CFD-related research.

4.2. The application of CFD in architectural projects

CFD can support analysis of a built environment as well as decision-making in design. Researchers have conducted case-based studies to show these capabilities of CFD and have demonstrated realistic outcomes. In case-based research on CFD, indoor climate analysis linked with HVAC systems used to be the most prevalent topic. However, new movements in the architectural field have extended the scope of CFD-related studies to include particular subjects such as natural ventilation, vernacular architecture, and human interactions with indoor air. Outdoor CFD analysis and its application in the design decision-making process are also novel trends.

Indoor climate study has been a popular research topic since the emergence of CFD in architectural research. Sinclair (2001) studied the movement of fire smoke in an atrium space by using CFD to find fire-prone areas in the building. Ji et al. (2007) also worked on an atrium space, but focused on natural ventilation in the space. Asfour and Gadi (2008) simulated natural ventilation in a domed roof, a typical element in classical architecture. Kristianto et al. (2014) studied natural ventilation in the Minahasa traditional house in Indonesia by simulating airflow around its raised floor. In contrast to this trend, other researchers concentrated on heating and cooling systems rather than natural ventilation. Webb (2013) evaluated the Under Floor Air Distribution (UFAD) system of an office building by using CFD and energy simulation; Moustafa and Aripin (2014) tested a pottery water wall system for cooling a place in Luxor, Egypt. Taking another approach, Malkawi and Srinivasan (2005) included the users as a part of their simulation and measured human interactions with airflow in a built environment by utilizing CFD.

CFD outdoor airflow analysis is also a major trend in architectural research. For example, Gousseau et al. (2011) tested pollutant dispersion in downtown Montreal, and Montazeri et al. (2013) simulated the airflow around a 78m high-rise tower in downtown Antwerp to evaluate a façade design of the tower. Wu, Hung, and Lin (2013) studied the wind environment of a community space in a residential complex in Taiwan. By using CFD, Wu, Hung, and Lin proved that adding a plaza around the building perimeter would create more exterior cooling. In their research, the results of the simulation were used to support the authors' suggestion to design more open space for future projects.

Wu et al. (2011) also utilized CFD to detect a problem and suggest a design improvement. The authors simulated the air movement in and around Renzo Piano's Tjibaou Cultural Center building in New Caledonia. Then, the simulation results were compared to the diagrams drawn by the architect during the early stages of design. Wu et al. found that the airflow in the simulation was different from the diagram. Emphasizing the need for a more accurate tool to support the architectural design process, Wu et al. suggested an improvement to the Tjibaou Cultural Center design, which could change the airflow to the direction that the architect initially intended (2011, 2795). This study is notable because: 1) CFD simulation was compared to an intuitive, diagrammatic analysis; 2) CFD simulation was the catalyst to move from the problem identification to the design solution.

With a further movement toward the early stages of architectural design, Van Hoof et al. (2011) utilized their simulation results to set up a guideline for designing a stadium. The authors created twelve design options for the roof and stands of a stadium based on the Club AZ football stadium plan. Then, by using CFD, they measured the flow of the wind and the stand area wetted by the wind-driven rain to find an optimized shape for the stadium stands and roof.

In a similar context, Janssen, Bloken, and Hooff studied the influences of a high-rise building on the wind comfort of pedestrians in an urban setting. Based on field measurement data and CFD simulation results, the authors detected the points with a high probability of wind discomfort (2013, 1922). After determining the problematic points, they suggested adding a canopy to the building entrance, which could mitigate the discomfort. Providing the wind condition of each canopy design option, the authors utilized CFD to find the optimum size of the building canopy (2013, 1923). In this simulation, the authors removed the turbulence at the east pedestrian access by increasing the canopy size. Van Hoof et al. and Janssen, Bloken, and Hooff started to engage CFD in the creative design process, whereas the previous role of CFD was closer to an evaluation tool for existing conditions.

In recent research, architects tend to use CFD more actively in the design decision-making process (Kaijima et al. 2013, Guo, Liu, and Yuan 2015, Kozlovsky and Grobman 2017). Kaijima et al. (2013) introduced an experimental project that used CFD in the early stages of design. The authors designed a bus-stop canopy in Singapore, and by manipulating the shape of the canopy, they intended to generate a natural airflow. By utilizing CFD, Kaijima et al. optimized the shape of the canopy. While Kaijima et al. focused on the building form in relation to CFD, Guo et al. (2015) worked on space planning in interaction with CFD. The authors performed simulations for three space planning options for an art gallery in Guangzhou. Based on the simulation results, Guo et al. found the best design option for natural ventilation. In another example, Kozlovsky and Grobman (2017) applied CFD to their seawall design decision-making process. They contended that esthetics should be considered further in seawall design since seawalls are significant components in landscape and urban design as well as functional protectors from the sea. For them, CFD was a decision-making tool to find a design that met both functional and esthetic needs.

4.3. Trends of CFD applications in architectural research

The CFD-related research topics presented at the IBPSA international conferences from 1997 to 2015 were counted and categorized as shown in Table . In the table, the "support for the application of CFD" category includes simplification of the CFD modeling process and coupling with other tools. The studies in this category tend to focus on simplification of the simulation process by developing numerical methods, scripting, and interfaces. The "application of CFD in architectural projects" category includes testing conditioned or naturally ventilated environments, or specific façade and roof systems, as well as the decision-making process supported by CFD.

According to Table , the number of CFD-related research topics has been constantly growing. This growth has occurred mainly due to the increase of case-based research in which CFD is applied to evaluate architectural systems or projects. While the analyses of indoor and outdoor environments are the mainstream of case-based research, the recent emergence of design decision-making research is remarkable.

This table has limitations in that it is based on one data source and that relevant studies having a title or abstract without any of the selected keywords could be excluded from the count. Therefore, the counted numbers in the table cannot be considered absolute, rather, this table is intended to provide an overview of the research trends when comparing the numbers relatively.

Table 1: The number of CFD-related topics presented at the IBPSA international conferences from 1997 to 2015.

Year\Topic	Application of CFD in Architectural Projects	Total

	Support for Application of CFD	HVAC System	Indoor	Outdoor	Building Envelope	Design Process	Total	
1997	2	1	2	0	0	0	3	5
1999	2	0	0	2	0	0	2	4
2001	6	0	0	0	0	0	0	6
2003	5	1	1	2	1	0	5	10
2005	3	3	2	2	2	0	9	12
2007	4	0	4	4	2	0	10	14
2009	4	0	4	4	0	0	8	12
2011	4	2	6	2	0	3	13	17
2013	4	1	7	7	0	0	15	19
2015	4	1	4	4	2	3	14	18

5.0. CONCLUSION

CFD-related research in the architectural field has been evolving during the last decade. When CFD was introduced, it was largely situated within the discipline of engineering and not intended to be accessible to most architectural designers. However, the interaction with architectural design has expanded the boundary of the research. As a result, the current CFD-related research tends to be more interdisciplinary, and closer to architectural design practice. The research trends dealing with the simulation process itself have developed from a focus on numerical methods to include additional topics such as simplified interface development. Similarly, indoor climate research utilizing CFD has been diversified with studies that simulate vernacular buildings along with studies that address other emerging issues in the architectural field. Furthermore, the improvement of computing power enabled researchers to expand their study area to include CFD outdoor analysis, allowing iterative building designs to be tested through simulation. As in the study by Janssen, Bloken, and Hooff (2013), the increased interaction between CFD and architectural design brought about the involvement of the simulation results in the design decision-making process. In other words, the trends of CFD-related studies in architectural research have been expanding from quantitative to qualitative across the boundary of engineering and architectural design. Figure 1 summarizes these general trends of CFD-related research in the architectural field.

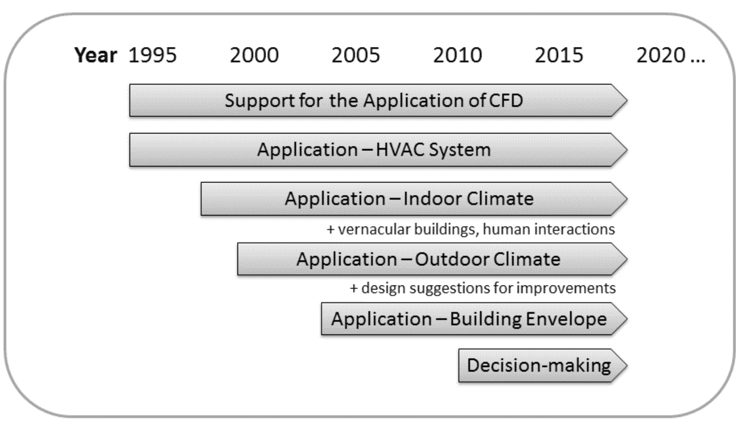

Figure 1: The expansion of CFD-related research areas in the architectural field.

These research trends show the potential of CFD as a tool for the early stages of design. Different from the conventional practice of using CFD to evaluate completed designs, these trends imply that CFD may be actively involved in the design decision-making process. The involvement of CFD may change the flow of the architectural design process as well.

In summary, we attempted to identify the major trends of CFD-related research in the architectural field by conducting an in-depth literature review and by analyzing the streams of relevant conference publications. Questioning how CFD research trends interact with architectural design practice, we found that the needs of current practice were reflected in the evolution of the research trends. Moreover, the boundary of the research has expanded to include early-design considerations, showing the potential of CFD as a tool for the early stages of design. As a future research direction, this paper could be improved by collecting data from further conferences, or could be developed into recommendations in connection with building codes.

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Joon-Ho Choi, Xiaoxin Lin, Marc Schiler

Investigation of A Real-Time Change of Human Eye Pupil Sizes Per Visual Sensation Condition

Investigation of human eye pupil size as an indicator of visual sensation

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Abstract: Lighting is the most crucial factor impacting an occupants' visual comfort in a building environment. However, most prevailing current lighting guidelines deriving from empirical values are designed primarily for paper-based tasks, rather than computer-based. In many cases, present guidelines have been reported that there is a limitation to meet the needs of a user's new task types. Above all, existing technical tools also have a limited function to evaluate a user's real-time visual perception which can be applied as an indicator to control a building lighting system. This research estimated each participant's visual sensations by analyzing pupil sizes and their change patterns since the human body have the physiological regulation ability which naturally minimizes the adverse effects of the surrounding environment on the human body. This study adopted a series of human subject experiments which were performed in an environmental chamber of USC. Based on a computer-based task which is most commonly performed in current offices, various ranges of ambient lighting parameters, including luminance (cd/m^2), illuminance (lux), contrast ratio, and UGR, were generated and controlled while each subject's pupil sizes were recorded. The experimental result data were statistically analyzed to identify a relationship between human visual sensations, lighting parameters, and also pupil sizes by ethnic origin and myopia condition. The research outcomes showed the potential use of pupil sizes for estimating an individual's visual sensationand confirmed the principle as an applicable technology to integrate an environmental design and control system with the help of a real-time sensing device.

1.0 Introduction

In the contemporary society, people in America spend about 9/10 of time in the built environment (Codasco E, Demeter S.1995). Hence, the quality conditions of indoor environment become more significant than ever before. The work productivity and environmental health of occupants in a building are largely influenced by perceived sensations on the environment and ambient conditions, such as conditions of acoustic comfort, air, lighting and thermal (Choi J-H, Loftness V, Aziz A. 2012). Among those factors, the one that exerts the most significant impact on the visual comfort and sensation of an occupant is visual quality, since it is susceptible to and affected by the instantaneous impact's quality of lighting on users (Illuminating Engineering Society of North America 2010). According to some researchers, the percentage of occupants in buildings who are exposed to improper lighting conditions amounts to 65% (Irlen H. 2005). Those defective conditions, consequently, could lead to visual stress and glare problems in the environment of a workplace and potentially result in physical symptoms (like a headache and eye fatigue) and lower working efficiency. Therefore, proper lighting condition is of great importance to ensure the healthy state of occupants in a building and protect them from disease or injury related to eyes. The existing design guidelines, such as the IESNA (Illuminating Engineering Society of North America), have been developed by empirical and experimental methods in monitored lab tests; while those recommended guidelines are mostly for tasks that are paper-based instead of computer-based. Their application could cause unnecessarily high lighting intensity in a computer-based task work environment, which is the most prevalent condition in today's workplace. In addition, visual perception in relation to prevailing multi-screen workstation environment should also be taken into account. Discomfort resulting from contrast ratios and glare problems in the user's field of view from the inappropriate placement of monitors can also considerably impair on a person's productive capacity and a general sense of well-being in the work-space (Andrew Scott Linney 2008). More importantly, no functional characteristics of those existing technical tools can evaluate the real-time visual sensation of a user in a workplace that could be applied to lighting control system. All these defects may limit the successful adoption of current guidelines for application in real industry.

The questionnaire for visual comfort is a good way to evaluate the visual satisfaction. However, one weakness of this method is that it is a subjective way. An objective way to quantitatively evaluate the visual satisfaction should be considered. According to the biomedical research about the human body, the autonomous nervous system can naturally assist the body to react properly to minimize any perceived environmental stress. As part of the push/pull of the autonomic nervous system, the sympathetic and parasympathetic systems can control the pupillary dilator and sphincter muscles, which work together to control pupil size (Cassin B. 2011). Much literature has studied the potential of using pupil size. Some have supported the relationship between pupil sizes and visual sensationsand reports that pupil sizes vary physically depending on human physiological characteristics (Berman S, 1996; Green DG 1980). Several research projects have identified pupil size is related to different visual objects, such as wall color and illuminance (Winn B. 1994; Berman S. 1997; Choi J H, Zhu R. 2015). Some have analyzed the pupillogram can be performed easily to produce a real-time assessment of the subject's alertness (Morad Y, 2000). Therefore, by utilizing this mechanism, this research identified a relationship between human visual sensations, lighting parameters, and pupil size by adopting pupil size as a physiological signal which response to the real-time lighting condition. The final result of this research could be considered as a valuable reference for real-time lighting control in the human-building integration domain.

2.0 Methodologies

2.1. Human subject experiments

The author conducted a series of human subject experiments in an environmental chamber at University of Southern California (USC) campus to evaluate the relationship between human pupil sizes and visual sensation. The USC Internal Review Board (IRB) Office approved this study, and a total of 10 people were selected as voluntary human subjects for this experiment. Participants were recruited through flyers and electronic postings, most of them are on-campus students. Because of the diversity limitation of the campus population, the demographic information of subjects shows some limitations. Therefore, to get as unbiased results as possible, efforts were made to balance the sample sizes by critical human factors of visual sensation when created data pool, including gender, age, ethnic origins and glasses-worn condition. Table 1 listed the demographic information about participants. The questionnaire was adopted in this experiment to collect each subject's visual sensations at the end of each step of lighting condition. The subject was asked to report his or her visual sensation on a 7-point scale survey. It consisted of seven options ranging from "very dark (-3)" to "very bright (+3), with a "neutral" (0) mid-point.

Table 1: Demographic information about human subjects

	Gender		Age		Iris Color		Glass-worn	
	Male	Female	<25	≥25	Blue	Brown	Yes	No
Sample No.	4	6	7	3	2	8	5	5

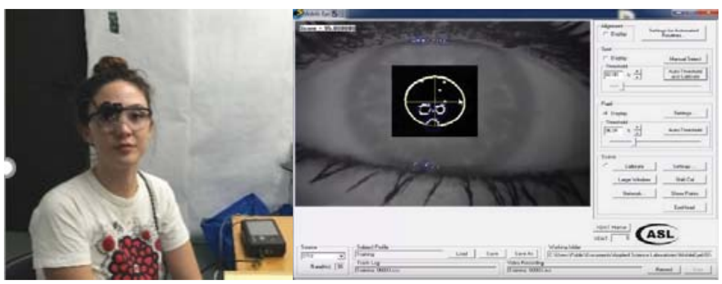

Figure 1 : Photo of subject wearing the pupilometer and the software for pupil size data collection

2.2. Environmental chamber settings

The experiment will be carried out in the environmental chamber at USC watt hall, located on the basement floor. This physical condition allows producing the experimental desired lighting condition more ideally by using installed LED bulb since there is no influence of daylight. The size of the entire chamber is 112"x120"x95", very close to the size of an ordinary workplace, which is the experiment environment wanted to be simulated. To obtain consistent environmental conditions, the ambient thermal, acoustic and air quality conditions were carefully controlled throughout the experiment. The air temperature, relative humidity, acoustic condition and CO_2 during the experiment were ranged from 24.5 ± 0.5℃, 32 ± 2.5%, 30db and 610 ± 35 ppm, respectively.

2.2.1 Illuminance Level

The chamber was equipped with 30 units of 9W 730 lumens dimmable LED light bulbs on the ceiling surface. LED light exerted no impact on the thermal environment of the laboratory since it does not generate thermal radiation. The color temperature was set around 5000 K, which is very common in the daily work environment and the generated lighting intensity on the workstation surface ranged from 50 lux to 1400. The illumination adjustment can be achieved using an analog regulator with an illumination interval of 150 lux, which is the minimum perceptible illumination change demonstrated in the previous study (J.-H. Choi, Zhu, and Johnson 2013). The average luminance was also considered in this experiment and measured by Photolux 2.1. The estimated correlation index was 0.99, with a p-value equals to 0.000. Since there is a strong linear relationship between average luminance and illuminance, all luminance data were given by using the illuminance measured during this experiment.

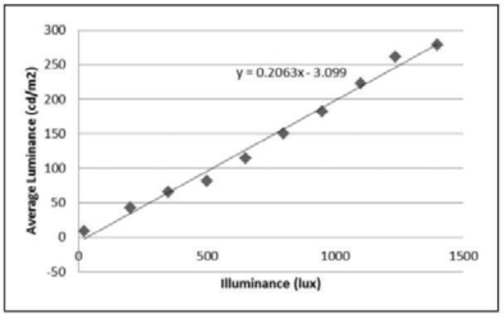

Figure2: The correlations between average luminance of the illuminance and the experimental settings.

2.2 Contrast Ratio and UGR Value

In this experiment, the TV was set as glare source that imitate expansive glass window in the office environment. Due to the improper placement of the workstation, these large glass windows can cause strong glare problem during sometime of the day since a lot of direct sunlight get through. The contrast ratios for visual comfort refer to the contrast between the task area luminance and glare source which is TV screen located right behind the task computer screen. The glare is defined by Unified Glare Rating (UGR) value which is an indication of the extent to which light sources cause lighting from a certain position from the user. The contrast ratios and UGR value used were determined by measuring the luminance of the computer screen, TV and surrounding surfaces (e.g., walls) using fish-eye lens camera (Model: Nikon Coolpix 8400). The luminance of the computer screen was calculated by Photolux software and set constant at a measured luminance of 75 cd/m^2. A number of extensive studies concluded that a luminance ratio of 3:1 between the task & nearby surroundings is desirable for visual comfort (Osterhaus, 2002). Generally, the UGR values are defined in steps of 13, 16, 19, 22, 25 and 28. The UGR limits of lighting products for various environments that should not be exceeded 16 for technical drawing and 19 for reading, writing, training, meetings, computer-based work (Liht 2016). The experimental settings should be able to validate the rationality of the recommendations. Based on this principle, also considered the actual situation of the laboratory, the result of the realizable contrast ratio was picked as 1/4.25, 1/1, 6.4/1 and UGR values were 18.1,12.2 and 14.7, respectively.

Table 2: realizable contrast ratio, related parameters and TV settings

NO.	Contrast ratio	Laptop luminance (cd/m^2)	TV luminance (cd/m^2)	TV Darkness	UGR
1	1/4.25	75	318	12%	18.1
2	1/1	75	73.2	60%	12.2
3	6.4/1	75	11.6	Turn off	14.7

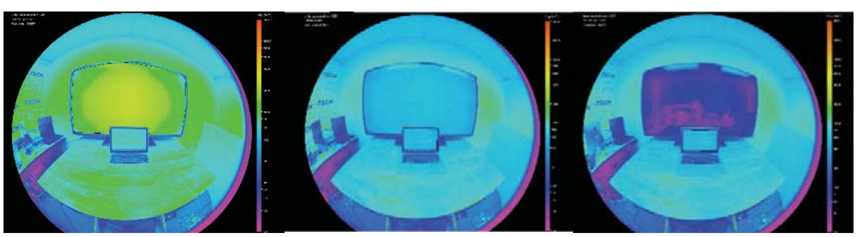

Figure 3: TV and computer screen luminance false color
(contrast ratio of computer screen to TV: a. 1/4.25; b. 1/1; c. 6.4/1)

2.3 Experimental Apparatus

Multiple sensory devices were selected to measure data for the human subject experiment. A mobile pupillometer was selected to measure and record a subject's pupil sizes change automatically (Model: Mobile-Eye, manufacturer: ASL). The device is a wearable sensor, combine two high-resolution digital cameras, one that records the scene image and the other, the participant's eye. These images and data recorded are then integrated into two documents, a single video recording and an excel document recording participant's pupil size 30 times every second. For the study, sensing frequency was set at one second to find significant changes in pupil sizes. Illuminance data were measured by light meters (Model: HHLM-2) which equipped on the surface of the table in the middle which is the main point of people's visual range.

2.4 Experimental Procedure

The experiment consists of three rounds of experiments and only one subject at a time. One fixed contrast ratio was set in each round experiment as illuminance level changed from 50lux to 1400lux with a 150lux interval. See the previous section for specific parameter settings. During the experiment, the light was changed from dark to bright gradually; this procedure is also known as light adaption which usually only takes human eyes less than 1 minute to adapt to the new lighting condition. Thus, each illuminance level step was designed with 2 minutes for stabilization and 1 minute for data collection. The whole experiment lasted one hour and thirty minutes, all data, such as illuminance, pupil size will be automatically recorded by the devices. The subjects were assigned some simple computer-based work during the test, such as reading and typing, at the end of each illuminance level changed; the subject was required to report his or her visual sensation by filling the 7-point scale questionnaire which mentioned in 2.1. All choice should be made based on subjects' perceptions about the lighting condition during the final 1 min. Overall procedures illustrated in figure 4.

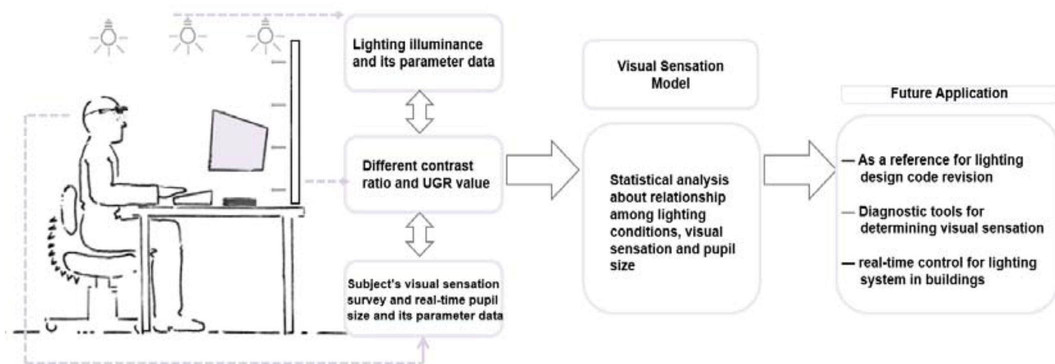

Figure 4: Procedures for data acquisition, expected outcomes and potential applications

3.0 Results and Discussion

3.1. Pupil Size per Sensation by Contrast Ratio

To examine the effect of the different contrast ratio on pupil size changes per visual sensation, each subject was asked to perform a comparative test under different contrast ratio lighting conditions while remaining other conditions unchanged. Figure 5-7 illustrated pupil size difference per sensation by three different contrast ratios, 1/4.25,1/1, 6.4/1 respectively. Overall speaking, compared the same level of a visual sensation among three different contrast ratio group, the average pupil size increases with the reduction of the background screen brightness. For example, the average pupil size is around 62 pixel for sensation 'very dark' (-3) when the contrast ratio is 1/4.25. By contrast, the average pupil size is around 65 and 69 pixels when the contrast ratio is 1/1 and 6.4/1 respectively.

The t-test of the pupil sizes of very dark sensation (-3) between 1/4.25 contrast ratio, 1/1 contrast ratio and 6.4/1 contrast ratio group revealed a p-value of 0.000,0.858 and 0.000 respectively, which the mean of 1/4.25 contrast ratio group significantly differs from the other two group. The one-way analysis of variance (ANOVA) test showed a statistically significant p-value that was lower than 0.05 for each group. Visual sensation could be more directly recognized as 'dark' which grouped -3, -2 and -1 level, 'neutral' which is 0 and 'bright' which included 1,2 and 3 level. The interval lines are distinct from each other, and the length of neutral sensation and bright sensation are much shorter than dark sensation, which indicates that pupillary dilator and sphincter muscles have greater adjustment range in order to find suitable pupil size in the dark compared to neutral and bright environment in which the pupil size is more stable.

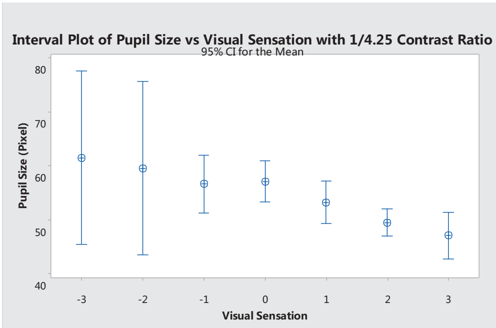

Figure 5 Interval plot of pupil size per visual sensation to 1/4.25 contrast ratio

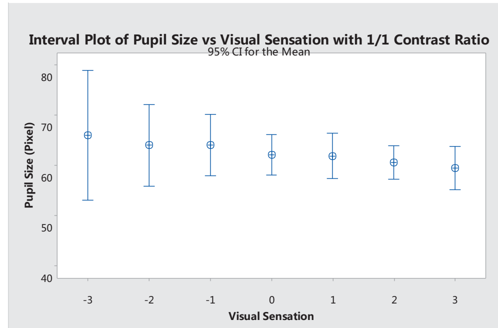

Figure 6 Interval plot of pupil size per visual sensation to 1/1 contrast ratio

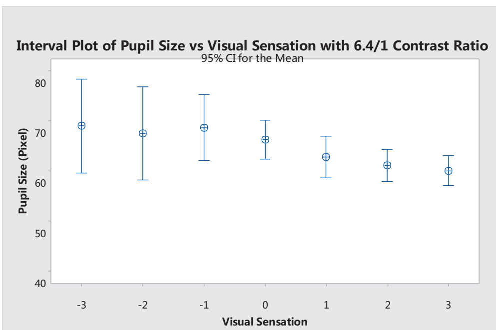

Figure 7 Interval plot of pupil size per visual sensation to 6.4/1 contrast ratio

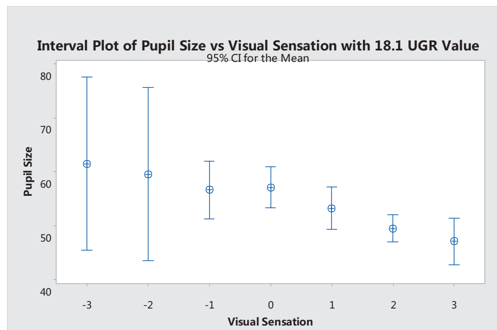

Figure 8 Interval plot of pupil size per visual sensation to 18.1 UGR value

3.3 Pupil Size per Sensation by UGR Value

The study also compared the pupil size change patterns by different UGR value. Figure 9-10 illustrated pupil size difference per sensation by three different UGR values, 18.1,12.2, 14.7 respectively. Although the analysis of variance (ANOVA) tests of all groups show p-values lower than 0.05, which means statistically significant, the actual differences in pupil sizes between visual sensation levels in the 12.2 UGR value and 14.7 UGR value group could be more difficult to detect in reality compared to 18.1 UGR group. In other words, pupil size is more stable with lower UGR value.

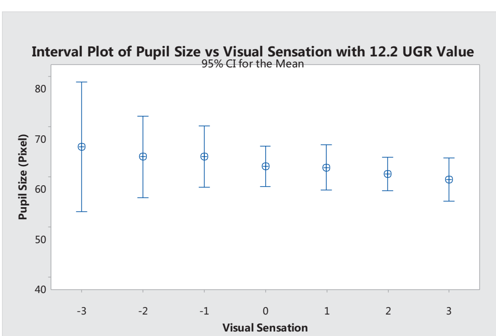

Figure 9 Interval plot of pupil size per visual sensation to 12.2 UGR value

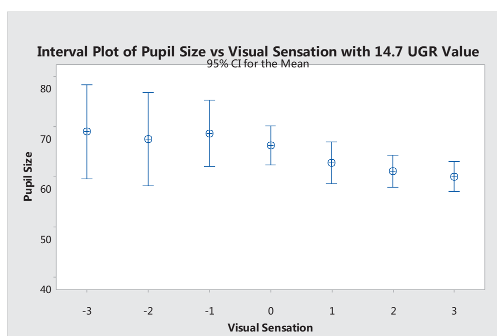

Figure 10 Interval plot of pupil size per visual sensation to 14.7 UGR value

4.0 Conclusion

As an early study, this research conducted a human subject experiment with ten subjects in an environmental chamber and investigated the differences in pupil sizes caused by different visual sensations due to varied contrast ratio and UGR values. Overall, significant differences in pupil sizes with various visual sensations could be told when grouped by contrast ratio and UGR value as well. Since it is a prerequisite for lighting control to distinguish different visual sensation through pupil size changes, these findings indicated that pupil size has the potential to be a viable indicator of preferred lighting conditions.

For each contrast ratio group, the adjustment range of pupil size is always greater in the dark compared to a bright environment. Compared to three contrast ratio group, the data showed that the adjustment range of pupil size reduced as the contrast ratio narrowed down between backlit and task screen. The amplitude range is relatively minimal when the backlit turned off. The adjustment range of pupil size was significantly greater in the dark than in the other two groups the when contrast ratio was 1/4.25. This also happened in the group UGR value equaled to 18.1 which is very close to the upper limit value 19. The eye requires a greater range of adjustment of the sphincter to achieve the proper pupil size, which may be one of the factors leading to eye fatigue. Also, there is no statistically significant difference between 1/1 contrast ratio and 6.4/1 contrast ratio group. Therefore, recommended contrast ratio range mentioned in chapter 2.2 have certain rationality based on the discussion above.

In addition, considering that this is a human subject experiment, the representativeness of the sample should always be taken into account. However, subjects selection was limited by campus population as shown in table 1. Therefore, future studies should include additional experiments on large samples and a balanced population of subjects.

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A Study of Validation on the Current POE Method by Using A Case Study in Southern California

A study of validation on the current POE method by using a case study in southern California

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ABSTRACT:
Post-occupancy evaluation (POE) is an architectural building evaluation tool that aims to improve indoor environmental quality and building performance using comparative metrics. POE has been performed to develop a better quality of human life through improving user satisfaction, productivity, and better matching of building design functions and occupants' needs. Despite the limitations of POE research due to its significant dependence on subjective user satisfaction surveys. researchers have developed methods that combine environmental datasets that integrate an occupant's satisfaction with real IEQ data. While these efforts have enhanced POE methodology, it still is limited by one-time data collection that is unlikely to adequately take varying degrees of human environmental perceptions into consideration in a manner that is consistant and reliable. Nevertheless, what distinguishes this study is the use of advanced POE testing, which uses multiple data collection methodologies to validate the current POE method and identify the potential necessity of an improved method. A modern office in Southern California was chosen as a testbed office to conduct plural occupant satisfaction surveys and on-site measurements were simultaneously made during two months. A statistical analysis of the aggregated data was conducted with consideration of various categories such as time differences and human factors. The result of this analysis revealed that the occupants experienced different levels of environmental satisfaction at different times even though environmental conditions at their workstations remained consistent, or only marginally changed. In addition, human factors, such as age and gender, indicated a significant relationship between occupant satisfaction and changes in human IEQ perceptions. These findings suggest a comprehensive approach is recommended to diagnose current space diagnostics and to provide optimal design solutions that boost users' well-being in a working environment.

KEYWORDS: Environmental comfort; Occupant well-being; Data acquisition; Healthy environment; Human factor

INTRODUCTION

Indoor environmental quality (IEQ), which includes air quality, lighting, acoustic and thermal comfort, has a significant impact on a building's user's health and productivity (Loftness et al. 2006). Due to its importance, various standards and guidelines have been suggested by building industry professionals to maintain a high quality of IEQ (Choi, Loftness, and Aziz 2012; Abbaszadeh et al. 2006). Post-occupancy evaluation (POE), as the primary methodology in the IEQ research domain has been used for several decades to understand and improve the quality of indoor space. Moreover, POE helps evaluate the IEQ and performance of buildings after construction is complete and been occupied for some time(Preiser 1995; Preiser et al. 2001; Watson 2013).

As a main method of POE, occupant satisfaction surveys have been used to identify significant relationships between IEQ components and user satisfaction. Kim (Kim and de Dear 2012) revealed that there are not linear relationships between individual IEQ factors and overall user satisfaction based on the analysis of the survey data. The study analyzed 43,021 respondent samples (from 351 different office buildings) that had been extracted from the database and suggested the categorization of IEQ factors. Altomonte (Altomonte, Saadouni, and Schiavon 2016) investigated occupant satisfaction in a BREEAM-Certified office building, comparing it with that in a Non-BREEAM-Certified building also shows noticeably lower IEQ satisfaction when occupants spent more than 24 months at the BREEAM office.

Due to significantly advanced sensing technologies, it is possible for current POE research to strengthen its validity by adopting multiple IEQ measuring sensory devices. Liang (Liang et al. 2014) investigated the improvement of IEQ condition in green office buildings in Taiwan by comparing occupant's environmental satisfaction survey with monitored IEQ components. In addition, Choi's recent study (Choi and Moon 2017) suggested an advanced POE method that integrates IEQ measurements of buildings and user's response of environmental satisfaction. The study collected 411 IEQ data from 14 different buildings to better diagnose the impact of IEQ factors on user satisfaction. Moreover, his study also illustrated an advanced data mining result that suggested an IEQ design guideline be created based on specific IEQ and human factors.

Although the current scientific trend in POE research has overcome one of the crucial limitations by combining survey data with IEQ measurement, it still primarily depends on one-time data acquisition instead of continuous monitoring. This limitation may affect the result of POE research and make it unreliable because it does not consider a time-varying occupant environmental perception. Since a user's environmental perceptions and behaviors are sensitively affected by dynamically changing indoor and outdoor conditions, it is difficult to fully accept these one-time data collections.

To minimise the uncertainty that one-time data acquisition gathering engenders, this research suggests the need to revise the common POE method into a more advanced method that performs data collections multiple times, continuously if possible. A revised method considers the fact that humans can be sensitive to time functions and the ambient environment because of their bio-rhythms. Instead of fully depending on one moment in time for the measurements and survey, a series of on-site measurements should form a database in which statistical and comparison analyses are conducted.

METHODOLOGIES

To overcome the limitation of current POE method, the study suggested an advanced POE method, which adopts plural data acquisition, to consider the potential variety of occupant's environmental satisfaction depending on measurement timings. In order to test the developed POE method, an office environment in a modern building in Southern California was selected as a sample office where data collection was repeatedly conducted. The office is located in the City of Irvine in climate zone 8 as established by the California Energy Commission. It is an office with an open floor plan and located on the ground level. As shown in Fig. 1, several private offices are located on two sides of the perimeter zone, therefore the data collection was mainly collected from workstations rather than the small private rooms. Two types of datasets were measured and collected from selected workstations: the first dataset was acquired through the on-site measurement of IEQ conditions (including temperature, acoustic level, illuminance, and air quality) at each selected workstation. Secondly, a user satisfaction survey was completed at the same time as the IEQ measurement to observe the occupant's environmental comfort. The data collections were performed from April to June to remove a seasonal impact on occupant's perception with no significant climate variations.

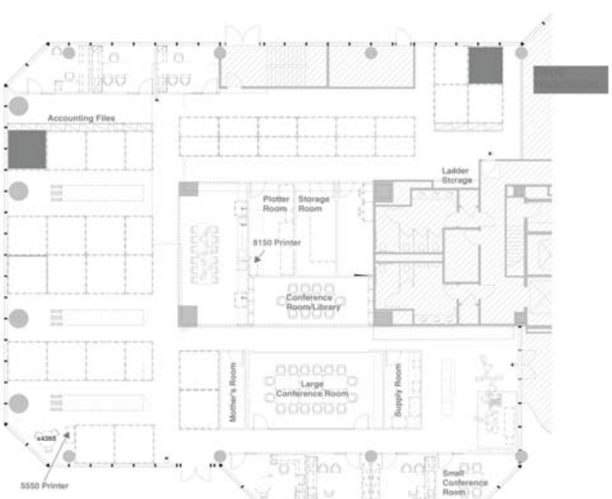

Figure 1: The plan of a selected office building. Source: (Glumac Irvine)

In total 39 datasets were collected from the sampled workstations. To identify the distribution of the collected data, the entire dataset was categorized into key factors such as month and human factor. As shown in Table 1, a total of 22 datasets and 17 datasets were collected in April and June respectively. In April, 15 male and 7 female occupants and their workstations were surveyed and measured, while 9 males and 8 females participated in June. In total, 15 users were categorized in the Junior group (18 – 29 years old), 16 in the Mid-age group (30 – 49 years old), and 8 in the Senior group (50 – 59 years old).

Table 1: Demographic Information of Occupants in Research.

		April			June			
Age group	Age	Female	Male	Total	Female	Male	Total	Total
Junior	18-29	3	6	9	3	3	6	15
Mid-age	30-49	3	6	9	2	5	7	16
Senior	50-59	1	3	4	3	1	4	8
Total		7	15	22	8	9	17	39

IEQ MEASUREMENT

IEQ measurements including lighting, air quality, thermal, and acoustic were performed with two types of sensing devices to diagnose the environmental quality of each workstation. The first device is the USC IEQ cart (named "e-BOT") that is equipped with various sensory devices which measures the temperatures at four different levels with respect to the floor, relative humidity, carbon-dioxide (CO_2), and background noise. The cart also consists of air quality sensors that measure particulate matter (PM) and total volatile organic compounds (TVOC) at the height of 1.2 m (Fig. 2). In addition to the sensing cart, several hand-held sensors and a high dynamic range (HDR) camera were included to measure air velocity, illuminance, radiant temperature, and unified glare rating (UGR) at each workstation.

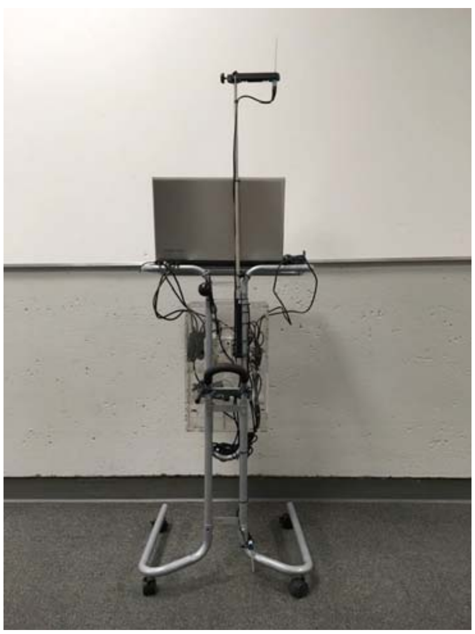

Figure 2: Indoor environmental quality measurement cart (e-BOT). Source: (USC Human-Building Integration Lab)

Table 2 summarizes the current industry standards/guidelines which indicate a comfortable range for each IEQ factor; these suggested standards have been adopted as a baseline in this study.

Table 2. Summary of adopted IEQ standards.

Variables	Guideline
Temperature floor ('C)	between 19 and 29 'C (ASHRAE 55)
Temperature 1.2m ('C)	between 23.3 and 27.8 'C (ASHRAE 55)

Vertical Air Temperature Difference ('C)	less than 3 'C (ASHRAE 55)
Radiant Temperature Asymmetry Ceiling ('C)	less than 5 'C (ASHRAE 55)
Radiant Temperature Asymmetry Wall ('C)	less than 10 'C (ASHRAE 55)
Relative Humidity (%)	65 % or less (ASHRAE 62)
CO2 level (ppm)	less than 1000 ppm (ASHRAE)
Work surface illuminance (lux)	between 200 - 500 lux (ANSI/IES RP-1-12)
Unified Glare Rating (UGR)	between 13 and 19 (CIE)
Acoustic decibel (dBA)	less than 40 dBA (ASHRAE)

SATISFACTION SURVEY

A paper-based survey was designed based on the Cost-effective Open-Plan Environments (COPE) environmental satisfaction questionnaire developed by the National Research Council Canada to support the COPE project (Newsham 2003). Based on the COPE, this study customized multiple questions to fit the research direction and goals. The survey consists of 29 questions regarding the satisfaction level of several IEQ components and spatial elements. The survey adopts a 7-point scale: -3: very dissatisfied, -2: dissatisfied, -1: slightly dissatisfied, 0: neutral, +1: slightly satisfied, +2: satisfied, +3: very satisfied.

STATISTICAL ANALYSIS

The dataset was categorized by selecting measurement time and human factors such as age group and gender. A two-sample T-test and analysis of variance with a 95% confidence level was adopted to identify the difference of user's satisfaction between two times ("Why Should I Use a 2-Sample T-Test?" 2017).

RESULTS

Table 3 illustrates a summary of measured IEQ data by using the statistical analyses of the various components of IEQ. Overall, the data were found to be mostly within the comfort zone of each IEQ element. However, 32% and 41% of the temperatures measured at the height of 1.2m were out of the recommended range. The relative humidity levels and CO_2 concentrations fall within the comfort zones, and their variations were not significant between the selected two months. The work surface illumination, UGR, and Acoustic decibel were notably outside of the recommended guidelines. The average illuminance levels in April and June were 173.9 lux and 136.6 lux respectively, which is lower than the guideline's minimum level by approximately 50 lux. UGR indicates 44% of the workstations were within the recommended comfort range. However, there was a slight improvement in lighting quality between the two different months. The mean value of the acoustic decibel was 62 dBA, which is higher than 40 dBA, the maximum level suggested by the ASHRAE.

Fig. 3 illustrates an average score for the occupants' responses to environmental satisfaction survey questions. The survey adopted a 7-point scale which ranged from -3 (very uncomfortable) to +3 (very comfortable), with "0" for neutral. In general, most of the criteria reaches a positive value of satisfaction, nevertheless the satisfaction levels of noise from other people, the operability of thermostats, and accessibility to views were relatively lower than the other factors. Moreover, the patterns of linear lines are significantly similar except for some specific criteria. In addition, statistical analysis revealed that some human factors, such as gender and age, seemed to affect the environmental satisfaction levels of respondents. A detailed discussion is available in Section 4.

Table 3: Summary of measured IEQ data by month.

	April			June		
Variable	Mean	StDev	Within guideline	Mean	StDev	Within guideline
Temperature Floor ('C)	23.02	0.419	100%	23.13	0.194	100%
Temperature 1.2m ('C)	23.31	0.378	68%	23.30	0.197	59%

Vertical Air Temperature Difference ('C)	0.302	0.195	100%	0.214	0.096	100%
Radiant Temperature Asymmetry Ceiling ('C)	0.741	0.733	100%	0.252	0.267	100%
Radiant Temperature Asymmetry Wall ('C)	1.573	1.466	100%	1.035	0.657	100%
Relative Humidity (%)	50.73	1.893	100%	57.58	0.531	100%
CO2 Level (ppm)	726.8	66.6	95%	660.2	29.04	100%
Work Surface Illuminance (lux)	173.9	203.6	14%	136.6	78	18%
UGR	11.41	4.117	41%	12.13	4.053	47%
Acoustic Decibel (dBa)	62.64	3.783	0%	62.36	2.441	0%

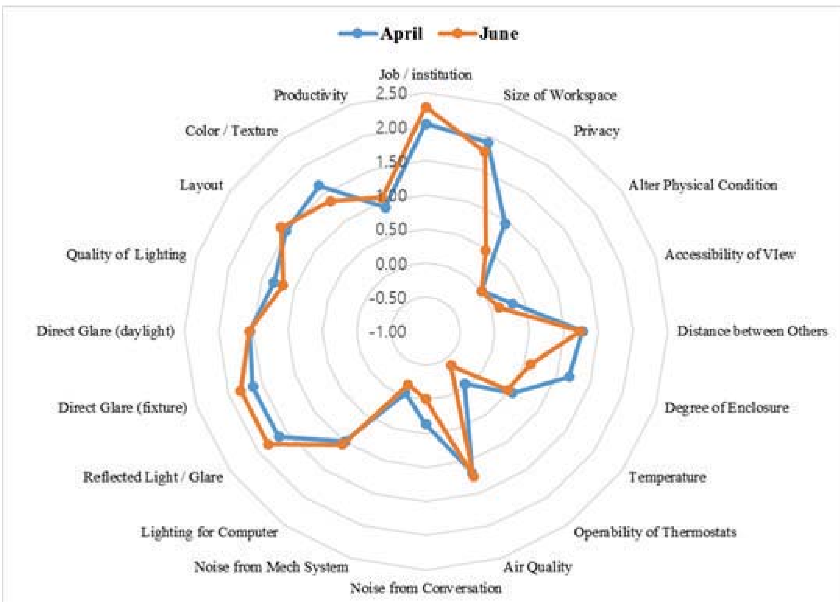

Figure 3: Rose chart of survey question by month.

DISCUSSION

As discussed in the previous section, there was a significant change in an occupant's environmental perception of specific IEQ criteria. According to statistical analysis, the differences of an occupant's satisfaction was statistically significant while their indoor environment was relatively consistent. In addition, human factors such as age and gender were observed to directly affect the users' environmental perception.

The first finding illustrates the impact of gender on an occupant's thermal perception. Fig. 4 (left) shows female occupants' response about Q13, which is about the same satisfaction level as the thermal condition. Female users were significantly more satisfied with their thermal environment in June than in April. A p-value was 0.079 which is statistically marginally significant. In general, females reported neutral or positive satisfaction in June, while they were unsatisfied with their thermal condition in April. However, unlike users' feedback, the actual temperatures were relatively similar between two months. As illustrated in Fig. 4 (right), the temperatures at the working level (1.2m) were almost consistent between the two months, although the distribution of April's data is wider than June's. Moreover, since the mean value of two datasets were nearly the same and the range of April's data is within 1.2°C, those two datasets differences are not statistically significant. This comparison reveals that the female group might have higher sensitivity to thermal condition because of physical and/or psychological factors, even though the variation of temperature was relatively small. Also, external factors, such as time function and weather conditions might affect a female's thermal satisfaction.

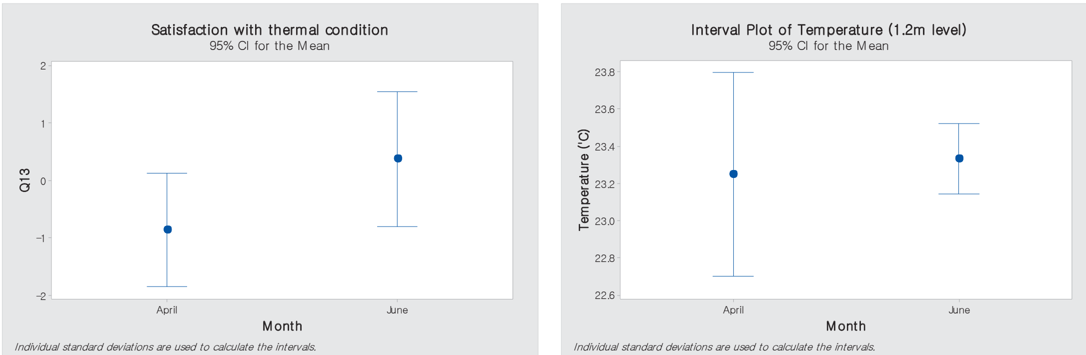

Figure 4: Comparison of the confidence interval of thermal quality satisfaction of each month (left) and measured temperature at 1.2m level (right) (Female group only).

The second analysis revealed that the age group also had an impact on users' satisfaction. According to the analysis, the age group between 18 to 29 years old showed significantly different responses to acoustic conditions as compared to answers from other age groups. As illustrated in Fig. 5 (left), the junior age group had a notably different satisfaction level for each of the two months with a p-value of 0.026. Occupants in the junior age group were neutral or marginally satisfied with their acoustic condition in April. However, they mostly had negative responses to the ambient acoustic environment in June. Despite the variation of users' answers regarding the acoustic condition, the collected acoustic data illustrated a constant distribution. Fig. 5 (right) illustrates that the distributions of both months are similar with no significant difference. Moreover, the acoustic levels were stronger than the industry standard, which is 40 dBA for the open-plan office. In conclusion, the junior age group's acoustic perceptions seemed to be easily influenced by other environmental factors. In addition, this age group showed various acoustic satisfactions, even when their background noise levels were consistent. Since the acoustic conditions were measured in dBA for sound pressure level, it is hard to define which specific frequency ranges of the sound source affected the acoustic satisfaction of the junior age group. Therefore, it is recommended to collect detailed sound pressure levels per acoustic frequency to better understand the impact of background noise on an individual's acoustic satisfaction.

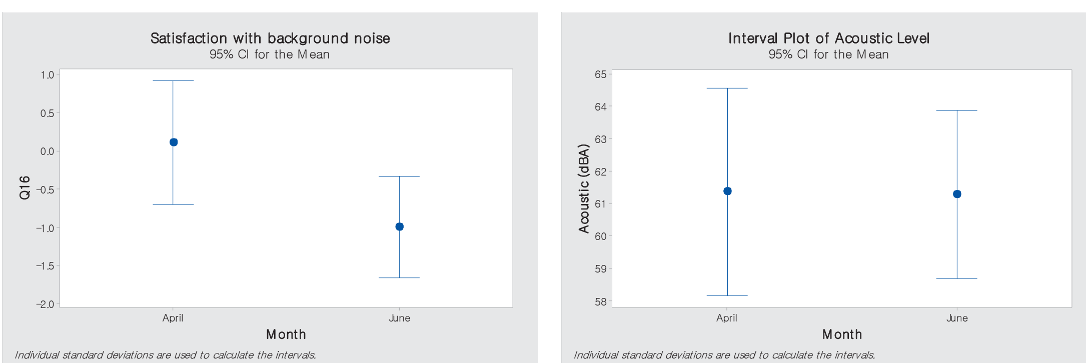

Figure 5: Confidence interval of monthly acoustic quality satisfaction (left); measured acoustic level (right) (Age group 18-29)

CONCLUSION

This research was conducted to identify the potential usage of a revised POE method that better integrates the time function of IEQ measurement in an office environment. In general, the collected IEQ data in a sample office were relatively consistent at the two measured times of April and June. However, this study revealed that the female group was more satisfied with their thermal condition in June than April, while the actual temperatures of the office were almost same during the two months. Moreover, the junior age group showed a higher acoustic satisfaction in April than in June, while the actual sound conditions had no significant difference. Findings of this case study assessed an idea that occupant's environmental satisfaction can change, depending on human factors and/or ambient elements, while the actual indoor conditions are consistently maintained. Because of the limitation of sample sizes and moderate climate conditions in Southern California, this study might find only a few statistically significant results. However, the study confirmed a possible difference or inconsistency in an occupant's environmental satisfaction. Based on these results, it is concluded that the multiple-time data acquisitions are necessary to improve the quality and accuracy of POE research methods that improve the consideration of human factors and time-relevant parameters. Also, multiple IEQ measurements and satisfaction surveys may provide evidence for establishing optimal design solutions with a better understanding of a user's satisfaction that is affected by human factors and outside conditions. Some improvements for future study should be considered as followed: firstly, the number of datasets need to increase to conduct more sophisticated analyses with consideration of various human factors, which provide a high impact on a user's satisfaction.

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A Growing Economic Challenge: Findings from a Survey on Building Energy Efficiency in Saudi Arabia

A growing economic challenge: Findings from a survey on building energy efficiency in SA

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ABSTRACT: Saudi Arabia (SA) has been giving significant attention to energy conservation since the year 2014 due to the oil crisis and the extensive energy consumption in the building sector, particularly residential buildings. Buildings in Saudi Arabia occupy between 75%-79% of the total electricity consumption (Tlili 2015; Alrashed et al. 2012; Krarti et al. 2017). Residential buildings are responsible for 49%-52% of the total building consumption in the country (Tlili 2015; Alrashed et al. 2012; Krarti et al. 2017). Air conditioners and refrigerators consume 80% of electricity in residential buildings. This paper aims to explore the following questions: What are the attitudes and design practices among design teams towards energy efficiency? What are the existing building features under the impact of the Saudi Arabian government's energy conservation policy? To be able to tackle these questions, a web-based survey on the energy efficient building design-related attitudes and practices of design teams was conducted. The survey was administered in July and August 2017. We categorized the existing buildings into four timeframes upon the SA policy's agenda: less than five years old (built after 2012), between six to ten years old (built between 2007 and 2012), between eleven to fifteen years old (built between 2002 and 2006), and over fifteen years old (built before 2002). The survey reached 119 participants who are design practitioners in the building construction area. The survey contains 18 questions divided into five categories, i.e. background information, walls, roof, exterior doors, and windows. The participants were asked to answer three to four questions for each building envelope component. The findings of the survey present the main energy efficient indicators which have been used by design practitioners since 2002. This study may advise on the content and format of the future energy efficient design guide and economical retrofitting strategies.

KEYWORDS: Energy Efficiency, Building Envelope, Saudi Arabia, Construction Practice, Economic Challenges.

INTRODUCTION

Buildings have always been associated with energy. Up until the energy boom in the 40s and 50s with the discovery of oil, buildings were more environmentally responsive (Roaf 2004; Maddex 1981). As a result of energy becoming more affordable than ever, architects designed buildings without serious considerations for energy conservation during that time (Maddex 1981). Later on, during the energy crisis, we re-discovered the need to wisely utilize renewable energy and achieve environmentally responsive design in buildings. Building regulations all over the world have been shifted towards more energy efficient buildings (Kharseh et al. 2016) and have influenced both new and existing buildings. This paper provides an overview of findings from a survey related to energy efficient building design practices in Saudi Arabia (SA). The paper is organized into four major sections, the first of which provides important building design contextual information regarding Saudi Arabia and its building regulations. Also, this section reviews the existing literature on energy consumption in the building sector in SA. Section two states the method used in this paper, which is mainly surveys and statistical analysis of survey data. The third section details the findings of the survey with some analyses. Furthermore, this section outlines the participants' characteristics and what the building envelope properties used in the country are. The fourth and final section discusses why this paper is important now more than ever. It also provides key principles behind the lack of using energy efficiency in buildings as well as pointing out possible solutions to improve efficiency.

1.0. BACKGROUND

The country by its nature has limited resources and highly depends on oil as a primary resource. As a new nation, most of the existing building stock in SA were built in the era of cheap energy. Therefore, the energy efficient design standards were not employed in the buildings with exception to the relatively new governmental buildings. Almost all the traditional buildings, which are actually energy efficient, were demolished to keep pace with modern development. Despite the government awareness program and initiatives, which were started in 1985 and updated in 2010 to reduce energy consumption in the private sector, owners choose not to apply any energy efficient products in their buildings because of the higher cost of these products (Saudi Electricity Company 2015). Nevertheless, soon after the oil crisis in 2014, the Saudi government started a new strategy called Vision 2030 (Nurunnabi 2017). One of the major parts of the agenda is to reduce the nation's reliance on oil. The government started enforcing and developing regulations that has been set in the past to increase energy efficiency in buildings (Mohammed 2014: Saudi Electricity Company 2015: Saudi Energy Efficiency Center). Buildings in Saudi Arabia occupy between 75%-79% of the total electricity consumption (Tlili 2015; Alrashed et al. 2012; Krarti et al. 2017). Out of that percentage, residential buildings are responsible for 49%-52%, that is about two third of the total building consumption in the country (Tlili 2015; Alrashed et al. 2012; Krarti et al. 2017). Air conditioners and refrigerators consume 80% of electricity in residential buildings (Taleb et al. 2011).

Different climates require different building techniques to achieve ideal energy performance. In SA, there are generally five different regions; each region is also distinguished from the rest by its unique climate, culture, and tradition. The climate of the western region, which is coastal land, is characterized by its hot tropical weather with hot-humid temperatures in summer and relatively warm conditions in winter. On the other side, the eastern region is hot-humid in summer, but cold in winter. Northern and southern regions generally located on mountains, therefore they are cool in summer and winter. Finally, the central region, which located between three deserts, is hot-dry in summer and cold in winter (Al-Jadeed 1994). Similarly, different types of buildings come with different functionalities, and therefore are important to understand the construction practices that have been used on all kind of buildings to achieve energy efficiency. Afterward, we must narrow down our focus to the residential buildings, as this sector has been shown to occupy most of the energy consumption in the country. In order to have a holistic approach and a better understanding of the practices that have been used in buildings, we should collect data about all the five regions in SA as well as all types of buildings before we focus our study on residential buildings.

According to a survey done by Al-Surf (2013), 52.2% of architects and engineers, who are affiliated with the Saudi Council of Engineers (SCE), which consist of a variety of professions; including mechanical, electrical, chemical, civil, and computer engineering as well as architecture, have not heard about sustainable housing before. The lack of awareness among the respondents in the previous study (Al-Surf 2013) could explain to some extent why energy efficient techniques are not considered in the construction practice. However, since the previous study involved many professions that are not related to construction, we saw a need to conduct a study on construction practice with more focus on building envelope. Therefore, this survey study is proposed to reach a wider platform with a specific target at building construction professionals such as architects, civil engineers, and contractors who have direct and great impacts on practices of existing buildings. Another objective of this study is to attain the design settings and information of building envelope of residential buildings, which may guide us for our future study of baseline model development.

2.0. METHODOLOGY

The present study employed a quantitative method to explore the following questions: What are the attitudes and design practices among design teams towards energy efficiency? What are the existing building features under the impact of the Saudi Arabia government's energy conservation policy? To be able to tackle these questions a web-based survey on current as well as the previous building design attitudes and practices among the design teams was conducted.

The survey was designed to collect a database about the energy efficient design-related methods and materials that have been used in building practices, especially about building envelope. The survey was sent out between July and August 2017 to the Saudi Green Building Forum group and other groups on social media that involve practitioners in the construction field. The total number of members from all the of groups was 1,833, of which only 119 have participated in the survey. The participants were asked to answer the questions on the survey based on their own experiences with designing and constructing buildings. The survey contains 18 questions divided into five categories, i.e. background information, walls, roofs, exterior doors, and windows. From the survey findings, we could establish a baseline for construction materials and methods that were used in existing residential buildings in SA. Additional data were gathered through different resource, to give context to the Saudi situation. Several sources have been used to collect additional information about building systems and existing typical retrofitting technology for creating building envelope. The result of this study may also provide insight on the content and format of future energy efficient design guide, and economical retrofitting strategies.

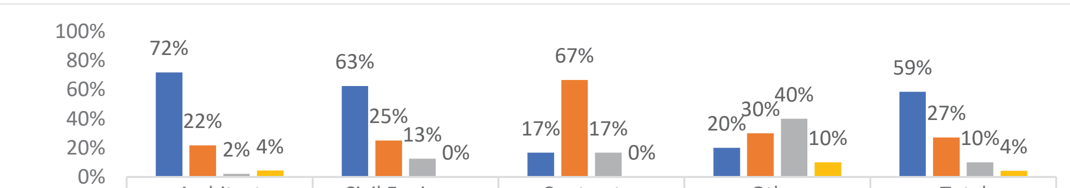
3.0. SURVEY FINDINGS

In this section, we analyze the data we extracted from the survey. The section is organized according to the online questionnaire structure which is mentioned in the previous section.

3.1. Characteristics of participants

The participants were asked to answer six questions about background information such as age, profession, experience, type of projects, region, and city. As shown in Figure 1, most participants were between the age of 25-34 (59%), and only 4% were 55 or older. The mean age was 35.79 (*SD*=7.8), and the mean year of professional experience is 8.97 (*SD*=3.84). The high number of younger participants also reveals the high percentage of young professionals who are currently working in the building construction area in SA. The same figure also shows that there is a high number of young professionals (age between 25-34) among both architects (72%) and civil engineers (63%). On the other hand, a significant portion of contractors (67%) are between the age of 35-44. While respondents of other disciplines, i.e. computer science, construction management, interior design, planning, electrical and mechanical engineering, and drafting, have reported to be between the age of 45-54.

In regard to the profession perspective, architects form the majority (66%) of the participants in this survey (Figure 2). Additionally, figure 3 shows that 37% of respondents have 5 years or less experience, and 34% have between 6-10 years, while 14% for each categories 11-15 and >15 years of experience. These data reveal the lack of experience on the Saudi construction market with about 71% of respondents having 10 years or less of experience, and only 24% having more than 10 years of experience.



	Architect	Civil Engineer	Contractor	Other	Total
25-34	72%	63%	17%	20%	59%
35-44	22%	25%	67%	30%	27%
45-54	2%	13%	17%	40%	10%
≥55	4%	0%	0%	10%	4%

Figure 1. Percentage of age in respect to professions and total percentage of age.

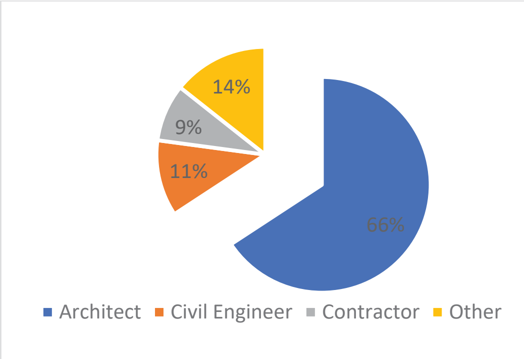


Figure 2. Profession percentage.

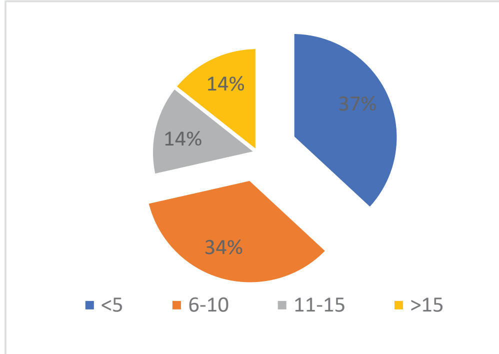


Figure 3. Experience percentage.

3.2 Building envelope properties

The first question in the building envelope component section, determines how frequently participants use thermal insulation, if they use any. The second question determines how they have been using the thermal insulation in building envelope in their practices within indicated years. We categorized building ages into four periods: five years old or less (built after 2012), between six to ten years old (built between 2007 and 2012), between eleven to fifteen years old (built between 2002 and 2006), and over fifteen years old (built before 2002). Finally, the participants had the option to input values that they have used in their projects.

The answers related to the wall insulation usage in all types of building projects are shown in Figure 4. It shows a clear trend that wall thermal insulations have been increasingly adopted in practices in the last 15 years. However, a dramatic change has happened in the past five years. This significant increase in wall insulation usage could be due to the economic challenge that the country has been facing since 2014, which encouraged people to be aware of the importance of using such products and techniques to cut energy costs. On the other side, the responses of the wall thermal insulation usage before 2012 also reveal that practitioners in the building construction area in SA were way behind with the governmental energy policy timetable, which was initially developed in 1985 and updated in 2010 (Saudi Electricity Company 2015). It is also worth mentioning that, even though there is great increase of wall thermal insulation adoption in practices in last five years, there is still a high percentage (25%) in practitioners who have not accepted the implementation of thermal insulations into walls in their practices.

With respect to the residential building projects, out of the 28 participants who work in residential projects, only one participant used wall insulation on buildings that were built between 11-15 years. Even though the number of participants using wall insulation in residential buildings has dramatically increased, still over a third of the participants say they never use wall insulation. Among all types of buildings, the residential buildings have a higher number of energy consumption, yet the number using wall insulation is way less than the rest of building types. This will result of wasting energy and thus burden the economy. From these findings, we may conclude that it was common for buildings that are between 11 to 15 years old to have almost no wall insulation in residential buildings.

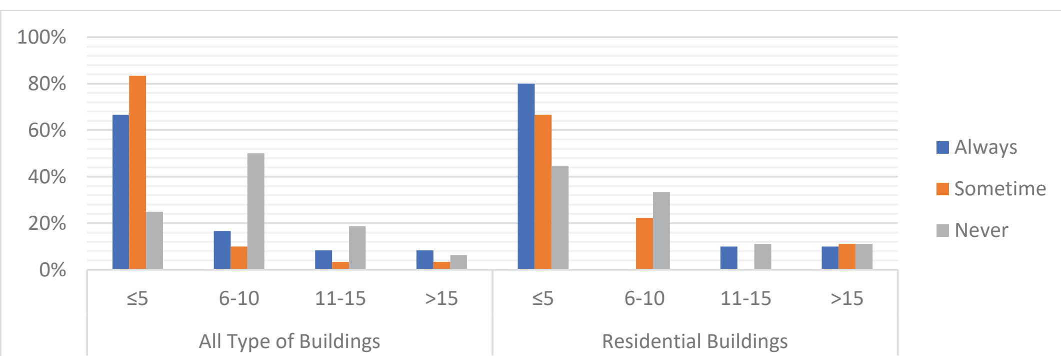


Figure 1. Thermal insulation in walls.

With regards to window types in buildings that have been built for over fifteen years, single-pane window usage occupies 60%, forming the majority. On the other hand, double-pane window usage contributes just 40% of the total number on that category (Figure 5). As we move forward, the results in the figure show that between 6-15 years ago the number of participants who used double-pane windows are equal to the number of participants who used single-pane windows. Correspondingly, in the residential building category, most of the responses were in favor of double-pane windows for the past five years, however, for older buildings, it is clear that the significant number of participants used single-pane windows (Figure 5). The trend of utilizing double-pane in the past five years will be further explained in the discussion section of this paper.

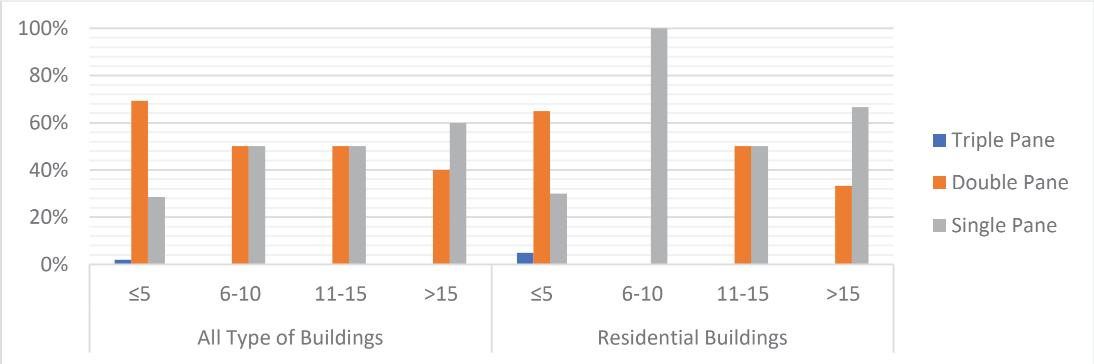


Figure 2. Thermal insulation in windows.

About two-thirds of participants have reported neither always nor sometime using thermal insulation in roofs since 2012 (figure 6). On the other hand, the number of participants who never use insulation in roofs has been drastically decreased from two-thirds before 2002 to only one-third in the past five years. Therefore, the results show a clear trend in utilizing thermal insulation in roofs for all building types. In residential buildings, however, there is a slight improvement in roofs insulation usage (figure 6). The previously mentioned figure reveals that the vast majority of participants have never utilized roofs insulation before the year of 2002. However, the number has decreased by 50% from 2002 to 2006, then jumped to 75% from 2007 to 2011, and eventually went down to 62% after 2012. This fluctuated pattern will be discussed further later in this paper. The data provide a convincing evidence against the usage of thermal insulation in exterior doors. A cursory glance at figure7 reveals that there is a slight increase of thermal insulation usage in exterior doors for all building types beside residential buildings. Yet, the majority of participants never utilized any kind of insulation. On the other hand, the result in residential buildings category show no strong evidence of insulation usage in exterior doors.

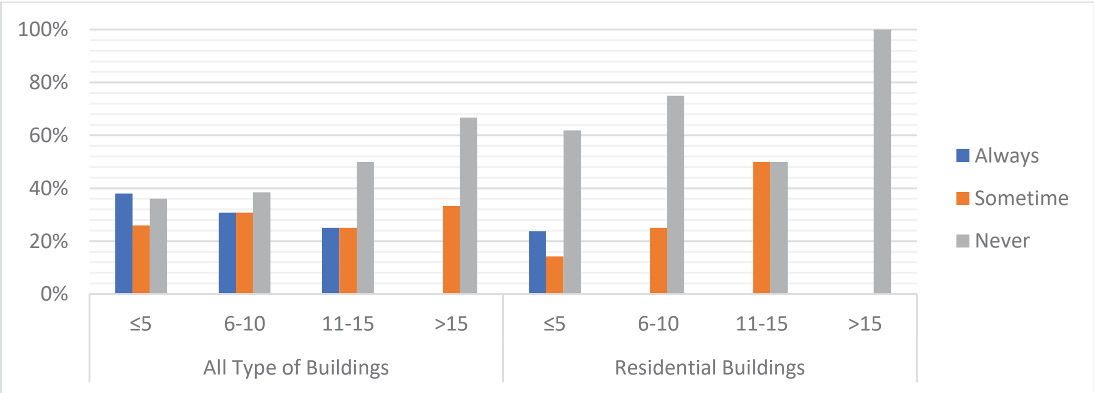


Figure 3. Thermal insulation in roofs.

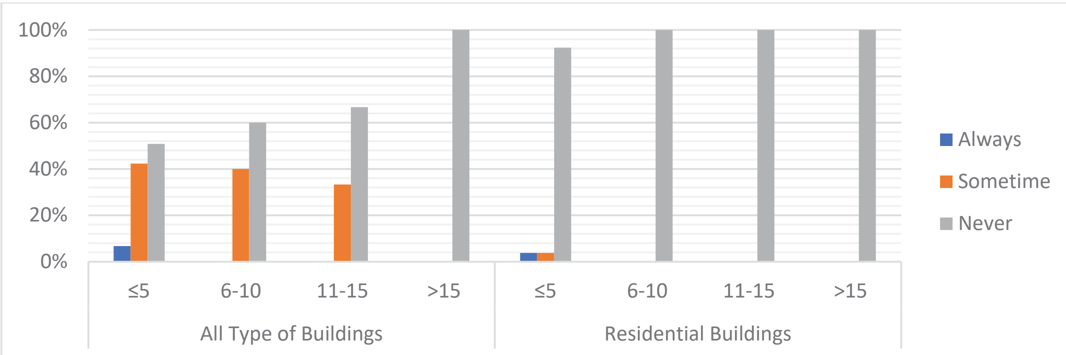


Figure 4. Thermal insulation in exterior doors.

To conclude this section, there is a significant difference of thermal insulation usage in buildings of all kinds. In regard of commercial and governmental buildings, the results reveal that thermal insulation has always been used and steadily improving in these kinds of building types. However, while there is growth in the number of practitioners who use thermal insulation in residential buildings, the number remains statistically insignificant. We can safely draw from the findings that the common ordinary residential buildings that were built before 2002 have no proper thermal insulation in walls, roofs, doors, and to some extent windows. This result provides a strong evidence that buildings falling into the residential category require a critical improvement in their envelope to reach a high level of energy efficiency.

4.0. DISCUSSION

In this section, we will identify the key factors behind the lack of energy efficiency techniques used in buildings. We will also discuss why this energy efficient design-related survey is important now more than ever. Lastly, we will point out some potential strategies and future works to improve energy efficiency in buildings.

4.1. Discussing survey findings

The number of contractors and other disciplines in the field of construction before 2002 and up to 2006 is higher than architects and civil engineers. Oppositely, architects and civil engineers form the majority of young professionals since 2007. The result yields a positive correlation between the increased number of architects and civil engineers on one side, and the increase of thermal insulation usage on another. A further investigation on the correlation between the trend of insulation usage and the trend of architect practitioners rate is needed in the future as there is still not enough evidence.

Even though the first edition of Saudi building code was published in 2007 (Saudi Building Code 2007), the growth rate in thermal insulation usage between 2007 and 2011, particularly for windows and roofs, has been relatively low comparing it to the growth rate of previous years. However, thermal insulation usage has been drastically increasing since 2012. There are two explanations for this gap. First the Saudi building code has not been formally enacted yet, thus practitioners have no obligation to apply the codes to their design. So, there is a need to enforce the Saudi building code as it will eventually help make more energy efficient buildings. The second explanation would involve economic factors; in the light of the economic resurgence, which took place between 2007 and 2011, the consumption in private sector has peaked (Bahgat 2012; Nurunnabi 2017). As a result, many buildings have been erected at this time with less than expected use of insulation. Good economic status makes people care less about energy consumption as it becomes affordable, thus they ignore using thermal insulation to lower their utility bills. Therefore, this may indicate that a negative correlation is possibly existing between economic growth and thermal insulation usage in buildings, particularly in the residential sector.

It has been observed in the findings section that commercial and government buildings have relatively better thermal insulation than residential buildings. These buildings, as opposed to residential buildings, usually involve higher construction standards, especially in windows. The cost of double-pane windows and the lack of awareness and informative data on the importance of utilizing high energy-efficient windows, are the main reasons why people in Saudi Arabia choose so-called affordability over efficiency. Furthermore, with the affordable cost of electricity bills, many decide to overlook the advantage of using energy-efficient windows as they normally cost much more than single-pane windows, which becomes a burden on buildings' owners, and investors.

The previously mentioned reasoning applies to walls and roofs, which also are consistently ignored by most of practitioners. Doors have received even less attention; they usually are not thought of as a critical building component in energy consumption; however, exterior doors are frequently used more than any other envelope components. Its mechanism demonstrates a high level of heat transfer in and out the building which causes a significant impact on energy conservation. In addition, the government, in the form of the Saudi Electricity Company (SEC), does not promote the importance of thermal insulation application in exterior doors. As shown in the SEC booklet for thermal insulation requirements, we can see that door insulation has been completely ignored in both existing and new buildings (Saudi Electricity Company 2015). Investigating the impact and potential benefits of using thermal insulation in residential exterior doors is thus also needed.

To conclude this section, the survey method is one of the most common methods used in developing baseline models for energy consumption (Attia et al. 2012). Usually a survey is applied to estimate the energy usage in many countries. In Saudi Arabia, there is a need to introduce a prototypical model studies that represent most of the country's building stock, especially with the increasing difficulties in optimizing energy efficiency in residential buildings. It is challenging to introduce a prototypical reference for residential buildings without understanding the current construction method used in terms of thermal insulation. Fortunately, we know for a fact that the majority, if not all buildings, especially residential ones, are built in reinforced concrete. However, there is no available data that reveals the methods and materials used in thermal insulation of the existing buildings. The result of this study is preliminary; however, it could be employed to lay some fundamental understandings for the next prototypical model development.

4.2. Importance

In this section, we will turn our attention to explain the importance of timing to conduct this study on energy efficient design-related surveys. Saudi Arabia is facing an energy crisis due to a combination of different factors, such as booming population, challenging economy, and water scarcity (Bahgat 2012). As a result of the energy crisis, the Saudi government has started to raise the cost of energy, i.e. electricity and gasoline, starting from the first day of the year of 2018 (Mohammed 2017; Saudi Press Agency 2017). On top of that, the government has also started enforcing 5% of value-added tax (VAT) for the first time in the country's history, thus many experts anticipate an apparent increase in the cost of living. Gasoline jumped by 127% and is projected to continue rising by 80% each year until the year of 2020. Similarly, electricity was increased by 260%. Saudis have been long accustomed to low energy prices, now that they have a drastic increase in the cost of living in general and energy cost in particular, it became challenging for them to acclimate to the new situation. This challenge will motivate Saudis to learn more about what methods are available to conserve energy in buildings and associated cost savings.

Sometimes, while it is the best option, consulting experts to study the insulation's condition in buildings costs a lot and seems an undesirable option with the challenging living cost. The result of this paper could be used as a baseline for current insulation usage status in buildings. This baseline could be used to show what kind of insulation has been used or not in the majority of buildings, just by looking at its age. This will help the government of Saudi Arabia as well as the people to know what they need to add or upgrade in their buildings in order to reach a higher energy efficiency standard. On the broader context, this paper could be used to help the government to determine how much energy is wasted and the burden to the country's economy, from there, they will be able to make a decision on how to mitigate this issue. Correspondingly, in a smaller context this paper will help owners to determine whether they need to add or upgrade any insulation with no or minimum consultation. For example, most of the buildings older than fifteen years lack insulation in walls. Knowing that, owners could apply complete thermal insulation coverage on all the outside surfaces of exterior walls, which helps inclosing the thermal bridging.

4.3. Suggestion

There is a potential to save energy through implementing some of the retrofitting measures. It has been proven that energy efficiency could be achieved through retrofitting existing buildings, specifically with upgrading components to meet the highest, yet economically viable, standards of energy efficiency. However, energy-efficient retrofitting is not common yet in Saudi Arabia (Kharseh et al. 2016), this might be because of two main reasons: First, there is a shortage in awareness about sustainable design in communities. Second, the lack of available information to the public on how much energy saving can be achieved by retrofitting technologies in a specific project. Studies have shown that upgrading existing buildings to current energy efficiency standards in SA could effectively reduce building loads (Al Surf et al. 2013). Energy efficiency upgrades do not only save building operational energy, but also save the cost associated with constructing new buildings. With the high rate of existing buildings and increased energy costs, it is important that the government of SA start to work extensively on promoting energy efficient retrofitting strategies for residential as well as commercial buildings.

CONCLUSION

As mentioned earlier in this paper, Saudi Arabia has been giving significant attention to energy conservation due to the extensive energy consumption in the building sector, particularly residential buildings. The result of the survey could prove that most of the existing residential buildings in the country do not have appropriate thermal insulations of building envelopes nor implemented according to the energy efficiency standards. From the conventional view, demolishing and then reconstruct a building used to be deemed as an easy and financially feasible strategy for building owners, however, after the increase in energy cost as well as living cost this is anticipated to be changed. Nevertheless, all energy saving analyses need a comprehensive process of building feature study, technology selection, and energy prediction or simulation upon an in-depth data collection of the current building conditions and user characteristics. However, there is no such framework available aiming at quantitative analysis on the pros and cons of architectural and technological features in Saudi Arabia. There was also a need to conduct a comprehensive study that shows current construction practices that have been used in the past years.

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Ageing Well In Place: Associating Functional and Affective Dimensions of Older People's Home

Ageing well in place: associating functional and affective dimensions of older people's home

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ABSTRACT: In front of the challenges that are brought about by the ageing of our population, it is a responsibility to all stakeholders in the field of architecture to consider today our housing of tomorrow. This article, focused on the topic of ageing in place and more specifically on housing adjustments favoring this process, attempts to clarify and assemble the existing literature, considering the topic at hand from three complementary viewpoints: the functional, the affective and the temporal dimension of feeling "at home". First, the functional dimension, which is closely linked to the architectural field, looks at different scales of housing interventions. Next, the affective dimension of the habitat is studied through the lenses of *home* and *subjective well-being*. These lenses enable us to assert the need to combine both the functional and affective dimensions of home in order to promote ageing well in place. Finally, the temporal dimension of the architectural intervention is discussed, in order to position these theoretical models while taking into account the constantly evolving context.

KEYWORDS: architecture; ageing in place; home; subjective well-being

INTRODUCTION

In 2050, the number of people in the world over 80 will have tripled, and more than a third of the European population will be over 60 (United Nations 2015). This increase in life expectancy and the arrival of the *Baby Boom* generation in retirement impel our societies to examine the viability of the current senior housing systems (Grebot 2015).

Nowadays, the relevance of the hospital-centrist model is questioned: the first health center of a person is now considered to be his/her daily living place, which enables him/her to preserve autonomy and privacy (Beyeler 2014). Considering the Walloon territory (i.e., the southern part of Belgium, Western Europe), ageing in place indeed appears to be the preferred way of living while growing old(er), both from a governmental point-of-view as from older people's perspective (Gouvernement Wallon 2014). As confirmed by a recent study that questioned 2000 Belgians aged from 60 to 85, more than 80% of older people wish to continue living at home as long as possible (Fondation Roi Baudouin 2017).

In this perspective, in order to offer realistic, appropriate and long-term solutions, it is essential to think about how older people can live at home as long and as pleasantly as possible. This article considers this challenge by discussing it from three angles: the functional, the affective and the temporal dimension of the home.

1.0 HABITAT FUNCTIONALITY: VARIOUS SCALES OF INTERVENTION

Today, it is acknowledged that the increased probability of experiencing functional limitations with age requires reflections on home adaptability (Auger 2016). To be relevant, this functional reasoning must be carried out at different scales: from the location of the dwelling to the details of the interior design.

1.1. Residential location & housing division

First of all, it is necessary to consider the location of the house itself. This (re)location is function of its environment and accessibility. Indeed, the ease of access and the proximity of "supports" (Masson et al. 2015) have a considerable impact on certain life choices, as well as on the socialization of older people. Three elements stand out in the literature: the density of circulations (Bontron 2013), which strongly depends on the concerned environment (urban, semi-urban or rural); the presence of equipment nearby (Masson et al. 2015) for the common necessities (e.g. food and care); and the location of personal points of interest

(Gabriel and Bowling 2004) like for instance leisure areas, the location of family/relatives or places related to people's personal history.

Once the residential choice is made, and more particularly when people continue living in the current dwelling, housing division procedures may be undertaken. Indeed, when children leave the family home, the environment generally becomes too spacious. The housing then gradually turns into a burden, difficult and expensive to maintain. As confirmed by De Decker and Dewilde (2010), the Belgian housing stock in particular is old, poorly equipped and badly isolated, with areas too large for the seniors who occupy them. In such cases, it can be considered to transform the "classic" single-family house to a collective alternative. Such a re-organization of housing enables seniors to continue to live qualitatively "at home". Among these alternatives, one could list the "kangaroo home": an older person receives a family in his/her home that has become too big in exchange for financial contribution and/or everyday help (Berger 2013). "Intergenerational housing" with a student is based on the same principle as the kangaroo habitat but the student is alone (not with a family) and the period of stay will cease at the end of the study program (De Briey 2011). Another possibility is the "twin home": a small home for the older person is added to the house of a family member, or vice versa (Mormont 2015). And finally, the "grouped habitat", which requires a move, involves buying/renting a house/apartment with other individuals, seniors or not (Fontaine 2016). In this case, each inhabitant has private spaces and shares collective areas (Senoah 2016).

1.2. Internal spatial organization & design interventions

Focusing on the private habitat, it is generally admitted that the priority should be to re-design spaces left by the children, in order to facilitate maintenance (physically and/or economically) and re-appropriation (Auger 2016).

In addition, *accessibility* and *usability* concepts need to be taken into account (Fabre and Sahmi 2011). Indeed, older people are generally, over the years, faced with several physical, dexterity and cognitive difficulties; and, typically a lot of current older people's housing presents several obstacles that prevent them to evolve towards a process of *ageing well in place*. It is not uncommon for a person to be placed in an institution after a fall at home, caused by a badly designed staircase or unfitted bathroom equipment. Thus, housing should favor the most autonomous circulation and uses possible for a person (CSTC et al. 2006). A reduction and simplification of the trajectories are recommended, as well as particular attention to the dimensions and materials of passages. Moreover, ideally, level differences should be light or non-existent.

The positioning of furniture/equipment is also significant. In the horizontal plane, certain distances must be preserved around the equipment to maintain ease of access. In the vertical plane, view and use heights must take into account the sitting position: it is for example preferable to position all the equipment (handles, switches, etc.) between 0.90m (2.95ft) and 1.20m (3.93ft) from the ground (CSTC et al. 2006). In such case, even with gradually decreasing mobility, the person can continue to live relatively well at home.

In parallel, particular attention must be paid to the aesthetics and the "hygienist" connotation new pieces of furniture and equipment might have (Heywood 2005). Older people might perceive negatively some adaptations, because they refer to a medicalization of their home. The culture of home is then affected, which brings us to the considerable importance of the following issue: the habitat affectivity.

2.0. HABITAT AFFECTIVITY: FROM A HOUSE TO A HOME

From a pragmatic perspective, the functional interventions discussed above are necessary steps to enable *ageing in place*. However, they do not guarantee continued "quality of life": functional aspects are a support of the affective dimensions. This second, more subjective dimension explains the difference between "a house" and "a home". The house defines above all a material property with extrinsic dimensions. It identifies itself from its occupants, its location and its architectural form (Ségaud et al. 1998). Home has a much broader meaning: it does not boil down to the simple fact of lodging but enables personal development and establishes a veritable link between one's own identity and the spatiality (Bernard 2005). Therefore, to help a person feeling truly at home throughout his/her life, the dwelling must not only meet the person's physiological needs (through functionality), but also the person's specific expectations (through affectivity). This affectivity of the home is, in terms of literature, directly related to the subjective well-being (SWB) of the occupant, which reflects the experience and the feeling of the person in regard of his/her own life (Petermans and Pohlmeyer 2014). As stated in Diener's original definition:

> People experience abundant SWB when they feel many pleasant and few unpleasant emotions, when they are engaged in interesting activities, when they experience many pleasures and few pains, and when they are satisfied with their lives. (Diener 2000, 34)

The literature on the meaning of home, and especially Heywood's writings (Heywood 2005), enable us to group these affective dimensions into five main points defining home for the older people as place of: safety, daily activities, identity, sociality, and anchorage/articulation with the outside.

2.1. Place of safety

Home is a place where the resident feels safe, both from a physical as from a psychological perspective. The dwelling evokes the idea of shelter against the outside (environment and climatic conditions) (Bernard 2005) and provides protection from others (Cassaigne 2006). Thus, by establishing limits in space, a boundary between an inside and an outside is created. These limits can be flexible (vegetation, furniture), permanent (wall, partition) or transient, allowing control of the surroundings (window).
The social environment also has a significant impact on home security: the neighborhood, by its proximity and solidarity, generally provides social security (Smetcoren 2016). In addition, staying in the same dwelling for several years and having the same daily routines for a long time is reassuring for many people (Morin et al. 2009).
Finally, to provide a sense of complete security, home must also prevent falls and reduce potential hazards. Heywood points out the importance of the perception of a home as a safe place:

> People described how, before adaptations, they had fallen or feared a fall. Many also described the terrible pain they endured, which again seemed to be an assault on the meaning of home as a place of security. […] Adaptations which removed danger and reduced suffering were therefore not just preventing an accident or alleviating a condition but were additionally restoring to a house its power to be a home in this sense of a place of security. (Heywood 2005, 541)

2.2. Place of daily activities

The habitat is strongly related to its daily and personal activities: the inhabitant must be able to realize the activities that he/she considers important. Two principles are essential in the realization of these occupations, and especially for older people: comfort and autonomy.
Comfort is associated with devices ensuring the well-being of the inhabitants, making life more pleasant (Morin et al. 2009). Two dimensions can thus be associated: a corporeal/physical dimension (comfort in shifting or at rest) and another, more symbolic dimension related to mental emotional well-being (Auger 2016).
The autonomy induces a freedom of action: the inhabitant must be able to go where he/she wants, and do what he/she wants. An inappropriate home prevents this autonomy: the presence of obstacles has then such an effect that some people end up associating their personal house with a prison (Heywood 2005). On the other hand, when home adaptation is adequate, the senior's independence increases and his/her need for assistance is reduced.

2.3. Place of identity

The habitat is an extension of one's self (Cassaigne 2006). The interiority of the home is in fact linked to the personality of the person: the identity necessarily comprises dimensions of place and space which constitute, once assembled, the identity of place of the individual (Serfaty-Garzon 2003).
This affirmation of identity is expressed through the appropriation of spaces: each inhabitant personalizes the places according to a personal dynamic. Landmarks develop in connection with other personal elements, such as memories, life events, tastes, values, qualities and defects (Cassaigne 2006). This appropriation is particularly present in the housing of older people: elements have accumulated throughout their lives in their personal spaces and remind them of history and personal memory.

2.4. Place of sociality

Home is a space where people can find a balance between the boundaries of their private and social/public life. Two situations stand out in this sociality: the temporary reception of others and the daily sharing of spaces.
Reception is deeply linked to the notion of threshold: the habitat provides the right to include/exclude people in its intimate sphere (Morin et al. 2009). The crossing of the housing threshold is then established differently according to the situation: the time/duration of the visit, the identity of the visitor and the purpose of the visit (Serfaty-Garzon and Condello 1989). These differentiations of relational frameworks allow the host to keep some control over the space. It is important that, in getting older, the inhabitant can continue to carry out this host role autonomously and that some rooms still allow to receive his/her family and relatives. Thus, housing may be a support for social development.
In addition to these visits, home can also be a place of daily sharing with other occupants. Spaces might be used and appropriated by several people (e.g. sacredness of family life), establishing a mutual respect. Adaptations in the habitat for the old days must induce favorable relationships between persons, particularly in the context of housing shared with other members than the family. It is also necessary not to neglect the importance of private spaces so that the shared spaces within the habitat remain sources of well-being (Heywood 2005).

2.5. Place of anchorage and articulation with the outside

Home is a source of attachment for the inhabitants. The meaning one can attach to a home confirms that the dwelling is much more than a physical place. Often, the time lived in the home helps to develop a feeling of

belonging to the place and the neighborhood. In Belgium, this attachment is referred to by 84% of older people (Fondation Roi Baudouin 2017).
Along with this feeling, the habitat enables to relax and open up to the world afterwards (Larceneux 2011): the inhabitant can more freely explore some foreign space, knowing that he/she will return to his/her home. Housing being a real anchor implies that the inhabitant always craves to return to it. However, housing can be a home where we return only if we are able to leave it: it is therefore fundamental to bring a particular importance to its relationship with the outside, so that it does not become a place of confinement and loneliness (Heywood 2005).

3.0. HABITAT TEMPORALITY: AN EVOLVING CONTEXT

In addition to the need to combine the functional and affective dimensions of the habitat when questioning *ageing well in place*, it is also important to put this reasoning in its temporal context.

3.1. Changing generations

The end of the Second World War marked a period of change. The generation of newborns from this period, the *Baby Boom* generation, has now reached retirement age. However, these persons grew up in a very different social, political and historical context than their elders and are more likely to reach an advanced age (Auger 2016). This differentiation between the pre- and post-war generations is analogous to the differentiation that will occur between current and future generations of seniors: generally better trained, more active/autonomous, with renewed technological resources, these people will also have a constantly growing health capital (Beyeler 2014).
These findings suggest to study ageing in place in a nuanced, contextualized and specific way. Reflection cannot be absolved from this context, especially since these specificities have a considerable impact on the expectations, wishes and longings of occupants regarding their housing.

3.2. Changing needs and expectations

Retirement and entrance into third age open new doors to life projects (Masson et al. 2015). By entering into a context of living older and (often) better, the expectations of the Baby Boom generation have evolved on several points.
Having lived their youth sometimes in great discomfort and, in parallel, experiencing development of comfort over short periods of their lives, imply several significant changes in their ways of living. In addition, society has gradually focused on the individual and its personal development (Bickel, Lalive d'Épinay, and Vollenwyder 2005). Happiness and progress became key words, with also significant implications in the areas of health and technology.
In parallel with technological aids, the use of human aids has also increased. The Baby Boom generations have become more familiar with society's services and outsourcing of tasks (Kaufmann 1995). This observation is particularly interesting in the context of ageing in place: in addition to an architectural approach of ageing, it is necessary to consider evolution of additional supports provided within housing.
Finally, the Baby Boom generation's ways of living are more impacted by mobility than their elders, given a *personal disposition to move* in the geographical area (Kaufmann 2017) : the attachment to the neighborhood, the links created throughout history and to a particular dwelling are no longer insurmountable obstacles, as attachment can be reproduced elsewhere.
All these changes in habits of the Baby Boom generation, and all expected changes for further generations obviously will have particular repercussions on how we should envisage ageing well in place.

3.3. Changing houses

Architecture, by its longevity, accompanies the life process of its inhabitants. To live in a dwelling includes living in the present, accumulating objects related to the memories of the past, while imagining future prospects. The relationship to space is evolving and the experience of home is redefined throughout life. To avoid altering the life objective of the occupants, it is therefore necessary for the habitat to evolve over time.
In this context, *adaptable housing* could provide some functionally flexible opportunities for the future housing of older people. This concept induces a temporality in three phases: (a) conception of an adaptable housing (Fig. 1); (b) accommodation and adaptation phase; (c) use of adapted housing (Fig. 2). The principle is to make possible, from the beginning of the construction, its transformation into a housing adapted to the main physical needs of the inhabitant, and particularly reduced mobility (CSTC et al. 2006). Thus, for instance, by adding or removing elements in the dwelling (simple/light work that does not affect the supporting structures), an inadequate room can turn into an "adapted" space.

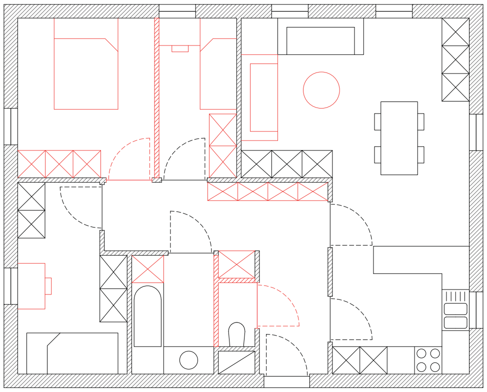

Figure 1 - Adaptable housing (CSTC et al. 2006)

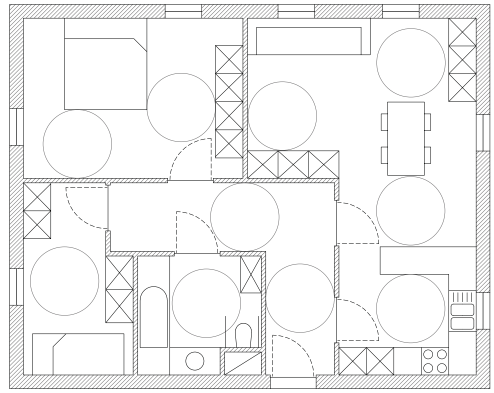

Figure 2 - Adapted housing (CSTC et al. 2006)

However, this alternative, although offering functional and temporal advantages, does not necessarily take into account the affective and subjective dimensions of the habitat. It is therefore essential, nowadays, to further explore existing and innovative housing possibilities for older people (e.g., three generation house, community living initiatives, co-housing initiatives, etc.), in order to favor the stages of life and then enable ageing people to continue to live, as they wish, as long and pleasantly as possible at their home place.

DISCUSSION AND CONCLUSION

This reflection on the functional, affective and temporal dimensions of housing in the context of ageing well in place allows us to confirm the importance of their association (Fig. 3).

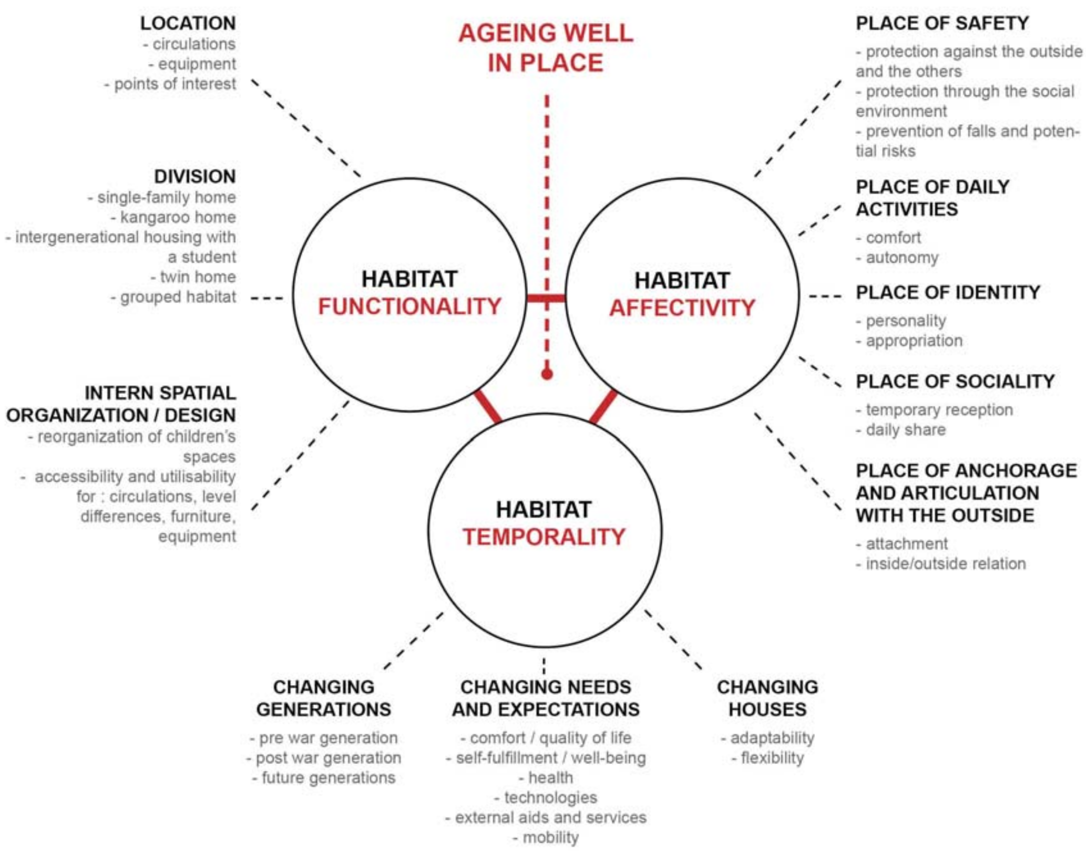

Figure 3 – “Ageing well in place” global scheme

The habitat functionality must be ensured at all scales, from the (re)location of housing to details of the architecture/design, passing by the housing division and its internal spatial organization.
In parallel, special attention must be given to the subjective/affective meanings of the home as a place of: safety, daily activities, identity, sociality and anchorage/articulation with the outside.
Finally, these reflections must necessarily be part of a temporal reasoning, taking into account the concerned generation(s) and their particular needs/expectations, as well as the evolutionary dimension of housing, to create architectural solutions all the more flexible in the future.

Research is now needed to propose new methodological frameworks and habitat adjustment solutions, in order to offer living environments adapted and appreciated by older people. Via our project, we aim to fill in this gap. To contribute to the body of knowledge, three research questions structure our project: (a) How to identify expectations and well-being factors of older people regarding their dwelling? (b) Which spatial devices may create or enhance a feeling of home for older persons (entering thus in a Subjective Well-Being reasoning)? (c) When/how can designers intervene in older people's homes to favor the quality of their living environment and allow them to live as long and as comfortable as possible at their home place?
Two objectives are targeted in our project: (i) providing designers with a methodology to interrogate and integrate the affective demands of older people regarding their homes and relating these to functional dimensions; (ii) proposing concrete generic spatial devices relating to subjective well-being.

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Clare Robinson

Architecture of College Union Buildings and the Changing Meaning of the Campus "Living Room"

Architecture of college union buildings and the changing meaning of the campus “living room”

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ABSTRACT: Student unions buildings are a window into the architectural and social history of college campuses. Designed to support student government and normative leisure activities outside of college classrooms, the buildings have served as instruments of social education and student culture since the invention of the building type in the late nineteenth century. With few precedents, architects of early student union buildings in North America took cues from private social clubs to shape and arrange spaces for reading, games, club meetings, and cultural events, such as recitals and dances. As the Association of College Unions (ACU) matured into an influential national organization, it augmented the most significant architectural elements and purpose of the buildings, and guided the planning and design of buildings nationwide through publications and appointed expert consultants.

Student union proponents and architects regularly referred to the campus buildings as “living rooms” throughout the twentieth century, invoking familiarity and domesticity for an otherwise public campus building. This paper makes extensive use of primary sources to depict and interpret the relationships among architecture, culture, and meaning by wedding methods in architectural history to methods in conceptual history. Specifically, it combines the close examination of college union architecture with the social and cultural intentions of the buildings during three distinct different periods in college union history to chart the persistent use yet changing meaning of the phrase the campus “living room” and other related metaphors. By analyzing the interdependence of architectural design and meaning, this study broadens the role of architecture in humanities research while also arguing for the knowledgeable use of metaphors in contemporary architectural practice.

KEYWORDS: [student union, history, campus living room, home, art of living]

INTRODUCTION

An advertisement for the University of Arizona Student Union prints a photograph of two college-aged women sitting on a ledge near a couple of saguaros, cacti barrel, and rocks. Their arms are bare, their shoes off, and their backpacks sit to the side. The photograph captures a portion of the student union building facade and the university logos appear at the bottom of the page. It is a typical sunny day and typical university publication. A banner across the top of the photograph, however, declares the union “UA’s living room” and a note penned across the bottom of the image states “make yourself at home.” The everyday moment captured in the photograph is thus freighted with other meanings. The student union building and its immediate environment is not just a public space for leisure, but it is where you make yourself at home in the campus living room.

Using methods in conceptual history and architectural history, this paper examines the use of the term “living room” and the related metaphors of “home” and the “art of living” that proponents uttered to describe student unions in the twentieth and twenty-first centuries, and compares the words and phrases to architecture during three distinct historical periods of college union design. The paper then argues that although the persistent use of these metaphors has allowed student union proponents to anchor the importance of student unions in the origins of the buildings themselves, the meaning of the metaphors changed because the spaces and programs of student union buildings have delivered different messages over time. By analyzing the interdependence of architectural design and metaphor, this study illuminates the architecture and meaning of student union buildings while broadening the role of architecture in humanities research.

College union buildings are familiar to nearly every North American college student because the buildings are now standard fixtures on most college and university campuses. The maturation and popularity of college unions as a campus building type began in the early twentieth century with professional proponents, a national organization called the Association of College Unions (ACU), and numerous architects. Although it had few direct architectural precedents, the building type emerged from a confluence of several forces and ideas in the nineteenth century and was firmly established as a building and social institution by the end of the Progressive Era. The buildings of the 1920s and 1930s varied in style – some were collegiate gothic while others were Georgian or classically inspired – but despite the variation, the buildings and their interiors tended to uplift college students with refined materials and stately spaces similar to private social clubs of the same and earlier eras. After World War II, when campuses absorbed G.I.s and expanded campus facilities, the architecture of student union buildings changed along with student enrollment and demographics. Thus, when campuses added, replaced, or expanded unions, the new buildings and building interiors tended to adopt the latest, most durable architectural materials and add recreational amenities appropriate to the middle class. By the turn of the last century, campuses had replaced or completely renovated older student unions to not only remedy normal wear and tear, but to also address the economic necessities of operating union facilities, especially on large public campuses. Many recent unions look and operate much like shopping malls.

The architectural changes to college union buildings generally reflected the development of campus planning and architecture because their spatial paradigms and materials adapted to the tastes and styles of architects and campus administrations. However, while architectural strategies developed, the metaphors underpinning the building type remained the same. Student union proponents and architects regularly referred to the campus buildings as “home” or a “living room” throughout the twentieth century, invoking familiarity and domesticity for an otherwise public campus building. The invocation was and remains metaphorical but it has helped college presidents in the early twentieth century argue for a well-rounded college student long before campus dormitories were commonplace; allowed administrators to envision the university community as a “family;” and enabled architects to link the civic functions of student government to familial socialization through design. By the postwar period, student union buildings were boldly modern; they prepared students for adult life by mimicking shopping malls and civic centers, even though they were still the campus “living room.” Thus, the shift from student-union-as-private-club to student union-as-civic-center relied upon the convergence of domestic and institutional ideas in non-residential campus buildings, as well as the potential of architectural modernism to reshape student culture on college campuses. As campuses revived unions with more food courts, stronger wi-fi, and a variety of spaces to hang out, the domestic metaphors were reshaped again as students were deemed users and consumers of college unions amenities.

1.0 SOCIAL CENTERS ESTABLISH IDEAS OF HOME AND BELONING

The social center movement of the Progressive Era fueled the North American student union movement. From it, student union proponents borrowed the idea of a physical space to gather, but also key social ideas embedded in social centers themselves. By the 1920s, when college unions were established as distinct and desirable buildings on campus, social centers bolstered citizen participation in political processes. Social centers, however, had additional ideological attributes: buildings became “home like” because social activities gave every member a community a chance to belong.[1] For Edward Ward, author of the 1913 book *The Social Center*, “home” stood as a critique of individualism and an antidote to modernization. “Home,” he argued, countered the loss of unity, of neighborship, and of the centrifugal forces distancing people from one another. Drawing upon familiar collective memory, “home” was not literal but a metaphor for the feeling of being part of a community. It borrowed from the mutual consideration, care for others, and cooperation taught by parents to chart the widening circles of family and community that led to patriarchal forms of government. Moreover, it acknowledged the evacuation of family functions – from food preparation, to the weaving and sewing of clothing, and the making and using tools – into the broader, specialized economy of modern civilization.

Few student unions existed in 1913, but Ward anticipated the utility of social centers for college graduates as well as the importance of campus social centers for students in college.[2] Social centers offered college graduates a place to participate meaningfully in the life of a community, and it was through social centers that community center proponents envisioned college graduates transforming society. Most importantly, similar to community centers around the country, social centers on campus united students from diverse socio-economic backgrounds and economized the discovery and formation of common values, especially at public universities before dormitories were commonplace. Unions, like social centers, were a place students could feel they belonged while being away from their families and hometowns.

University presidents and later presidents of the ACU would embrace social center ideas. Glenn Frank, President of the University of Wisconsin at the turn of the nineteenth and twentieth century was a proponent of student socialization, and the first person to bundle “home,” “living room,” and student unions together. He uttered the words in 1904 when he advanced the idea of a student union on the Wisconsin campus. In particular, Frank believed that if a student union were a campus “living room,” then the building would readily transform the university from a “house” into a “home of learning.”[3] In a similar vein, ACU President J. E. Walters would later describe the union as the “home” for the “university family” in 1925.[4] Thus, leadership in higher education used the metaphor of “home” and “living room” to cast student unions as familiar and establish them as social institutions with egalitarian community membership.[5] Thus, it was simultaneously a social metaphor for belonging, a material goal for culture, and a reason for campuses to build a union.

2.0 ARCHITECTS AND THE "ART OF LIVING," FROM PRE TO POST-WWII BUILDINGS

The "living room" supported variant ideas, especially the "art of living" popularized by student union architects. As a concept, the "art of living" gained popularity in the United States during the nineteenth and early twentieth centuries.[6] Early iterations of the idea had a reformist imperative that pointed out the moral and physical ills of the individual, society or cities.[7] Early student unions fit into this scheme as institutions through which socialization of college students occurred. Later, ideas about the "art of living" targeted personal improvement and professional success.[8] Taken together, the popular advice addressed the daily aspects of life (from marriage and family to personal direction, work and leadership) and advanced various ideas about happiness, contentment, and success. Those in academia took the art of living to mean an antidote to systems and science, an infusion of the humanities in daily life, and a path to living well. Particularly, administrators and educators argued that leisure activities and humanities courses in college taught graduates life-long cultural interests, and how to measure the quality of life not by professional success but by intellectual interests and day-to day relationships.[9] By the postwar period, the "art of living" happened when professionals, such as lawyers and businessmen, enjoyed hand-crafts and the arts, and when craftsmen, such as carpenters, plumbers and painters, cultivated interest in fine art and humanities, thus making the "art of living" a synthetic and democratic notion attainable by all.[10]

2.1. Irving Pond

Although the handful of student unions built before World War I influenced discussions about college union buildings, the unions built during the 1920s solidified the common characteristics of the first generation of buildings. Whether funding came as wholesale gifts, alumni subscriptions, or WPA programs, by the 1930s it was commonplace to describe the buildings as the campus "living room." As rhetoric, the term conjured ideas about the comforts of home and domestic order, but the notion of "living" or "art of living" structured social education of student unions buildings.

Early surveys of campus architecture by Jens Fredrick Larson and Archie MacInnes Palmer, *Architectural Planning of the American College* (1933), and Charles Klauder and Herbert Wise, *College Architecture in America* (1929) devote several pages to student union buildings.[11] However, Irving Pond, who designed the unions at Purdue, Michigan State and the University of Michigan, penned the first professional article on planning a union in 1931.[12] As an architect, he was primarily concerned with program, how to reconcile conflicting interests concerning the allocation of rooms and spaces, and to how create spaces for "living." In his analysis, he contended that any university serious about the success of its union should hire an architect versed in the sciences of psychology, sociology, economics, and the "art of living."[13] Thus, if living were an art on campus, it came from scrupulous planning and design of a standard set of union spaces. In his essay "The College Union," Pond authoritatively discussed 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. Through these environments, he painted a backdrop for the everyday and upscale celebrations that would reinforce social norms and life on campus. Upholstery and wood paneling 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. In other words, for Pond it was the suite of spaces, not a single room, which freighted social education and "the art of living."[14]

Pond's manifesto labored over the social divisions between the staff and students, as well as the use of the union by non-members or outsiders at a time when college enrollment had grown significantly over three decades. Between 1929 and 1930 alone college enrollment rose by 84%. Although more than half of college students in the U.S. enrolled in public schools, students generally came from families with financial security and professional aspirations and more than half of the student were male.[15] For these reasons, Pond separated the users of student unions carefully. Non-members, who were often women, would be suitably welcomed when they used a separate entrance to the dining room or theater. Under this arrangement, they would not intrude on "elite" members-only spaces. Similarly, support staff, such as cafeteria cashiers, line servers, and cooks, should have their own offices, storage, and amenities near the kitchen. This physical separation kept a clear division between white-collar staff who attended to the psychological and social well-being of students and blue-collar staff who cooked, cleaned, and performed maintenance. The making of these divisions – between men and visiting women, staff, and outsiders – reinforced social hierarchy found in upper-class homes and set parameters for the "living room" metaphor and meaning of the "art of living."

At Purdue, the architectural firm Pond and Pond designed a union with few but well-planned amenities for male undergraduates.[16] Completed in 1930, it had a large commercial kitchen and cafeteria, a barbershop, a billiards room, ballroom, guest rooms, and a memorial hall and men's lounge on the first floor. The overall building layout created a three-sided exterior courtyard, but the main interior on the first floor was a layered set of spaces that permitted the visual supervision of activities by staff. Thus, the grandeur of Purdue's double-height memorial hall adjacent to the men's lounged served a dual purpose: to elevate and to supervise men's everyday leisure activities.[17] The spatial arrangement and architectural materials balanced the casual and refined, the practical and recreational in the same way it the "art of living" contained ideas of practical know-how and art or humanities.

2.2. Michael Hare

After World War II, the influence of ACU had reached a national scale. Association publications, such as the *Bulletin*, and regional and national conventions circulated ideas about college union buildings. But consultants worked to champion student union ideas as well. Among them were individuals such as Porter Butts, who directed the Wisconsin Union and served as the long-time editor of ACU publications, and Michael Hare, a New York-based architect who designed the Wisconsin Union's 1930s theater addition and sought subsequent consulting opportunities and design commissions for student union buildings.

Looking beyond the campus, Hare argued in his essay "Thoughts on Union Architecture" that union buildings should relate to the future homes and neighborhoods of college alumni. To this end, he furthered the Progressive Era use of "home" by linking unions to the physical space of cities and suburbs. More specifically, he imagined the architecture of the union was the consequential preface to the built environment of graduates. He knew that drill presses were not essential to enjoy the pleasure of woodwork in the same way he knew that the activities and grandeur of student union facilities might be absent from the neighborhoods and communities of alumni. Nonetheless, the principal role of the union was to show students how to live after college. Student unions, conceived of in this way, would have "the qualities … necessary to practice the *art of living*"" on campus, at home, and around the neighborhood to secure a congenial postwar society.[18] The importance of Hare's conceptual framing is that it reached into the private realm from the public realm of the student union to establish a direct and reciprocal relationship between public and private life. Moreover, Hare reinforced how the "art of living" was at once a way of life, a material reality, as well as personal and civic matter. Hare's "art of living" was thus synthetic and democratic, public and private, and reduced the socio-economic distinctions made by Pond.

Hare designed few student unions but he consulted for many institutions, including the postwar unions at William Jewell College in Missouri, DePauw University in Indiana, Case College at Cleveland, the University of Maine, the University of Arizona, Washington State College in Pullman, the University of Oregon, and the Rhode Island State College.[19] For this reason, it is not Hare's architectural projects but the ideas he put forward and the work of local architects following his consultation services that mattered. Among Hare's many clients, the University of Oregon stands out as an early postwar college union building.

The 1950 Erb Memorial Union at the University of Oregon exemplified the social ethos and physical manifestation of student unions of the period. Designed by the Portland architecture firm Lawrence, Tucker, and Wallman with the guidance of the architectural consultant Michael Hare, the building included long-standing recreational and cultural spaces found in most prewar unions, such as dining facilities, a ballroom, and student offices, but it was coed and used an updated material palette and spatial order. The brick exterior walls, interior brass handrails, and polished terrazzo floors harkened back to the unions of the 1920s, and reminded users of the private clubs union architects once found inspiration from.[20] In this case, however, the architects and interior designer combined these tried and true materials with exposed concrete columns, aluminum storefront windows, and contemporary textiles. Equally important, designers brought recreational activities once tucked in basements or behind doors to the most visible parts of the building, thereby modernizing the union both materially and spatially.[21]

The ground floor of the Oregon Union had the cafeteria, snack bar, and lounge. While aluminum storefront windows, plastic plaid seating, Formica table tops, and the latest kitchen equipment of the food services served and socialized students, carpeting and upholstered furniture in the lounge provided respite from the bustle of campus. The lowest level contained bowling lanes, game tables, and a barber shop while the upper floors hosted the grand ballroom and student offices.[22] The spatial proximity of the offices to other union rooms allowed students to coordinate events, collaborate, and practice democratic decision-making regularly. The spaces for recreation, including cultural areas for browsing books and music as well as popular areas for bowling and billiards, offered students contrasting, ample, and common leisure activities suitable to the postwar period. Both special events and daily breaks between classes presented students opportunities to consume culture and social activities during their leisure time. Although students attended planned events in the ballroom, the cafeteria held the most prominent position on the main floor, which put food and its consumption in the center of the union building. In Oregon and other postwar college union buildings, activities concerning student self-government and leisure coalesced under one roof, and the architecture and program of postwar unions introduced students to a new material and consumer culture.

In general, postwar buildings tended to be larger and more complex, with spaces dedicated to technology-laden programs such as bowling, music listening rooms, and kitchens for quantity cooking. Equally important, architectural design and building programs equalized differences among students, gave students access to sanctioned activities, and made them social and economic participants in the life of the student union building. Generously-sized and efficient cafeterias anchored lounges, television rooms, workshops and craft rooms, and well-supplied bookstores. Arranged according to activity, the myriad of postwar unions targeted student demographics by meeting them in the cultural middle of America's broad middle class. As student enrollment rose by 49% in the 1950s and 120% in the 1960s, public colleges expanded to meet the demand and ultimately account for 74% of the total enrollment among all US colleges and universities. Although men still outnumbered women, campuses welcomed greater numbers of middle-income students.[23] For these reasons, the "art of living" served postwar union leaders because it allowed them to promote a well-rounded college student while loosely drawing upon middle class social norms, including the character of environments in which socialization occurred. Similar to suburban communities, shopping centers, and bowling alleys – all sites of normative social interaction and leisure – student union proponents provided spaces that fit within middle-class culture. In this way, by the postwar period the "living room" was not simply a container for the social education or living taking place, it was charged with socio-economic aspirations, particularly middle-class aspirations. Thus, between the 1920s and 1950s, the meaning of the "living room" shifted from being the arbiter of social organization and appropriate leisure activities to also be a concept that straddled public and private life of the postwar era. Less important was social hierarchy. More important were democratic activities and the pursuit of middle-class lifestyle and material culture.

3.0 BEING AT "HOME" IN THE CAMPUS "LIVING ROOM" CIRCA 2018

The University of Arizona's claim to "make yourself at home" in "UA's living room" represents the contemporary combination of architecture and metaphor at a point in university history when thousands of more students are enrolled in institutions of higher education and massive campus protests are largely a phenomena of the past.[24] In this particular case, the Student Union Memorial Center on the University of Arizona campus, rebuilt since the postwar period, is comprised of several buildings connected by exterior passageways that are either corridors or plazas and landscapes. The northwest building contains a ground and basement-level bookstore and upper-level offices for both student government and building operations. The northeast building contains a theater, game room, business center, and food services – including an underground industrial kitchen, ground floor food court and mini-mart, and upper level cafeteria – as well as meeting and ballrooms. The buildings on the south side contain ground floor restaurants, student and alumni services, as well as additional meeting rooms and restaurants.

The main exterior passageway is open to the sky and separates the east and west buildings (Fig.1). It is also where students find the entrance to the bookstore, a convenience store, and entrances to corridors that lead to the food court. The space has palm trees, a fountain, music, and lighting, and is crossed by upper-level passageways that create shade but also reveal the scale of the four-story building. The exterior circulation that cuts through the building creates several interior and exterior facades, and therefore allows for visual and spatial complexity. Most important, the ambiance and scale of the exterior spaces compare to outdoor shopping centers found throughout North America.

Student union buildings on large public campuses treat the spaces within the union as interchangeable similar to the way shopping centers treat retail spaces. The strategy allows the union staff or student organizations to replace one franchise for another or readily change the location of activities. In the case of Arizona, some of these spaces are outside, but elsewhere they would line interior corridors. The commercial character of the contemporary student union recasts the meaning of the "living room" in important ways. The concept and primary spaces no longer contain social hierarchy once pertinent to Pond, nor the connections to democracy and private life celebrated by Hare. The concept retains a vision of public life and being at home, but the public life presented by the architecture and programs of the University of Arizona centers around consumption.

Figure 1: Main exterior passageway of University of Arizona's Student Union Memorial Center looking south (Source: photograph by author).

University of Arizona's message may be unintentional but the continued use of the metaphor "living room" reflects the University's acceptance of the ACU's leadership, and the continued tenacity of the Association to disseminate information and bind student unions together in common purpose. ACU's publication *Fifty-one Facts about College Unions*, is a recent example.[25] Inexpensively printed at four by four inches, the booklet garners fifty-one ideas about student unions believed to be core tenants or benefits of unions. Fact number one builds on the tradition of the "living room." It states "traditionally considered the "*living room*"… today's union is the gathering place of the college." Specifically, "the union provides services and conveniences that members of the campus community need in their daily lives."[26] If consumerism is the spatial and programmatic backbone of the contemporary student union, then the living room is now a place of familial *exchange* or the *transaction* of conversation, goods, and services.

CONCLUSION

The dissemination and widespread acceptance of the idea of the union as "home" was crucial to union builders and practitioners. Professionals in the union business, old and new, would have read about the importance of the campus "living room" in the Association's quarterly *Bulletin* and hear the idea uttered by consultants and organization members national conventions. In no place – *Bulletins* or convention proceedings – did professionals debate the merit of "home" or "living room" as a guide for planning, building, and running student unions. No one has in the union business has openly challenged the viability of the "living room" as a metaphor. Instead, campus visionaries updated the idea of the "living room" as they updated student union architecture. The introduction of "home" and "living room" into the discourse of student union buildings is therefore worth exploring.

When university president Frank, and past ACU president Walters, made the fine-grained distinction between house and home, they called out the difference between a practical structure that shelters a family and the emotional feelings that bind a family together. If the university is conceived as a house, it is measured by the suitability of its physical plant for scholarly endeavors. If, however, the university is conceived as a home, it is measured by the quality of human relationships and emotional bonds that members of the academic community have with each other and to the campus. The original use of "home" and "living room" plainly, and astutely, gave credence to the social life and experience of college as a place to *belong*. Joining middle-class Americans, union proponents of the postwar era took the idea of a "living room," understood as a respectable multipurpose space, and linked it more deeply to both the public and private realms of society, including democracy. Activities in the union prepared students for activities done in their future homes and neighborhoods. In this way, the "living room" was both civic and personal. By the twenty-first century, the "living room" changed again. With student unions as commercial enterprises akin to shopping centers, the metaphor of "home" and "living room" anchor college unions in the past but their message is different. To belong and live is to now gather and consume. Looking to the future, proponents and architects of unions must ask if the continued use of these metaphors serves the college community, society, and humanity, or ask if it is time to again change the architectural form and function of student unions.

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ENDNOTES

[1] See "Like Home" in Edward J. Ward, *The Social Center* (New York: D. Appleton and Company, 1913), pp96-122.

[2] See "The Social Center and the University" in Edward J. Ward, *The Social Center* (New York: D. Appleton and Company, 1913), pp315-323.

[3] Statement of president Glen Frank, n.d. (General Files of Porter Butts, University Archives, University of Wisconsin [series 26 11 1 box 1]).

[4] Association of College Unions Convention Proceedings, 1925, p11 (National Student Affairs Archives, Bowling Green State University).

[5] The earliest unions treated women as guests and it wasn't until the 1930s when universities and colleges built coed unions with greater regularity than unions for only men. By the 1950s, with the exception of women's colleges and a few unwavering traditional schools, unions were for the entire student body.

[6] A cursory survey of texts titled *The Art of Living* illustrates the persistence of the idea. Although varied in scope and purpose, see Ellen Moore Rich, *The Art of Living* (1894); Robert Grant, *The Art of Living* (Charles Scribner's Sons, 1985, 1899); Frank Henry Lyon, *The Art of Living* (New York: Thomas Y. Crowell & Company,1897); Ellen Goodell Smith, *The Art of Living* (1903); J.W. Williams, *The Art of Living* (1908); Karl Potschner, *The Art of Living* (Dover, OH: Karl Potschner, 1935); André Maurois, *The Art of Living* (New York: Harper, 1940); Margorie Barstow Greeble, The Art of Living in Wartime (New York: McGraw-Hill Book Complany, Inc, 1943); and finally a collection of drawings by artist Paul Steinberg published as *The Art of Living* (New York: Harper, 1949). Shorter essays conveyed similar ideas on the art of living. See, for example, Gustav Mueller, "The Art of Living" in *Ethics*, Vol. 48 No. 3 (April 1938), 401-415.

[7] See Smith and Williams above but also Frederick Hoffman, "The Art of Living a Hundred Years: morality, temperance, and industry" in *The Sanitarian* Vol. 47 No. 382 (Sept 1, 1901), 237.

[8] Karl Potschner, *The Art of Living* (Dover, OH: Karl Potschner, 1935).

[9] See Harold Willis Dodds Baccalaureate address delivered at Princeton University June 16, 1935 "The Art of Living" in *Vital Speeches of the Day* Vol 1 No 20 (July 1, 1953), 618-620 and Paul Mackendrick, "Education for the Art of Living" in *The Journal of Higher Education*, Vol 23 No 8 (Nov 1952), 423-428, 456.

[10] See citations above as well as John Harmon, "The Art of Living" in *Physical Educator*, Vol 10 No 4 (Dec 1953), 99-100. Unlike the "art of living" later invoked by French philosophers, the idea in the United States was apolitical (See discussion by Mary McLeod in her 2003 book *Charlotte Perriand: an Art of Living* (New York: Harry N. Abrams)).

[11] Nikolaus Pevsner, *A History of Building Types* (Princeton: Princeton University Press, 1976); Jens Fredrick Larson and Archi MacInnes Palmer, *Architectural Planning of the American College* (New York: McGraw-Hill Book Company, 1933); and Charles Klauder and Herbert Wise, *College Architecture in America* (New York: Charles Scribner's Sons, 1929).

[12] Irving Pond, "The College Union" in *Architectural Forum,* June 1931, 771-778.

[13] Pond, 771.

[14] Understandably, the ideal Student Union was rarely achieved because of practical constraints, but schools likened variability to a well-tailored suit designed for a specific student body.

[15] National Center for Educational Statistics, "Higher Education," *120 Year of American Education* (1993), 65.

[16] The Purdue Union is one of the few buildings of its era designed for men. By the 1930s most unions were created coed or become coed as the number of women students increased. After World War II, nearly all

new unions were coed, unless they were part of a single sex campus. See Edith Outzs Humphrey's, *College Union: a handbook on college community centers* (Ithaca, NY: Association of College Unions, 1951).

[17] "Purdue University Memorial Union Building" in *Architectural Forum,* June 1931, 713-16.

[18] Michael Hare, "Thoughts on Union Architecture." *Bulletin of the Association of College Unions* (February 1945), 1, 8.

[19] "Building Boom on the Way." *The Bulletin of the Association of College Unions* (July 1945), 5.

[20] Adell McMillan, in *A Common Ground: Erb Memorial Union 1950-2000* (University of Oregon, Eugene, OR: Xlibris Corporation, 2003) recounts the early history of the Oregon Union. Also see *Ellis Lawrence Building Survey*. v.2 (Eugene), compiled by the Historic Preservation Program, School of Architecture and Allied Arts, University of Oregon (Salem, OR: State Historic Preservation Office, 1989); and the *Erb Memorial Union Preliminary Historic Assessment*, compiled by the Office of Campus Planning and Real Estate at the University of Oregon (Eugene, OR, 2011).

[21] The University of Oregon hired Dan Cooper of Dan Cooper Interiors, Textiles, and Furniture of New York City as an interior design consultant. Adell McMillan pointed out that it was he who selected modern, low maintenance furnishings for the Union's most important spaces, and he who believed respectfully furnished spaces led to respect and care of a building (Adell McMillan, *A Common Ground: Erb Memorial Union 1950-2000* (University of Oregon, Eugene, OR: Xlibris Corporation, 2003), 51).

[22] Bill Frye, "Let's Look Inside the Student Union" in *Old Oregon* No.2 Vol.32 (December 1950), 19-22.

[23] National Center for Educational Statistics, "Higher Education," *120 Year of American Education* (1993), 66.

[24] See specifically published statistics published by the National Center for Educational Statistics, "Higher Education," *120 Year of American Education* (1993). Protests still occur on college campuses.

[25] ACUI, *Fifty-one Facts about College Unions* (Indiana: Association of College Unions International, n.d.), p1. Although the publication is without a date, as recently as 2015 it was printed and for sale by the Association of College Unions International.

[26] Original document used bold type-face instead of italics and quotation marks are original to ACUI's *Fifty-one Facts about College Unions*.

Irem Oz, Alexandra Staub

The Tale of Two Mosques: Marxloher Merkez Mosque vs. Cologne Central Mosque

The tale of two mosques: Marxloher Merkez Mosque vs. Cologne Central Mosque

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On October 2008, the biggest mosque in Germany at the time was opened in Duisburg's Marxloh district. In addition to its size, what distinguishes this building from other mosques in Germany was the lack of protests against the construction of this building. On the other hand, in Cologne, just 40 minutes away from Duisburg, the construction of the Cologne Central Mosque was faced with so many disputes that its opening has delayed by 10 years, opening in June, 2017 in spite of the fact that both project were started around the same time. This paper presents two stories: the success story of the DITIB commissioned Marxloher Merkez Mosque and problems surrounding the Cologne Central Mosque. Through this analysis and a theoretical framework based on the notion of visibility, the aim is to investigate the factors that contribute to the successful reception of the mosque by the public through an exhaustive contextual analysis. I theorize that three factors enabled this positive reception of the mosque. These factors are: (1) the architecture and local context, which contributes to the visibility of the mosque (2) urban design process of the mosque, which plays a role bringing different actors together and (3) the politics of visibility which was framed through the self-presentation and the reception of the mosque by the media. I argue that although the Marxloher Merkez Mosque project compared to the Cologne Central Project is perceived as a successful project that managed to overcome the risks associated with social conflict, this "Miracle" of Duisburg only provides social cohesion on the surface and leads to "self-orientalism" and further alienation.

Keywords: Turkish diaspora in Germany, Cologne Central Mosque, Marxloher Merkez Mosque

1. Turkish mosques beyond the visibility-representation nexus

Today, wherever one looks, Islam - and whether it belongs to Germany or not – stirs a heated debate ("Is Islam Changing Germany" 2017). Before 2015, Germany had already been home to over 4 million Muslims, most of whom came from Turkey after World War II. Even before the start of the contemporary refugee crisis, the debate on Islam and its place in Germany was framed around a Turkish population that had not been well-integrated into the German society. Today, many Turks prefer to live in social (and spatial) enclaves within big cities, where the dominant language is Turkish rather than German and attend mosques that are operated by DITIB - Turkish-Islamic Union for Religious Affairs, an organization linked directly to the Turkish Government Authority for Religious Affairs (Su 2017). This involvement of the Turkish government - and its self-defined role as the administrator of Islam in Germany - has been shown by scholars and politicians as one of the most important factors preventing Turkish Muslims from integrating into German society (Kern 2017).

The involvement of the Turkish government in the administration of Islam is closely related to the legal status and accommodation of Islam in Germany. European nation-states' handling of Islam, the minority religion, differs substantially as the institutionalization of any religion builds upon the pre-existing patterns of church-state relations (Bader 2007, König 2007). Especially in Germany, the institutional position of Islam is very underprivileged. Christian churches and Jewish synagogues in Germany have formal status as corporations according to public law. This status allows them to profit from the taxes collected by the state. As Muslims living in Germany do not have such an organizational structure, German authorities do not grant Islam the same legal status (Fetzner & Soper 2005). For this reason, Islamic organizations in Germany remain disadvantaged compared to the established churches as they lack legal recognition and financial support (Fleischmann & Phalet 2012). Nielsen (2004) explains the operational structure of Islam in Germany. Since Islam is not a formal religious community recognized by the state, the religious associations operate under the category of registered associations (*eingetragener Verein, e.V.)*. Unlike the Jewish, Catholic and Protestant communities that work closely with state authorities and are included in the decision-making process in the areas of education, welfare and health, the lack of a legal recognition prevents Islamic associations from taking part in the policy making process (Tol 2008).

Although the Turkish government has been sending imams to Europe since 1975, it was not until the establishment of DITIB in 1984 that efforts to organize the religious life of Turkish immigrants took effect (Pederson 1999, 26). DITIB denies links to any official or private organizations and defines itself as an independent umbrella organization, however, it is the Turkish government's extension for religious affairs abroad and relies on financial support from the Turkish government. DITIB works under the Directorate for Religious Affairs, which is a part of the Turkish prime minister's office. The organization is responsible for delegation of imams and employees abroad and these employees have the status of civil servants of the Turkish Government (Tol 2008). The imams are sent abroad temporarily and replaced every four years. DITIB functions through 14 state level organizations and 930 registered cultural associations (e.V.) that also act as mosques and follow the official Turkish view of Islam ("*Hakkımızda*" 2017). The role of the Turkish government as a major religious organizer or even the administrator of Islam in Germany has served to further alienate an important section of the Turkish immigrant population who still lack basic citizenship rights despite their long presence in the country. Because Turkish immigrants do not have the right to vote unless they have acquired German citizenship, Islam and Islamic organizations have become the only platform to voice social grievances within German society (Tol 2008). Within this sphere of limited rights, mosques mark the unmistakable presence of Islam in Germany and provide Turkish people their *right to the city*.

Lefebvre argues that the true citizens of a place are those who use the space daily, however the ethnic Turks living in Germany have been denied their "right to city" as they remain marginalized the German society (1996). Pollack concluded that this feeling of not being accepted is expressed through the passionate defense of Islam as an attempt to be a part of a group (2016). As Lefebvre affirms that the struggle for "right to city" remains symbolic until it is given a material form, the "right to the city" in this case is claimed by appropriating the urban space through mosque spaces. As the presence of Turkish-Germans cannot be asserted through formal means, such as work or social participation, they exercise their "right to city" in *alternative publics* which are neither public nor private spaces where participation is closely related to the sense of comfort and belonging (1996). The increasing mosque attendance among Turkish-Muslims in Germany shows that mosque spaces are being transformed into such "alternative publics" where Turkish-Muslims find new gendered ways of resituating themselves within that social space, appropriate the public space of the mosque, and negotiate their identities both as immigrants and Muslims within the context of the immigrant neighborhood. Spain also views the houses of worship and asserts that these "alternative places" straddle the divide between private and public while providing a platform to battle marginalization (2016). The Turkish diaspora mosques in Germany, whether they are adapted or purpose built, present excellent examples of these alternative publics by overlaying the material structure of the mosque with the social dynamics of identity politics.

Unlike their counterparts in Turkey, where are familiar elements of the urban landscape, the diaspora mosques in Germany function differently. Although mosques design in Germany is heavily influenced by trends in Turkish stylistically, the meaning and use of the mosques differ substantially in these two contexts. While mosques in Turkey only serve the purpose of religious practice, their counterparts in Europe become social and physical spaces where Turkish immigrants can organize around a common identity (Tol 2008). Muslims in Europe often redefine themselves as minorities which in turn changes the religious practices and subjectivities of Muslims and repositions them in secular Europe. From the point of view of certain European collectives, this process is far from a quiet process of immigration, adaptation and accommodation and the increasing Islamic presence in public life changes their collective memories and self-perceptions. Islamic signs and symbols in the European landscape become more and more visible, and become major sources of cultural and political controversy as they connote a visible expression of a local Muslim community spatially transgressing the invisible cultural boundaries of the German public sphere (Allievi 2009; Göle 2011). Disputes surrounding the increasing visibility of Islam in the urban landscape through the construction of diaspora mosques signals the reterritorialization of Muslims and reveals how the European public deals with cultural and religious difference (Göle 2011). This visibility of Islam is occasionally seen as shocking and shifts the public discourse from social and economically related problems to religion and citizenship issues. It is exactly this visibility of the purpose-built mosque that makes it the material symbol and center for conflict over whether Islam can ever be a part of European public life (Landler 2006).

With the increased visibility of mosques in European public space over the last three decades, the conflict over the place and meaning of mosques stems from the politics of visibility (Göle 2011, Jonker 2005, Bowen 2007). In the past, the religious activities of Muslims in Europe were confined to invisible and private prayer rooms, while today mosques publicly and visibly mark the presence of Islam (Es 2012). The public visibility of Muslims is informed by negative cultural associations related to Islam (Fekete 2004). Cheng's research on the discussions of minaret bans in Swiss parliament shows how these negative feelings attached to Islamophobia combines with national identity (2015). Islamophobia has been analyzed through paradigms of radicalization to explain cultural differentiation between Europe's Muslim religious minorities and its mainstream (Becker

2017, Bayoumi 2006, Elver 2012, Meer 2013). According to recent studies, the fear of Islam and Muslims among certain European citizens stems from a number of notions: presumed failure of prioritizing democratic values and ideals (Tyrer & Sayyid 2012, Romeyn 2014), different and unequal understandings of gender (Ewing 2008) and expected inclination towards extremism (Fekete 2004). In media, representations of Islam are dominated by these notions, creating a “publicly available” and shared grammar that might be understood as equating Islam with threat (Becker 2017, Said 1981, de Galembert 2005).

Although for Muslims, a mosque is not only a place of worship but also a cultural space of religiosity and sociability that is reminiscent of a familiar landscape, Göle refers to the “loss of innocence” of the mosques. Politicization of the mosque, especially after the 1979 Revolution in Iran, from where the revolutionary fervor spread, made mosques visible sites for the contestation of urbanism, pious politics and political Islam. In other words, mosques as religious public spaces cannot be confined to the boundaries of its community of believers. The mosque claims its visibility both in national and global contexts, contesting the existing separation between private religious and secular public fields; “between personal piousness and secular publicness” (2011). To conclude, mosques and their visibility signify a process of spatial transgression of Muslims into the European public which contests the secular and cultural norms of the host country. In this context, Islam does not only cross the geographical boundaries through immigration but also transgresses the invisible cultural borders of the European public space.

The following case studies of the Marxloher Merkez Mosque in Duisburg and Cologne Central Mosque show the complicated nature of the notion of visibility, demonstrating how the local context, public staging and performance of mosques within can have a very important effect on the reception of the mosque and become a symbol of inclusion or exclusion. Becker states that, although all mosques have a heavy symbolic weight on the society, what matters is their performance and concludes that “not all mosques are considered equal” (2017). While some mosques cause serious and lasting conflict, others blend smoothly into the existing social and physical pattern of the city. In this paper, by using two case studies in Germany, I discuss the factors that influence the public reception of the mosque. I argue that public acceptance of the diaspora mosque into the mainstream depends upon three factors: (1) the architecture and local context, which contributes to the visibility of the mosque (2) urban design process of the mosque, which plays a role bringing different actors together and (3) the politics of visibility which relates to how the mosque project was framed by the media and presented by the mosque organization itself and effected by their communication with the mainstream society.

2. The “Miracle of Duisburg”: Marxloher Merkez Mosque

Marxloher Merkez Mosque (*Marxloh Merkez Camii*), located in the northern section of the Marxloh neighborhood of Duisburg, is the largest mosque in the city built partly in classic Ottoman style (Fig. 1). Although the area where the mosque is situated is very accessible via the main business street, Weselerstrasse, the overall area has been faced with urban decline.

Marxloher Merkez Mosque, designed by the Turkish - German architect Cavit Şahin, is a much more direct depiction of the Ottoman style compared to other Turkish mosques in Germany. The external structure of the mosque is dominated by a dome structure that includes a central dome and four half-domes around it. The entrance hall is covered by five small domes placed relatively lower than the level of the central dome structure. The 23-meter-high dome is complemented with a single 34-meter-high “pencil form” minaret typical of the Ottoman period (Korn 2013).

Fig. 1. Marxloher Merkez Mosque, (“Merkez Moschee, Marxloh”, 2011)

Inside the mosque, there is a 40x28m praying area surrounded by a second-level mezzanine (Korn 2013) (Fig. 2). This second level mezzanine, *mahfil*, is reserved for the use of women for daily prayers and at important religious days, when attendance to the mosque by the congregation is much higher, it used by the men. The prayer room can accommodate 1200 people, 800 in the main prayer area downstairs and 400 in the women’s section upstairs.

Fig. 2. Marxloher Merkez Mosque ("Merkez Moschee, Marxloh", 2011)

Due to its foreign style, the mosque stands out from the rest of Marxloh's urban landscape with its minaret and ensemble of domes and half-domes. Although mosques are becoming a more familiar element in German cities, according to Gorzewski three characteristics of the Merkez Mosque make it a unique one (2015). The first feature is related to the size of the mosque. At the time of its opening in 2008, Merkez Camii was the largest mosque in Germany with its capacity of 1200-people.

The second characteristic of the mosque is related to the double character of the building, serving both as a place to practice Islam and as a community center. Although both of these functions are accommodated within the same space, they are run by organizations independent from each other. The building has a total usable area of 2500 m^2, 55% of which is used by the DITIB mosque organization for praying and the rest is attributed to the community center. While the community center functions to promote interfaith dialogue, it also serves as a community center for the local Turkish population, offering homework support for students, language courses and intercultural seminars (Gorzewski 2015). This establishment the mosque as an educational and meeting place along with its religious functions, signals the opening up of the Turkish community and Islam to the general population (Yılmaz 2010).

The third characteristic of the mosque that sets it apart from other mosque projects in Germany is related to its funding. The 7.5 million Euro budget of the construction project was equally shared between donations made to the local DITIB and the EU and the state of North Rhine-Westphalia (NRW) (Yılmaz 2010). Due to the fact that the construction of the mosque was financed partially by the subsidies of NRW and the EU (especially for the community center), the mosque project became one of the very few projects undertaken by an urban development agency (Winkel 2012). Since Islam is not legally recognized by the German government, to overcome the legal issues, the construction of the mosque was funded by DITIB and donations from the congregation while local authorities and the EU incorporated the project into the urban and regional development plan and funded the construction of the community center (Topçu 2009).

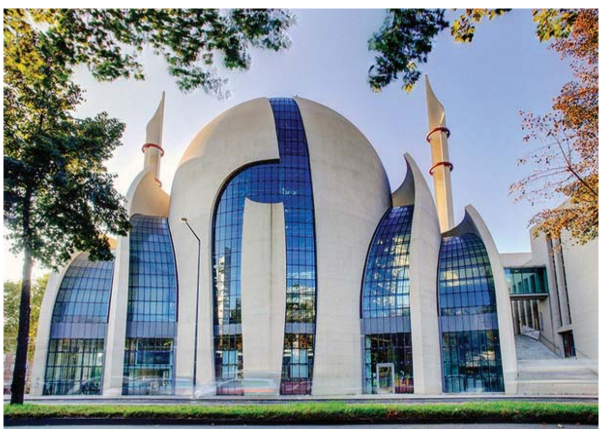
As one of the largest construction projects of DITIB, the Merkez Camii has a long history. Marxloh is characterized by its high immigrant population which is predominantly Turkish. Out of 20,500 people living in Marxloh, it is estimated that 13,500 of them have a Turkish background (Uslar 2017). The small backyard mosques, the former DITIB mosque which was established in an unused cafeteria space, was regularly overcrowded on public holidays (Gorzewski 2015), making it a not very favorable for religious use (Jenker 2008) and was becoming insufficient for the use of approximately 500 households (Ehrkamp 2007). The local DITIB was active in the area since its establishment in 1984, and decided that these makeshift prayer rooms were too small and they needed a new building. In 1997, DITIB proposed the construction of a classical Ottoman style mosque with the support of the local Turkish community. Being aware that such construction projects may become a source of anxiety in the district, the association's board of directors in Marxloh sought for cooperation with local administration, the Duisburg Development Union (*der Entwicklungsgesellschaft Duisburg* – EG DU), churches and other institutions. By 2002, an advisory council for the project was established with representatives from political parties, churches, local associations, neighborhood residents and businesses (Topçu 2009). The ultimate aim was transparency and openness. During the construction phase alone the project received 40.000 visitors, who wanted to learn more about Islam and the Muslim population of Marxloh. Although in 2006, this friendly and peaceful process was clouded by media reports on the involvement of the construction company's members in right-wing circles, the incident was almost forgotten by the time the mosque was opened in 2008 (Gorzewski 2015). Despite these problems related to its administration, Merkez Camii still functions as a religious, cultural and social meeting place, and continues to provide educational and interfaith dialogue programs to bring together people from different backgrounds.

3. DITIB's Mega-Mosque: Cologne Central Mosque

Cologne Central Mosque (*Marxloh Merkez Camii*), located in the north-western section of the Cologne city center, is the largest mosque in Germany built in non-Ottoman style with glass walls, two minarets and a dome (Fig. 3). The area where the mosque is situated is very accessible via the main business streets, Innere

Kanalstrasse and Venloer Strasse, which is the main reason of the controversy revolving around the construction of the mosque. The designer of the Cologne Central mosque, German architect Paul Böhm who specializes in building churches, planned the building as a domed structure with two minarets. The five-story domed-structure covers an area of 4500 m^2, which includes a bazaar, lecture and seminar halls and an Islam library in addition to the praying area. The praying area can accommodate up to 4000 people and includes a *mahfil* area in the gallery for the use of women. The 35-meter-high dome of the mosque is complemented with 55-meter-high stylized pencil minarets. Unlike the other DITIB commissioned mosques in Germany, the mosque does not mimic the traditional Ottoman mosque. Böhm aimed for an “open”, “inviting” and “light” mosque and designed the massive dome broken by glass shells to achieve this aim.

Although the Cologne Central Mosque project was initiated around the same time when Marxloher Merkez Mosque was started, the controversy surrounding the mega-mosque has delayed both its construction and opening. Just like in the case of Marxloh, the planning process of the Cologne Central Mosque has an even longer history which starts with the request of DITIB in 2001 and ends with the opening of the mosque in June, 2017. Cologne has the highest number of Muslims in Germany and usually referred to as the capital of Islam in Germany. Although there existed more than 40 backyard mosques and prayer rooms in the area, the lack of a large representative mosque caused small Islamic associations to be spread out in the city. In 2001, DITIB decided to demolish the old pharmaceutical factory that was used as mosque and served as the headquarters of the association and build a new mosque in the Ehrenfeld district that would answer the increasing demands of the mosque congregation. Unlike the approach that was adopted in the design of the Marxloher Mosque, DITIB opted for a different approach in 2005 and decided to organize an architectural competition with the support of the Cologne city government. The 30.000 Euro award competition required a modern urban building, not imitating the Ottoman mosque and had a jury that included DITIB chairs, Cologne Cathedral project architect Barbara Schock and politicians from the major parties in Cologne. As soon as it was announced that Böhm’s design was the winner, the debates about the mosque has begun (Gorzewski 2015).



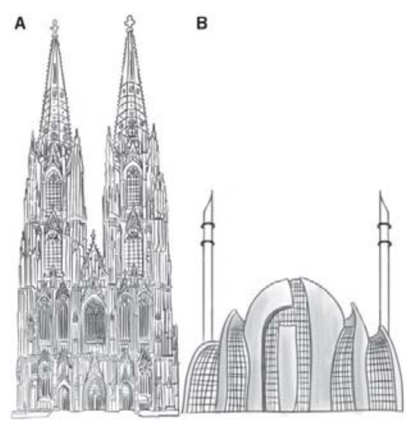


Fig. 3 and 4. Cologne Central Mosque and the sketch portraying its size in relation to Cologne cathedral (Becker, 2017)

The first round of oppositions was about the architectural design of the mosque. The size of the dome and the height of the minarets ignited the criticism on the grounds that the mosques appears too strong in the Cologne urban landscape and feared that it would cast a shadow on the Cologne Cathedral (Fig. 4). Böhm and DITIB opposed to those criticism by claiming that the office buildings and the nearby TV tower are much higher than the minarets. Over the years, the shape of the minarets and the dome has changed but the height of the minaret remained the same. The second round of oppositions came from the author Ralph Giordano, the district mayor Jörg Uckermann, right-wing groups and Pro-Cologne group on the grounds that construction of the mosque would transform the neighborhood into a Turkish ghetto and empower the Muslim population (Haeusler 2008). By 2007, the tone of the conflict was shifted from a debate on the Cologne Mosque towards debate on Islam in German society. While Uckermann voiced his belief that the residents should reject the mosque as Cologne is a “Christian city”, Giordano claimed that the mosque represents “the creeping Islamization” of Germany (Harris 2007). The protest of these authors and politicians were effective to arouse emotion among the Cologne people to have a mosque built in their Christian city. The surveys showed that only 30% of the population of Cologne was in favor of the mosque.

By 2007, in the face of possible right-wing extremist protests, to ameliorate the heavy criticisms, a mosque advisory council was formed in Cologne as well. It included the then-mayor Schramma, representatives of the churches and Jewish community, members of the city administration and the political parties. Together with DITIB chairs, a decision was taken to build a smaller mosque which is in line with German democratic ideal, which gave way to the beginning of the construction phase in November, 2009. Unlike the ground-breaking ceremony of the Marxloher Mosque, German politicians refused to take part in the ceremony, showing their opposition and clearly distancing themselves from the project (Gorzewski 2015). After the start of the construction, the project was first suffered from financial problems, as the costs got out of hand. Unlike Marxloher Merkez Mosque, Cologne Central Mosque was funded fully by DITIB itself, not relying on any public funds from Germany or Turkey. The project also suffered from DITIB's attempts to scapegoat Böhm with the allegations that he caused massive constructed defects responsible for bankrupting the project, drew further media attention to the failed public status of the project. The mosque project was finally completed by 2016 and the mosque was opened in the June of 2017 (Becker 2017).

4. Discussion: What makes a miracle? Or an illusion?

Today, in Germany, the increasing number and visibility of mosques has become an undeniable phenomenon. The minarets of the mosques have started to join the cathedral towers and high-rise buildings in the German landscape and become a part of the urban silhouette. So far, this paper has presented the stories of the Marxloher Merkez Mosque and Cologne Central Mosque, both located deep in the belly of North Rhine Westphalia, and present exceptional examples of how Muslim identity became (in)compatible with the German mainstream. Here the actors included in the design process accomplished a politics of positive visibility through three main factors.

The first factor that contributed to positive visibility of the Marxloher Mosque is related to the local context and architecture. Although the mosque is much larger compared to other Turkish mosques in Germany, physically it remains quite invisible due to its location. Being located in an isolated area inhabited by a Turkish majority population undergoing a rapid urban decline contributed to the lack of public reaction (Alder 2008). On the other hand, Cologne Central Mosque has been located in a central area which would provide high levels of urban rent (Gorzewski 2015), the seemingly unprofitable location of the Marxloher Merkez Mosque did not raise any questions from the public. One of the main debates about the Cologne Central Mosque was related to the disputes over where the money gained from the shops and bazaar inside the mosque complex would be spent. On the other hand, the main issue that caused problems in the case of Cologne Central Mosque was related to symbolic decision of building an Islamic dome in the "Rome of the North", in the city that houses the most significant Catholic religious structure in Germany (Becker 2017, Lander 2006). The main cause of the debate was the fear of the dome of Cologne Central Mosque to cast shadows over the Cologne Cathedral which materializes in the height of the minarets of the mosque (Becker 2017). Furthermore, the architecture of the Marxloher mosque proved to be a tool of integration as it became symbol of openness and transparency, thereby contributing to the positive public reception. The mosque provided transparency through very large windows on its façade, a detail that diverges from traditional Anatolian style. Unlike disputes over the architecture of Cologne Central Mosque, whose dome and minarets would symbolically cast shadows over the Köln Dom and whose central location would start a process of "ghettoization" of the neighborhood (Becker 2017). The construction of Merkez Mosque in Duisburg became an exemplar project showing successful planning and communication, which can also be seen from lack of resistance and reservations from local German population, making the mosque "the miracle of Marxloh".

The second factor that made the Marxloher Mosque a successful project is related to its design process. According to Küçük, the participatory work of the advisory board, the "transparent funding" and the endorsement of the project by different parties created a friendly atmosphere and a sympathetic attitude around the construction project, in contrast to the ongoing mosque project in Cologne (Gorzewski 2005). According to Becker, during the design process of the mosque, neither a clear leader came forward to present the mosque project to the public, nor did the planning board engage in public debates to address to the public concerns that might arise from perceived differences (extremism, ethnic exclusion and the role of women). Becker (2017) even addresses the difficulties she encountered related to the "opaqueness" of this design process while researching. She failed to find any information related to the controversy around the Cologne Central Mosque and whenever she could, the failure of the mosque was blamed entirely on outsiders, especially on the architect, Paul Böhm who was dismissed as the project construction manager in 2011. As can be seen, while the participatory design process of Marxloher Merkez Mosque made it a successful one, the reluctance to include representative actors from different segments of the community caused the failure of the Cologne Central Mosque. This second factor is also related to the funding process. Marxloher Mosque, became almost an urban project that brings the local-government and DITIB together, as it received funding from both however, Cologne Mosque relied solely on the funding from DITIB itself, raising further suspicions on DITIB being the long-arm of the Turkish government.

The last factor that contributed to the social cohesion framed around Marxloher Merkez Mosque is related to the media reception and self-presentation. At the time of its opening, city marketing also contributed to bringing the community together by a media campaign and the slogan “Made in Marxloh” referring to the participatory planning process that brought different coexisting groups in Marxloh together (Winkel 2012). Although the reaction that Merkez Camii received from the public and politicians was a positive one, as mentioned before this peaceful process was shadowed by the conflicts within the mosque association itself in the later years. The rising conflict between conservatives and liberals in Turkey also caused tension within the Turkish diaspora in Germany and the mosque association itself, resulting in the resignation of the chairman of the mosque association, Özay, and dismissal of the press representative Küçük in 2009. Özay’s view of liberal Islam was criticized extensively by the conservative group within DITIB (Gorzewski 2015). By 2010, DITIB declared that the conflict within the administration was settled (Klinkhardt 2010). The effective staging and performance of civic ideals – loyalty, participation and transparency – in the case of Marxloher Merkez Mosque highlights the absence of these ideals in the case of Cologne Central Mosque even more. By being open about the disputes even within the advisory board of the Marxloher Mosque and its transparent self-presentation, the design process did not encounter much negative reaction from the media and public. On the other hand, the opaque approach of the Cologne Mosque board, the dispute between the board and Böhm, show the absence of the German civil ideals, loyalty, participation and transparency, that were effectively performed in the case of Marxloher Mosque (Becker 2017).

Although the Marxloher Merkez Mosque project is perceived as a successful effort that managed to overcome the risks associated with social conflict, I argue the “alternative public” that “Miracle” of Duisburg creates, only provides social cohesion on the surface and leads to what Batuman defines as “self-orientalism” (2016). With its distinctive architectural style, the mosque stands out in the urban landscape, working as a signifier of the Turkish-Muslim presence in the area. The architecture of the building with strong references to 16th century Ottoman mosques has major implications for the people living in the area. For the Turkish people, the mosque connotes a Turkish-Muslim identity, not a Turkish-German one and due to its performative nature, the mosque causes Turkish people to identify themselves with their old Turkish and Islamic characters, not with the Turkish-German identity which was aimed to be achieved through integration, resulting in a self-othering process. In this way, rather than becoming a symbol of integration as intended, it remains a representation of Turkishness, causing Turks to identify themselves as others in the Marxloh landscape. The other implication is related to the perception of the mosque by the German population living in the area. Although the mosque was designed to promote integration, because it embodies only Turkish elements in its design, it pushes the German population further away as it fails to address the German audience. For the German people living in the area, the mosque remains a foreign building due to the lack of familiar architectural elements. Such a distinct representation is only attractive for the Turkish population living in the area, pushing the German population further away both physically and socially. In addition to this, because the mosque represents a conscious identification with the stereotypical Turkish Muslim identity it disrupts the shared collective imaginaries and self-perception of Germans (Göle 2011). Seyran Ateş, a Turkish born lawyer and women’s right activist also warns against the exaggerated expectations regarding the integration-promoting effect of the mosque in Duisburg. Parallel to Batuman’s argument on self-Orientalism, she expresses her fear that such a community center would function as a socialization center among Turkish people, thereby contributing to the consolidation of a parallel Turkish society through the “alternative spaces” constructed by the mosque and provide no social and cultural exchange with Germans.

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The "Tate Effect" on the South Bank: Urban Regeneration through the Bankside Urban Forest

Regeneration through the Bankside Urban Forest

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ABSTRACT: Opening in 2000, the Tate Modern presented a compelling type of museum building. Housed in a former power station, the industrial character of the original structure was maintained, even celebrated, in the conversion. In addition to providing much needed space for the Tate's growing twentieth-century art collection, the transformation of the building into a museum of modern art was intended to have larger urban implications with the ambitious goal of stimulating regeneration in South Bank, "the Cultural Heart of London." As a flagship of the South Bank's Millennium Mile and directly linked to St. Paul's Cathedral by the new London Millennium Footbridge, the Tate Modern would infuse culture and money into a depressed part of London.

In the decade and a half since the publication of Richard Florida's *The Rise of the Creative Class* and the opening of the Tate Modern, the role of culture in urban reimaging efforts has been exploited, debated, and problematized. This paper explores select exemplars of the spillover benefits of the Tate Modern's success and positive externalities that produced modest and sometimes ephemeral installations that breathed new life and joy into the South Bank. Considered through the lens of educational reformer and philosopher John Dewey's call to reposition art within the realm of the everyday, the Tate multiplier effect is considerable. In particular, works created within the *Bankside Urban Forest* framework, a collaboration-driven initiative of Better Bankside Business Improvement District, are foregrounded as remarkable and authentic examples of how a design framework can employ urban heritage, contemporary art and design, and ecological expertise to generate urban improvements at all scales. From these evidences, it is clear that the instrumentality of the museum is rightfully a strategy that should continue in public policy and museological discussions as governments attempt to curate architecture, heritage, and history in urban regeneration initiatives.

KEYWORDS: museum, regeneration, multiplier effect, spillover benefits

INTRODUCTION

Peter C. Rowe's 1999 book, *Civic Realism*, posits that urban spaces that are truly civic in character "belong to everyone and yet to nobody in particular." Rowe argues that a joyfully vibrant, viable civic space is

> …as much about the broad processes and attitudes behind civic place making as it is about urban architecture per se, and it reflects a concomitant belief that civic place making cannot occur successfully without a propitious conjunction of local opportunity, community wherewithal, and design capability (Rowe 6).

What is particularly compelling in Rowe's approach is how the process of urban "making" is foregrounded with a particular emphasis on community and the local context. In their research on neighborhood change and cohesion in urban regeneration policies in Liverpool, Richard Meegan and Alison Mitchell, identify 'place-based community' and the 'neighborhood' as appropriate spatial scales for understanding the operation of 'everyday life-worlds' (Meegan and Mitchell 2167). Quoting from the Social Exclusion Unit's report, 'Bringing Britain Together,' the importance of community bonds are further reinforced:

> The most powerful resource in turning around neighbourhoods should be the community itself. Community involvement can take many forms: formal volunteering; helping a neighbour; taking part in a community organisation. It can have the triple benefit of getting things done that need to be, fostering community links and building the skills, self-esteem and networks of those who give their time (Meegan and Mitchell 2168).

Participatory planning, local opportunity, design capability, community identity, and neighborhoods: all of these features come together in a productive way on London's Southbank. In particular, works created within the *Bankside Urban Forest* framework, a collaboration-driven initiative of Better Bankside Business Improvement District, are foregrounded as remarkable and authentic examples of how a design framework can employ urban heritage, contemporary art and design, and ecological expertise to generate urban improvements at many scales.

1.0 URBAN HERITAGE

In 2000, Tate Modern opened on the south bank of the Thames River. It was a primary feature of London's Millennium Mile, a mile-long stretch of riverbank stretching from the London Eye Ferris Wheel down past the Tate to the new Shakespeare Globe Theatre. The riverfront was renewed with a new pedestrian walkway, plantings, and the Norman Foster designed Millennium Bridge – a pedestrian suspension bridge linking the

Bankside, one of the oldest settled areas in London, offers an urban palimpsest with traces of its gritty history including brothels, the Globe Theatre (a replica of which was built in the 1990s), and a variety of industries including warehouses and docks. Bankside featured a power generating station since the late nineteenth century which was replaced in 1947 with a design by Sir Giles Gilbert Scott, the well-known architect of the Liverpool Cathedral and the Battersea Power Station. This monumental and impressive structure was in active service from 1953-1981 at which point it lay mostly unused for decades. Transformed into the Tate Modern by the Swiss architecture firm Herzog and de Meuron, the museum opened to great acclaim (Fig.1). The thoughtful adaptive reuse approach provides a memorable frame for the viewing of the modern collection. With its tall chimney and industrial skin, the Tate Modern provided a functionalist vernacular architecture; the perfect iconography for a growing museum brand.

Figure 1 Tate Modern. Source: tate.org.uk

As a canvas for contemporary art, the industrial building offered an ambience not unlike the loft spaces in which the works were produced, allowing for continuity in context. In addition, for some art genres, the juxtaposition of the pieces and the rough spatial frame offered a pleasurable sense of shock. This disjuncture between the culture of art and the raw or downbeat surroundings accentuated the experience of the art and provided an edgy contrast to the older structures (Williams 115).

In the Tate project, as with many other industrial adaptive reuse cultural initiatives since, the museum as an institution is instrumentalized to act as anchor, as well as beacon, for economic development. While the Thames riverfront saw considerable development for the millennium, one of the goals of the Tate project was to see the urban and economic benefits of the new museum permeate further into Southwark. This desire resulted in the Tate hiring Richard Rogers and Partners to develop an urban strategy that would complement the adaptation of the power station being designed by Herzog and de Meuron. While elements of the Bankside Urban Study were implemented, the study also laid the groundwork for continued efforts in Southwark, specifically the *Bankside Urban Forest*, an initiative involving many different planning agencies and community groups.

2.0 ROOTED IN PLACE: THE *BANKSIDE URBAN FOREST*

Figure 2 Bankside Urban Forest. Source: wwmarchitects.co.uk

The *Bankside Urban Forest* is an urban design and landscape architecture framework designed by the British architecture firm of Witherford Watson Mann (WWM). The name "Urban Forest" is a metaphor that evokes the network of streets, scattered open spaces and strong local identity of the area (Fig. 2). Unlike top-down masterplans, the *Bankside Urban Forest* advocates a "User Centered Design" approach to researching and designing urban projects. Using ethnographic studies as a guide, WWM worked with a historian to write a local history and had a photographer capture parts of Bankside that were of particular importance to the community. The framework included a number of illustrative projects including the creation of a Tate Modern playground and a planted arch, improved landscaping and pedestrian access, and the widening of several public gathering spaces including Flat Iron Square. The framework, instead of being prescriptive, is designed to manage incremental changes across Bankside. At a recent Greater London Authority regeneration conference, Alistair Huggett, a Project Manager in Southwark discussed the implementation of the *Bankside Urban Forest*'s micro-development strategies as tools of renewal:

> We did not approach Bankside with the 'dead hand' of master planning. You will not find anywhere a masterplan for Bankside. There has been much more of an organic approach to our way of dealing with the area. Architects must focus on people, not masterplans, if they want to reinvigorate failing town centers (Huggett).

Continuing the participatory agenda that emerged in the 1980s, the Bankside planning agencies and the Tate management considered not just the substantive value that design can play in a community, but also the value of a design process that includes the various stakeholders.

Bankside has seen tremendous growth since the Tate conversion. Emerging from the *Bankside Urban Forest* framework, landscape and streetscape improvements continue throughout the area bringing pockets of light, green, and activity. Mixed-use business and residential construction persist unabated with a consistent tempo of improvement despite the difficult economy in Britain. While not all of the projects are large in scale, the positive multiplier effect of the Tate Modern is indisputable.

3.0 IDENTITY: THE STREET AND NEIGHBORHOOD

In his 2002 seminal work, *The Rise of the Creative Class*, Richard Florida wrote about the powerful force of creativity that was shaping cities. Specifically, Florida focuses on creativity and diversity as the primary drivers of innovation and growth. His thesis is that creative people are drawn to and create vibrant civic spaces; spaces with a "quality of place" that emphasizes the hegemony of the street.

> The culture is "street-level" because it tends to cluster along certain streets lined with a multitude of small venues. These may include coffee shops, restaurants and bars, some of which offer performance or exhibits along with the food and drink; art galleries; bookstores and other stores; small to mid-sized theaters for film or live performance or both; and various hybrid spaces—like a bookstore/tearoom/little theater or gallery/studio/live music space—often in storefronts or old buildings converted from other purposes. The scene may spill out onto the sidewalks, with dining tables, musicians, vendors, panhandlers, performers and plenty of passersby at all hours of the day and night (Florida 182-3).

These clusters are expressions of cultural identity that enliven the street with music, art, and people.

Bankside is a place historically associated with bawdy entertainment. Nevertheless, in keeping with Florida's emphasis on the street as the primary unit of a healthy civic space, the *Bankside Urban Forest* framework has been focused on incremental street-level improvements. One example of how the spillover benefits of the Tate Modern have energized the streetscape is powerfully illustrated in the Low Line project, an adaptive reuse initiative currently in development (Fig. 3). The Low Line, evoking Manhattan's High Line, focuses on the rail arches that have been part of Bankside's heritage for over 150 years. The multi-stage project aims to transform the public realm by opening up a walkway that runs along the base of viaducts.

3.1 The Low Line

As with many of the projects that have emerged from the *Bankside Urban Forest*, the Low Line is a simple idea – to work in partnership with local residents, businesses and community groups and Network Rail to reinstate the common spaces that run along the base of the viaduct, connecting London Bridge with Waterloo stations through a traffic-free route. Historically the viaduct that extends between these two stations has contributed to the segregation of the urban interior at Bankside from the active river edge. The route which runs adjacent to the arches, once provided easy pedestrian access across Bankside but development, both planned and informal, has blocked access along its length.

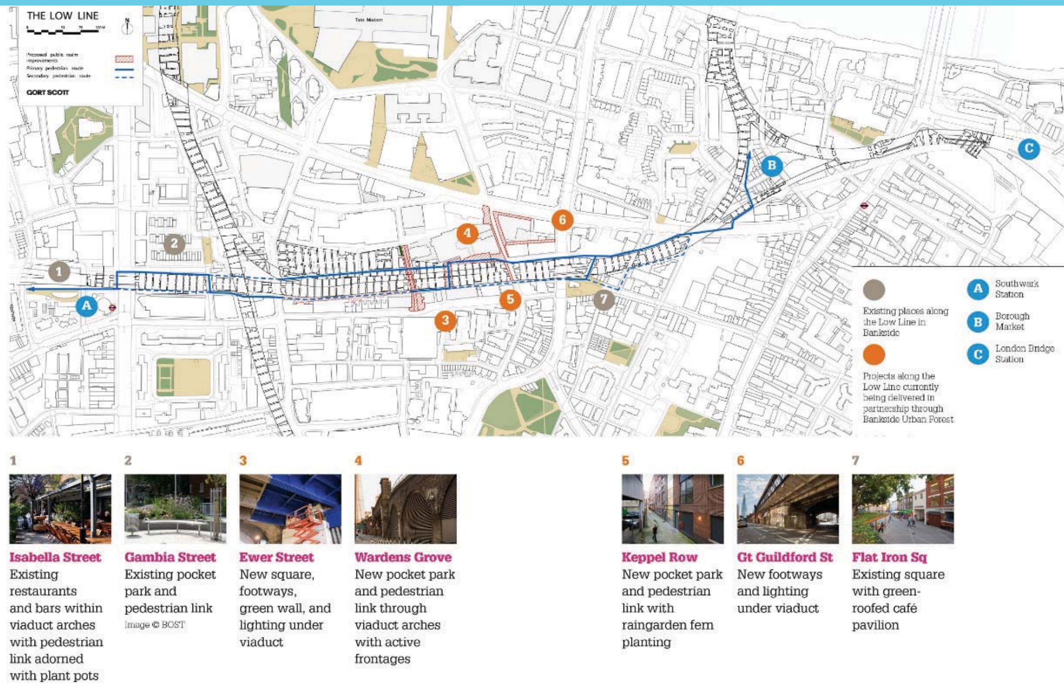

Figure 3 The Low Line. Source: todolist.org.uk

The Low Line design will stitch these disconnected spaces back into the urban fabric through a range of large and small projects. With Better Bankside's push for an ecologically sound and artistically resonant streetscape, the Low Line project aims to bring economic, social, and environmental vitality while developing a strategy that allows for the creative and sensitive regeneration of the arches, coupled with an ambition to bring creativity and vitality to the public spaces that run along the base of the viaduct.

4.0 ART AS CATALYST, ART AS EXPERIENCE

While visitors in the first decade of the Tate Modern might best remember the immersive and spellbinding impact of the Unilever Series installations – featuring artists including Anish Kapoor and Rachel Whiteread – in the sublime space Turbine Hall, outside the walls has experienced equally powerful changes that can be read as extensions of those museum-sanctioned creative exploits. In an effort to capitalize on the success of the Tate Modern, the Better Bankside Business Improvement District, worked to extend the revitalizing power of culture deeper into the borough of Bankside through a multi-pronged approach involving partners engaged in all aspects of urban living. Specifically, the stated mission of Better Bankside is to "improve the public realm" and **"**to make Bankside a thriving place to work, live and visit." From art installations to green walls and botanical gardens to pop-up business ventures and sustainability ventures, the *Bankside Urban Forest* projects demonstrate over and over again the positive multiplier effect of the Tate Modern.

American social philosopher and educational reformer, John Dewey, argued for the repositioning of art within the realm of the everyday. As "carriers of meaning" art had the potential to profoundly affect daily life and to bring joy and connectedness.

> In art as an experience, actuality and possibility or ideality, the new and the old, objective material and personal response, the individual and the universal, surface and depth, sense and meaning, are integrated in an experience in which they are all transfigured from the significance that belongs to them when isolated in reflection (Dewey 301).

A key aspect of Dewey's argument in *Art as Experience* was that engagement with art was fundamental to progressive social goals and to cultural improvement.

4.1 Colourful Crossings

Encounters with contemporary art and design have also been leveraged with significant success in Bankside. A recent series – Avenue of Art: Colourful Crossings – which launched in 2016 and is ongoing, saw the introduction of public art into the streetscape in a very direct way. "The aim of the Colourful Crossings commission is to explore how everyday infrastructures in the city, such as pedestrian crossings, are perceived and can be transformed" (Better Bankside). In this project, Better Bankside commissioned three international artists to bring color and animation to Southwark Street. The goal was to take art out of its traditional gallery contexts and use it to transform public spaces. The Avenue of Arts initiatives include:

- Commissions in the public realm will contribute to the creation of a lively and multi-faceted urban environment, which re-tunes the 'place' functions of Southwark Street over the 'movement' functions.
- Commissions will contribute to Bankside's identity and create a cultural content that will give a sense of co-ownership to the diverse groups of people who work, live and visit the neighborhood.
- Commissions will strengthen the ties between public realm projects and cultural activities both locally and more widely.
- Art will be supported for its own intrinsic value as art.(Better Bankside)

One of the first Colourful Crossings was a temporary, interactive art installation, "Performer," by the New York artist Adam Frank. Visitors to Bankside received a spontaneous round of applause as they pass under the railway bridge at the junction of Redcross Way. The more movement, the louder the applause, encouraging people to dance and interact further with the installation. If the viewer is still, the virtual audience calms and eventually goes silent except for an occasional cough. When the viewer leaves the illuminated area the viewer hears applause proportional to the total amount of movement in that session.

Figure 4 Colourful Crossing. Source: betterbankside.co.uk

A second Colourful Crossing are the semi-permanent installations called the "Crossing Stories" – a series of vivid graphic image applied to the streetscape outside the Menier Gallery. This series of pavement applications have completely transformed a pedestrian crossing. One resembles a playful board game on the pavement, another is composed of pictograms associated with Bankside urban history. "The ballet of the good city sidewalk never repeats itself from place to place, and in any one place is always replete with new improvisations" (Jacobs 50). The streetscape is now host to endless possibilities of energy and encounter.
The most recent design, installed in 2016, is by the artist Camille Walala (Fig. 4). In these works, Walala's signature graphic style is applied to pedestrian crossings along Southwark Street. As one of the busiest streets in Bankside, Southwark Street can sometimes be a barrier to people exploring the neighborhood. "We want to make Bankside a better place to live, work and visit," said Donald Hyslop, Head of Partnerships at Tate and Chair of Better Bankside. "The Colourful Crossings project will transform the public realm to the benefit of the local businesses and visitors to the area. We aim to draw footfall further south from the busy riverside stretch, encouraging people to explore Southwark Street and discover Bankside's full cultural offer" (Better Bankside). Tasked with reimagining the everyday experience of crossing the road, Walala used bold colors and shaped to delineate the crossing zone. The project aimed to increase pedestrian footfall along the street, changing the way it is used and perceived by the public and motorists. Evaluation from the Colourful Crossings delivered to date have found that nearly 70% people felt happier as a result of the creative project, and 85% wanted to see more creative projects along Southwark Street (Better Bankside).

5.0 ECOLOGICAL INSERTIONS

A forest is a place with a strong overall character, which allows diverse activities, freedoms and places within it. The aim of the *Bankside Urban Forest* is to achieve this quality in a city context. The strategy is not literally to turn the area into a forest, although it does create opportunities for greening, using trees, planted walls, and other means (Bankside Urban Forest).

5.1 Bankside Urban Orchard

Commissioned by The Architecture Foundation and built by the Bankside Open Space Trust and hundreds of volunteers, the Bankside Urban Orchard was a temporary installation part of the London Festival of Architecture in 2010. Designed by the American landscape architect Heather Ring of the Wayward Plant Registry, the project transformed a derelict site into a public garden with planters, raised garden beds, and a

Figure 5 Bankside Urban Orchard. Source: architectsjournal.co.uk

timber pavilion (Fig. 5). The pavilion was presented by the Finish Institute and designed by students and in-house architects from the Aalto University Wood Program. Constructed from reclaimed materials, fruit trees, and plants, the orchard became the site of a series of workshops and discussions on urban agriculture and biodiversity, a plant adoption and exchange program.

A point of particular interest is that the Wayward Plant Registry organized and ran the 6-week community build where they taught local volunteers skills in gardening and carpentry. In addition to the educational objectives which were handsomely met, the Urban Orchard hosted film screenings, musical performances, and local community gatherings. At the end of the summer, the garden was dismantled and all the trees were given to local estates and other community gardens to remain as a lasting legacy of the project. As a place for encounter and a "meanwhile space"- a redundant space temporarily brought into productive use – the Bankside Urban Orchard is a potent exemplar (Meanwhile Space).

Reclaiming and animating disused corners of Bankside is a key component of *Bankside Urban Forest*'s strategy to enhance the area. A recent green infrastructure audit of green spaces and assets in the Bankside neighborhood which was carried out by Better Bankside and the Ecology Consultancy highlighted a range of opportunities for increasing green cover in the area in line with Mayoral targets. The Mayor of London is working to increase green cover in London by 5% by 2025. In Bankside they are working to exceed these targets through initiatives like *Bankside Urban Forest* and the Bankside Neighbourhood Plan. In 2017, Bankside applied for and was awarded funds from the Mayor of London to focus on a "Clean Air Mini Neighbourhood" (Giordana).

Figure 6 Verdant Viaduct. Source: betterbankside.co.uk

5.2 Verdant Viaduct
A green effort that spearheaded these most recent successes can be seen in the 2013 Verdant Viaduct project, funded by Network Rail and Skanska. Unlike the transient Bankside Urban Orchard, the Verdant Viaduct project is a longstanding initiative seen as an important step in improving the ecological health of Bankside. This effort transformed an existing masonry viaduct in Borough Market into a green wall; a piece of green infrastructure to improve the public realm in Bankside (Fig. 6). The access stairwell on the viaduct on Stoney Street was transformed into a lush green wall featuring nearly 200 plants. The wall was created by building a modular frame on the existing access stair to the new railway viaduct. The planting was performed over a number of weeks by the vertical garden specialists Treebox and is continually maintained.

CONCLUSION

It has become increasingly important in recent years for public museums and galleries in Britain and elsewhere to justify their share of government funding by demonstrating that they function for the benefit of a broad public rather than a privileged few. At the same time, museums have come to be seen not simply as more or less worthy recipients of subsidy, but as potential generators of income for the communities in which they are located. The museum that does not prove an outcome to its community is as socially irresponsible as the business that fails to show a profit. They are crucial to the cultural policies adopted by many local governments and other official bodies in order to improve the quality of life in the city or region, and to promote economic growth.

To create the *Bankside Urban Forest* framework, the designers worked with local constituents and groups to find common needs and a productive vision for future urban development and improvement. Resonating with Rowe's call for a "civic realism" focused on people and the process of making, the framework is especially notable for its focus on community involvement, an approach favored by the Tate leadership. As an institution, Tate Modern has been very active in its outreach activities. It plays a significant role in its locality, working closely with other employers businesses and community organizations. It has been actively involved in developing in tourism and marketing initiatives (Bankside Marketing Group) and the development of the business sector (Better Bankside, Tate Trustees, 2002: 20). Not satisfied with simply opening their museum, the Tate simultaneously set into motion the urban studies and evaluations that would result, ultimately, in the *Bankside Urban Forest*. The resulting framework, intentionally not a masterplan but instead a guiding force, has been implemented in myriad ways big and small, permanent and ephemeral, to improve the quality of life for Bankside inhabitants. From the select design exemplars presented here, it is clear that the instrumentality of the museum to bring joy is rightfully a theme that should continue in current public policy and museological discussions as governments attempt to curate architecture, heritage, and history in urban regeneration initiatives.

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Design Thinking for the Global Community in an Era of Disruption

Design Thinking for the Global Community in an Era of Disruption

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ABSTRACT: What can the entrepreneur's version of design thinking teach architects practicing globally in an era of disruption? A literature survey and comparative analysis of design thinking in architecture and the business community leads to a set of recommendations for architectural educators preparing students to enter a rapidly changing, globalized practice environment. Two aspects of design thinking particularly relevant to this endeavor are teamwork and problem definition.

Architectural projects often begin with a defined problem that embodies its solution. Typically, a client seeks an architect when the organization has determined that it needs a building. The architect's design challenge contained within that solution space. Programming process refines that design challenge by defining elements, qualities, and performance requirements of any potential solution. Programming may be performed by the design architect, but often by a consultant, and considered additional services. Consequently, architects often enter the scene after the problem has been defined. Design thinking in architecture tends to focus on individual cognitive processes.

By contrast, the entrepreneurial community stresses the importance of discovering the right problem to solve. The foundation of this process is empathy; the underlying theory is that a product or service will only be embraced if it addresses the needs, desires, and emotions of its users. The next step is to define the problem, based upon insights gained through empathizing. At this point in the process, the solution is still far in the distance. Defining the problem is like discovering a research question in what Herbert Simon termed the science of the artificial (Simon 1996), pursuit of knowledge about what might be. Entrepreneurial design thinking tends to focus on collaborative process and value of diverse teams.

Lessons from this form of design thinking can prepare students for a practice environment characterized by diversity and disruption of familiar institutions and typologies.

KEYWORDS: design thinking, programming, architectural education, globalization, disruption

INTRODUCTION

Two current forces, globalization of practice and disruption of business models, are transforming the environment of architectural practice. Once a profession of the elite for the elite, the profession and its clientele began to democratize in the early twentieth century. The growing globalization of the architecture profession and its markets amplifies the magnitude of the issue that architects increasingly work with and design for people unlike themselves. Architects work in diverse teams, sometimes virtual teams that collaborate across countries and continents. And they may serve clients and users around the world. Architecture students need to develop cross-cultural capacity in order to succeed in this globalized practice context.

The era of disruption offers both challenges and opportunities to the architecture profession. Disruptive innovation is changing industries and institutions – and the architectural typologies that have developed to house them. For example, consider how Amazon's leadership in online retail has led to the closing of physical stores and the death of malls, transforming urban fabric and suburban landscapes, and offering opportunities to repurpose and adaptively reuse those places. And, consider how Airbnb has transformed the concept of travel lodging, challenging the hotel and motel typologies by adding a flexible network of accommodations that challenges notions of what is public and what is private. This disruption challenges the nature of the architect's role. Scott Simpson sees this change as follows:

> While architects have traditionally seen themselves primarily as creators of static objects called buildings, buildings are never really static. They are teeming with human activity, constantly changing and adapting to the needs of their occupants. Disruptive technology opens up all kinds of opportunities for architects and engineers to be the designers of processes as well as places. (Simpson 2014)

Architects, therefore, become the designers of settings for change. And, their responsibility to their clients and users of those settings is not necessarily to serve their espoused needs, but perhaps to challenge their assumptions, to search for the seeds of change in those industries and institutions, and to offer creative visioning expertise to move those organizations into the future.

For architects to succeed in global practice in the present era of disruption, they need to develop cross-cultural capacities that equip them to thrive on diverse teams, communicate with clients around the planet, and understand the needs of users beyond their own experiences. And they must use their design expertise to serve clients operating in a rapidly transforming environment, in which envisioning the future may be a more valuable service than accommodating known needs. A form of design thinking popularized in the business community offers lessons for architects and architectural education.

We will briefly survey the literature of design thinking for architecture and entrepreneurship to identify the divergence of perspectives and identify the concepts relevant to practice in an environment characterized by globalization and disruption.

1.0 THEORIES OF DESIGN THINKING IN ARCHITECTURE AND ENTREPRENEURSHIP

1.1. The term design thinking

Design thinking has divergent meanings in different branches of the literature. The term “design thinking” emerged out of a pool of alternate terms from the 1960’s onwards as architects, engineers, designers, social scientists, psychologists, computer scientists, and philosophers explored design. Although much of the literature of design thinking traces its roots to Herbert Simon’s *The Sciences of the Artificial*, first published as lectures in 1968 and as a book in 1969, the term design thinking does not appear in that work in which Simon discussed the science of design and the psychology of thinking (Simon, 1996). The first published instance of the term “design thinking” relevant to the field appears in Bryan Lawson’s book, *How Designers Think*, first published in 1980, in which Lawson devoted a chapter to exploring and explaining the modes of thought involved in design (Lawson 1980). Three years later, Donald A. Schon investigated the same subject in *The Reflective Practitioner: How Professionals Think in Action,* using instead the term “reflective practice” to focus attention on the way that design insight results from a feedback loop in which action is followed by thoughtful consideration that in turn leads to new action (Schon 1983). When Rowe wrote *Design Thinking* in 1987, he adopted the term “design thinking” without defining it or referring to its source (Rowe 1987). Rowe’s book firmly claimed the term “design thinking” for the discipline of architecture. Horst Rittel, who introduced the concept of wicked problems in design, used the term “design reasoning” in “The Reasoning of Designers” in 1988 to describe the mental process of designers (Rittel 1988). Richard Buchanan, in “Wicked Problems in Design Thinking” of 1992, united the terms “wicked problems” and “design thinking (Buchanan 1992).” Nigel Cross used “design thinking” as the title of his book, *Design Thinking*, of 2011 (Cross 2011).

Case studies in *Design Thinking* by Rowe and *Design Thinking* by Cross report behaviors of designers as evidence of their thought processes. Rowe chose three particular case studies “because they illustrate three different styles of design thinking.” (Rowe 1987) In each case, Rowe introduced the reader to a sequence of design activities in order to illuminate the underlying thought processes. He proceeded to survey the development of design process to gain insight into how architects think by interpreting the activities of design and surveyed architectural theory to offer insight into the source of ideas. Cross’s book alternates chapters of case studies with chapters of analysis. He described his search for insight as follows,

> My approach to trying to understand how designers think and work is research-based: I look for and report evidence that comes from observation, experiment, analysis, and reflection. My aim is to reveal and articulate the apparently mysterious (and sometimes deliberately mystified) cognitive and creative abilities of designers, that are common across many design domains. (Cross 2011)

While authors have used a variety of terms in their explorations of a theory of design, the one term that has developed the most traction in the field is “design thinking.” While general agreement seems to have emerged on the terminology, there is no consensus on the exact meaning of the term. All of the works discussed above consider design thinking as cognition. It is interesting to note that design thinking is taught as a topic by the faculty of Cognitive Science at the ETH Zurich and design thinking is an area of interest in cognitive science research (Alterman and Kirsch 2003).

Cross characterized design thinking as a cognitive ability, saying,

> The most significant outcome from the varied studies and research into design practice has been the growth of respect for the inherent, natural intelligence that is manifested in design ability. Early attempts to reshape the process of design into something more rational and systematic were founded perhaps on a disrespect for this natural design ability, and a strong desire to impose order onto design thinking." (Cross 2011, 29)

In this quote, Cross not only sums up the predominant credo of current thought on design thinking for architecture that the term design thinking refers to a cognitive ability of an individual. He furthermore repudiates the architecture discipline's scholarship of design methods that formed part of and related to the emerging discourse of design thinking in the 1960's and 1970's.

1.2. Teaching and learning design thinking

A result of this current view of architectural design thinking is that the practice of architecture is characterized by the absence of an explicit design process, consequent lack of agreement on what constitutes design methodology, and a general reluctance to bring this discourse into the open. This may be construed as a way of protecting the central mystery of the profession. It results in a form of architectural design studio education in which students are typically left to discover how to design.

The meaning of the term "design thinking" has taken on a new identity as a liberal art. In "Wicked Problems in Design Thinking," Buchanan heralded design thinking as a "new liberal art of technological culture." He identified the problem that the traditional subject matters of the liberal arts have narrowed in scope, proliferated, and become disconnected from one other and the concerns of daily life. Buchanan explained the potential for design thinking to address this problem as follows:

> The emergence of design thinking in the twentieth century is important in this context. The significance of seeking a scientific basis for design does not lie in the likelihood of reducing design to one or another of the sciences – an extension of the neo-positivist project and still presented in these terms by some design theorists. Rather, it lies in a concern to connect and integrate useful knowledge from the arts and sciences alike, but in ways that are suited to the problems and purposes of the present. Designers are exploring concrete integrations of knowledge that will combine theory with practice for new productive purposes, and this is the reason why we turn to design thinking for insight into the new liberal arts of technological culture. (Buchanan 1992, 5-6)

There are some important implications here. When design thinking becomes a liberal art, it emerges from the silos of the professional schools into the university at large and from the discourses of the design disciplines into the broader academic discourse. And, when design thinking is recast from a discipline-specific mode of cognition to a way of developing general intellectual capacity, it becomes a subject for general education. An example of an institution that has adopted design thinking as a liberal art is the University of Maryland, where the Academy for Innovation and Entrepreneurship teaches design thinking across the curriculum. And, design thinking is no longer just for design professionals, but for everyone. It is significant that it is design thinking, not design, that is the term of choice for the new integrative field. The design professions still maintain control of design, but design thinking has entered the public realm.

1.3. Design thinking: for architects or for everyone?

In *A Whole New Mind*, published in 2005, Daniel Pink reinforced the idea that design (he used the term design, not design thinking) is for everyone. He characterized design as one of the six senses, claiming that,

> In the Conceptual Age, we will need to complement our L-Directed reasoning by mastering six essential R-Directed aptitudes. Together these six high-concept, high-touch senses can help develop the whole new mind this new era demands." (Pink 2005, 65)

The concept of design as an aptitude is related to Cross's characterization of design as an ability. The key difference is that, while Cross views the ability as particular to designers, Pink advocates for everyone to develop that ability. The discourse of creativity addresses the ability to design. *The Universal Traveler*, by Don Koberg & Jim Bagnall, first published in 1974 offers an amusing travel guide for everyone to the realm of creative problem-solving, which the authors claim is "synonymous with design process" (Koberg and Bagnall 1974, 10). The concept that everyone is creative when they tap into their right brain was popularized by Betty Edwards in Drawing on the *Right Side of the Brain*, first published in 1979. Edwards drew the link between creativity and problem-solving and illustrated her point with an example of a designer at work:

> This is my major premise: having learned to *know* perceptual skills through actually using them in drawing will enhance your success in transferring your visual skills to thinking and problem solving…These visual skills are useful for problem solving of all kinds, in every field of human endeavor, from solving business or personal problems to enhancing general thinking about world problems (large scale) or local problems (smaller scale). More important, they can help you produce new and unique innovations of social value. (Edwards 2012, 248)

In *Creative Confidence*, published in 2013, IDEO founder David Kelley and his partner/brother Tom Kelley situated themselves within this tradition as they set forth their belief that “we are *all* creative” (Kelley and Kelley 2013, 3).

1.4. Design thinking: mode of cognition or methodology of action?

As design thinking has moved into the public domain it has undergone a shift from mode of cognition to methodology, from a way of thinking to a way of acting. In an article titled “Design Thinking” in the *Harvard Business Review* in 2008, IDEO CEO Tim Brown characterized design as,

> …a methodology that imbues the full spectrum of innovation activities within a human-centered design ethos…it is a discipline that uses the designer’s sensibility and methods to match people’s needs with what is technologically feasible and what a viable business strategy can convert into customer value and market opportunity.” In this definition, Brown shifts the territory of design thinking from thought to action. He also claims design thinking for the business community. Brown has recast design thinking from a way that design professionals think to a way that business people act.

IDEO essentially recast design thinking from a mode of cognition to a methodology. In *Creative Confidence*, David Kelley and Tom Kelley characterized design thinking as “a methodology for innovating routinely” (Kelley and Kelley 2013, 4). This seems to be result from a return to the earlier literature of design thinking that deals less with cognition and more with the activities of design. This particular statement, however, is particularly significant, because *Creative Confidence*, a *New York Times* Best Seller, has been widely read outside the design community. The Kelleys, partners in IDEO, a firm noted for expertise in branding, have effectively branded design thinking as a methodology.

This brief review of the literature of design thinking illustrates a shift from the use of the two words design and thinking in conjunction to the popularization of the term “design thinking.” In the discourse of architecture, design thinking refers to the way architects think during the design process. In the discourse of business, design thinking refers to the process itself.

1.5. Design process models

Architectural projects often begin with a defined problem that embodies its solution. Typically, a client seeks an architect when the organization has determined that it needs a building. The solution is the building; the architect’s design challenge contained within that solution space. Programming process is intended to refine that design challenge by defining elements, qualities, and performance requirements of any potential solution. Programming may be performed by the design architect, but programming services are often provided by a consultant, and considered additional services. Consequently, architects typically enter the scene after the problem has been defined. The architect’s project process is a series of iterations through which ideas are generated, represented, tested against client criteria, at increasingly greater scales and specificity, then translated into built form by a constructor under observation of the architect. The five process steps are known as schematic design, design development, construction documents, procurement, and construction administration (Architect’s Handbook 2014). The first three steps form the design process. They are essentially iterations of the same process, with design exploration increasing in scale and level of detail throughout the sequence.

The version of design thinking codified by the Stanford d.school faculty and popularized in the entrepreneurial community, on the other hand, promulgates a clear and simple process model with five distinct and clearly defined and modes of design thinking, Empathize, Define, Ideate, Prototype, and Test (Bootcamp Bootleg). And, it stresses the importance of discovering the right problem to solve. The foundation of this process is empathy; the underlying theory is that a product or service will only be embraced if it addresses the needs, desires, and emotions of its users. The next step is to define the problem, based upon insights gained through empathizing. At this point in the process, the solution is still far in the distance. Defining the problem is like discovering a research question in the science that Herbert Simon termed the science of the artificial, the pursuit of knowledge about what might be (Simon 1996). In the next step, ideation, the designer seeks to discover the solution set for that research question. Prototyping makes the idea visible and testable. Testing elicits user feedback. The designer iterates in response to feedback.

1.6. Defining the design problem

The American Institute of Architects (AIA) is the authoritative source for current design process in architectural practice, because AIA contract documents are typically used to establish the legal environment of projects. *AIA Document B-101-2017 Standard Form of Agreement Between Owner and Architect*, establishes the mutual responsibilities of Owner and Architect (AIA website). The Owner is assigned responsibility for providing the architect a written program. The architect’s basic services are defined as schematic design, design development, construction documents, procurement (assisting the Owner in getting construction services through bidding or negotiation), and construction phase services. This document makes it clear that the architect's work begins after the development of the program, the document that defines the architectural problem. The work of the architect, therefore, is to solve a pre-determined problem.

Some owners may have in-house programming capacity; others may out-source the programming function, sometimes to architects. The Architect's Handbook of Professional Practice offers guidance to architects on how to perform programming as an additional service to clients. The key concept reflected in the contractual structure, however, is that the architect's leadership in programming is considered optional.

Architectural education tends to reflect this de-emphasis on the architect's inclusion in the design process.

> In the 1980s and 1990s, some architectural schools began to drop architectural programming from their curricula. The emphasis of the Post-Modern and Deconstruction agendas was instead on form-making. Programming and its attention to the users of buildings was not a priority. Now, several generations of architects have little familiarity with architectural programming and the advantages it offers… (Cherry and Petronis 2016)

In her earlier book on programming for design, Cherry points out that programming began to become a discipline in response to the availability of computer technology. Computer programming required explicit definition of information and operations, making it imperative that "…ideas frequently processed at the unconscious level had to be brought up to the conscious level and described to others, either people or machines…" (Cherry 1999, 6). Interestingly, one of the pioneers of design methods in architecture, Christopher Alexander, became influential in the field of computer science, with his concept of pattern language (Alexander 1977) translated into object oriented programming (Alexander 1999).

Two seminal texts were particularly influential in the development of programming methodologies and process for architectural practice. *Problem Seeking*, written in the 1960's at the Texas firm Caudill Rowlett Scott by William Pena and others argued that programming is separate from design and that the two activities require different modes of thought. Programming requires analysis; design requires synthesis. Programming is problem seeking; design is problem solving. For Pena, problem definition is the overlap zone, the passing of the baton from programmer to designer. Problem Seeking posited a 5-step programming process: (1) Establish Goals, (2) Collect and Analyze Facts, (3) Uncover and Test Concepts, (4) Determine Needs, and (5) State the Problem (Pena 1987). Note that these five steps precede the present-day architectural design and construction phase services.

Henry Sanoff's 1970's text on the programming process, *Methods of Architectural Programming,* lays out a five step project process: Program Development, Preliminary Design Phase, Production Phase, Construction Phase, and Evaluation Phase (Sanoff 2016 reprint). In Sanoff's model the present-day architectural design and construction phase services are bookended by Program Development and Evaluation. At present, programming is not included in architects' basic services, and evaluation, often termed post-occupancy evaluation, is considered an additional service and rarely provided by architects.

In the Stanford d.school design thinking model, problem definition is the second step of the five-step process. The Define mode follows the Empathy mode. Whereas empathizing requires "flaring," defining requires "focus." In the Define mode, the designer develops "how might we?" statements that become design research questions to be addressed in the next step, Ideation. The "how might we?" question functions like Pena's handoff between program seeking and problem solving.

1.7. Individual thought vs. collaborative activity

As noted above, the literature of design thinking for architecture tends to focus on the thought processes of individuals. While architectural practices typically organize teams of people to execute projects, there is little study in the discipline of how teams design and little guidance for students in the literature. *The Architect's Handbook of Professional Practice Student Edition* (Haviland 2014, 545-555) offers some information about team management, along with a few suggestions about team building. In the section on "Managing Personalities," architects are advised to use the Meyers-Briggs Type Indicator to develop self-awareness and learn to work with others by understanding their personality types.

In the fields of business and software development, by contrast, there is substantial research on team process. For example, Google recently completed Project Aristotle, a study of team process that concluded that the most important characteristic of successful teams is psychological safety (Duhigg 2016). And there is a body of scholarly work on diverse teams and virtual teams in journals in the field of business. For example, Gibson and Gibb's work examining the effects of geographic dispersion, electronic dependence, dynamic structure, and national diversity on teams similarly concludes that "a psychologically safe communication climate" is instrumental in mitigating these factors (Gibson and Gibbs 2006). Harvey, Novicevic, and Garrison's work finds human, social, political, and cross-cultural capital to be essential to successful virtual teams (Harvey, Novicevic, and Garrison 2005). While there is a considerable body of work highly relevant to architectural practice for the global community, there is little evidence of application to the discipline of architecture.

2.0. LESSONS FOR PRACTICE IN THE GLOBAL COMMUNITY IN AN ERA OF DISRUPTION

2.1. Focus on learning to collaborate in diverse teams and in the global arena

As the literature review reveals, the area of team collaboration has been well-studied, with work on diverse teams and virtual collaboration, areas of teamwork implicated in both innovation and global practice. Not well-studied, however, are the applications of this research to architectural practice, with its unique aspects of intensive local engagement in the global community, where international practice means working with local practitioners and designing for local cultures and environments. This is a research opportunity for scholars of architectural practice. Lack of a literature of teamwork in the discipline means that students are typically not exposed to this area of theory of practice.

The lack of a theoretical underpinning for teamwork in architecture manifests itself in the design studio. While, in the author's experience as design studio faculty and guest critic at a variety of institutions, she has noted that team projects have become the norm in many studios, team assignments are typically made without explicit guidance and preparation for collaborative work. This contrasts with the author's experience participating in a Design Thinking Bootcamp, aimed at educating professionals to become agents of disruptive change in corporations and institutions, at the Stanford d.school. In this executive education program, team process was an explicit part of the curriculum, with game storming (Gray et al 2010) type activities to warm teams up and guide team interactions.

The author has applied this experience of explicit teaching of collaborative process to fostering a diverse, virtual team in the Bridging the Gap studio that brings architecture students from the University of Maryland (UMD) in College Park and Al-Nahrain University (ANU) in Baghdad together to design projects in one another's countries. The objective of preparing students for practice in the global community is reflecting in the learning outcomes for this architectural design studio course:

1. Demonstrate the ability to work effectively in international teams to study sites and propose urban design and architectural responses
2. Identify the challenges and benefits of international teamwork in urban design and architecture projects where the project is located in an international location
3. Be able to articulate commonalities and differences in international perspectives on the design of public urban places and how these result in physical form and space
4. Identify their own cultural assumptions and reflect on how these shape their attitudes and behaviors in design thinking

Figure 1: UMD and ANU students share each other's foods at video-conference. Source: Z. Alwash 2016

Figure 2: ANU students researching Karrada Market to inform UMD students. Source: S. Hussein 2018

2.2. Importance of empathy
A practice environment characterized by globalization and disruption requires architects to exercise empathy. Understanding the feelings, thoughts, and experiences of those unlike oneself is a capacity for creating trust, identified as the key factor for success of collaborative teams. And, empathy is a key skill for building cross-cultural capital, identified as a factor for success in virtual teams. Not only is empathy important to building strong collaborative relationships on teams, it is also key to designing for clients and users. While architects typically design for clients unlike themselves in important ways, for example, client organizations engaged in a variety of different industries, the globalization of markets for architectural services magnifies the aspect of difference.

Architectural education would benefit from the emphasis that the business and entrepreneurship community puts on empathy as the foundation of the design thinking process. Architectural design studio courses have traditionally provided students with a project brief outlining client's needs. In the case where students are asked to develop a project program, they may have access to clients and users, for example, in community-engaged studios. In this situation, students would benefit from instruction in how to engage with communities.

In the more typical situation in which students do not have access to clients and users, their only resource for determining human needs is to use their imaginations. This poses the risk of students imagining that their own feelings, beliefs, and cultural norms are shared by the users of their designs. As students move into a practice environment where they will serve a diverse and globalized community, ability to discover and design for human needs is clearly required.

The five-step design thinking process developed by the Stanford d.school grounds the design process in empathy, offering guidance on how designers can build empathy through the activities of immersing, interacting, and interviewing. The Stanford d.school's model for teaching design thinking offers methods and resources to teach students how to practice empathy to discover human needs.

2.1. Defining the problem
The sub-discipline of programming that flourished during the 1960's and 1970's, concurrent with the interest in design methods, has faded from prominence in the discipline of architecture. Programming courses have largely disappeared from architecture curricula. A study of professional degree programs in architecture at the Big Ten universities, by the author, reveals that none require courses in programming. This means that students graduate ill-equipped to discover the present needs of clients and users. And, in this era of disruption, they are consequently unprepared to take the next step of creatively envisioning future needs for individuals, industries, and institutions.

Empathy is considered the foundation of design thinking for innovation. A key concept of designing for disruption is to focus on extreme users, those found on the tails of the bell curve, in order to discover needs that can lead to innovative solutions. Another key concept is to clearly separate the modes of empathy, problem definition, and ideation in the design thinking process. This helps designers to avoid defining problems on the basis of assumptions and to avoid pre-determined solutions. To better prepare students for practice in an era of disruption, architectural educators have an important opportunity to replace the extinct programming course with a new pedagogy of empathy-building and problem-definition that can teach students how to practice design thinking in an era of disruption.

CONCLUSION
The challenges of practice for the global community in an era of disruption demand a set of competencies that are key to a form of design thinking popular in the entrepreneurial community that has some key differences from what architects are talking about when they use the term design thinking. First of all, designing for the global community requires the ability to practice empathy, both to function effectively as a member of diverse, sometimes virtual teams, to insightfully discover the needs of clients and users different from oneself, and to discover the new ways of working, inhabiting, living, etc. that can lead to disruption of traditional building typologies and offer innovative proposals to clients in ways that serve emerging needs of users.

While architecture schools typically currently incorporate team projects into design studio curricula, they typically do not explicitly teach collaborative team processes. A study of the literature of design thinking, including some of the foundational texts from the discipline of architecture as well as recent material from design thinking in the service of innovation and entrepreneurship, reveals rich material on techniques and modes of thought for effective team process. Incorporating this knowledge into studio would enhance students' preparation for practice on diverse teams. A further recommendation is to give students opportunities for cross-cultural engagement, such as virtual and on-site studio collaborations between universities in diverse settings.

And, along with opportunities to engage, students will require explicit instruction in cross-cultural communication, diverse team collaboration, and design thinking process.

The seminal texts of architectural programming and current material on design thinking offer specific techniques, activities, mindsets, and principles to guide designers in collecting and acting upon information in ways that can lead to innovative problem definition based upon insightful understandings. A recommendation for architectural education is that the time is ripe to replace the programming courses that have largely disappeared from architecture curricula with innovative instruction that conveys the value of and capabilities required to discover information and define architectural problems both current and emerging.

Armed with the knowledge and capabilities to operate across cultures and to act upon emerging tendencies, architectural students will be better prepared to become change-makers in the global community in an era of disruption.

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The PhD X-Ray: A European Survey into Doctoral Training in Architecture

The PhD x-Ray: a European survey into doctoral training in Architecture

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ABSTRACT: Since the signing of the Bologna Declaration in 1999, third cycle education, or, most specifically, doctoral training, has been growing in number of candidates and in relevance in most European schools of Architecture. The European Association for Architectural Education (EAAE), through its Research Academy group (RA), created a questionnaire with the purpose of understanding the possibilities and challenges of the current third cycle education programmes within the range of the EAAE full-member schools. The questionnaire was prepared in 2016 and sent to all the EAAE 's full-member schools throughout 2017. The questionnaire was conceived as a survey, including both quantitative and qualitative questions, thus providing a broad understanding of the third cycle education programmes assessed. This paper aims to present the first results assessed through a comparative analysis of the answers to the questionnaires. Thus far, the EAAE-RA has received answers from 39 schools; however, we have limited this initial paper to the analysis of 23 schools. The results arising from this questionnaire aim to initiate a debate on architectural research based not on assumptions but on actual data. We wish to disseminate these original findings in the ARCC-EAAE 2018 conference to invite a broader group of schools and researchers into this discussion. These results can later be used, on one hand, to support a further global interconnection and research network and, on the other hand, to promote a European policy paper in support of the doctoral training in architecture, identifying good practices and strategic possibilities within a global architectural research community that is, today, united in diversity, safeguarding local culture while seeking a common ground for dialogue and change.

KEYWORDS: EAAE, Research in Architecture, PhD, doctoral training, third cycle education

INTRODUCTION

“Architectural research is original investigation undertaken in order to generate knowledge, insights and understanding based on competencies, methods and tools proper to the discipline of architecture. It has its own particular knowledge base, mode, scope, tactics and strategies.” This is stated in the Charter on Architectural Research, approved by the General Assembly of the European Association for Architectural Education (EAAE) on the 3rd of September 2012.

The specificity and the cross disciplinary nature of Architectural Research, which the EAAE’s Charter sought to define in 2012, was developed four years later into the document edited by the European League of Institutes of the Arts (ELIA). This document focused on the doctoral training in the arts, where architecture was seen as one of the artistic disciplines: “The Florence Principles on the Doctorate in the Arts”, (The Florence Principles, 2016). The “Florence Principles” document was inspired by the Salzburg Principles, established in 2005, which laid the ground for discussing doctoral education as part of the Bologna process.

Since the EAAE’s Charter’s approval in 2012, there have been several initiatives to push forward the challenges of finding common ground for research in architecture at a European level, including an International Forum on Doctoral Education in Europe, held in Riga, in 2013, which gave rise to the book “Doctoral Education in Schools of Architecture across Europe” (Voyatzaki, 2014), supported by the European Network of Heads of Schools of Architecture (ENHSA). This publication compiles, on one hand, descriptions of selected PhD programmes, and, on the other, a general overview of the evolution of architectural research in Europe. In this overview, the editor, Maria Voyatzaki, argues that architectural research in Europe has gone through three paradigms: Attachment, Autonomy and Ambivalence.

According to Voyatzaki (2014, pp. 19-30), the “Attachment paradigm” describes the initial phase of architectural research, when it remained attached to the methodologies of other fields of knowledge. Research developed in the earlier stages was characterised by the strong influence from the positive sciences and engineering focusing on the measurable inputs of architectural production. In the later stages, the research methods began shifting into the fields of humanities, looking into the effects of the output of architectural production on society.

In the second phase, the “Autonomy paradigm”, the architectural research developed referred to the architectural design process itself, seeking ways to stand on its own field, thus, no longer attached to other fields of knowledge. The Autonomy phase refers to the research-by-design discussion, or research by practice, bringing forth its possibilities, but remaining aware of the underlining “myths” of practice as research, as stated by Till (2007). This discussion allowed for the emergence of creative research methodologies, such as those presented in the research network ADAPT-r (Architecture, Design and Art Practice Training-research) where borders of traditional research methods are questioned by a “supra-disciplinary” field of possibilities, seeking how research can trigger transformation in the behaviour communities (Zupancic, 2017).

In the current phase, the “Ambivalence paradigm”, the lines between research and practice, between academia and the profession, appear to be undefined. As stated by Voyatzaki (2014, p.24), “This new situation creates an unclear and vague middle ground. One of its extremities is a handsome-hybrid understanding of this match where social needs, material constraints and creative gestures can meet in an experimental environment. The other extremity is an impure alloy amalgamating, in a confusing and unclear way, aspects of thinking and making presented as innovation and as creative experience and original knowledge. We are already in a new paradigm of doctoral research, which we can define as the Ambivalence paradigm.”

In 2014, the general feeling was that “Schools of Architecture in Europe have not yet made significant progress on this subject” (Voyatzaki, 2014, p14). Today, we believe that, in 2018, almost 20 years after the Bologna agreement, and 12 years after the development of the Salzburg principles, this statement cannot stand as true any more. What we see on the ground, in the schools through the data collected thus far, is that schools have made progress, after having started, reinvented or restarted their PhD curricula following Bologna.

Today, we believe there is a need to provide an overview of doctoral training in Europe supported by an extensive survey of all EAAE member schools. This overview aims to go both beyond a listing of a limited number of PhD programmes and beyond a general overview created without the support of empirical data, namely without a survey of what is really happening on the ground. That is the result this research group hopes to provide; thus, in 2017, we began mapping systematically the progress of doctoral training in Architecture throughout Europe.

1.0 TIME, PEOPLE AND COSTS

1.1. Quantitative and Qualitative Survey

The questionnaire was conceived as a survey, including both quantitative and qualitative questions, thus providing a broad understanding of the third cycle education programmes reviewed.

The quantitative analysis of the questionnaire aims to assess the quantities of time, people and costs. The quantitative answers inquire into: the year the PhD training began; the number of students enrolled; the number of researchers, supervisors, staff or professors involved in the program; both the hours per week and the total number of years dedicated per student to the research; enrolment costs; and, the year each third cycle program began.

The qualitative analysis aims to understand: the profile of the professors, supervisors and tutors involved; the program’s specific field of study within the field of architecture; the language/languages spoken; the research methodologies used, through the outputs expected; and, finally, the main challenges and / or opportunities detected by the school answering the questionnaire.

1.2. When did doctoral training in Architecture in Europe begin?

From the data collected thus far, most schools place the beginning of their formal PhD training in Architecture within the timeframe that ranges from 1990 to 2010. We aim to focus on this formal training for this research, considering the common ground provided by the signing of the Bologna Declaration. Nevertheless, there are indications that Doctoral degrees in Architecture were awarded decades earlier than 1990, albeit being in different formats and with different definitions.

The earliest PhD degree in the schools assessed can be traced to 1960, to the Faculty of Architecture of the University of Ljubljana. Three of the assessed schools trace the origins of their doctoral training to the 1980s: the Aarhus School of Architecture (1988), the Politecnico de Milano (1983); and in the Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation (1980). From the formulation of the questions that refer to the 3rd cycle education, it can be assumed that some answers are related to the 3rd cycle programme introduction after Bologna renewal, and that earlier attempts are not indicated in some questionnaires though they might exist.

Of the schools 23 assessed thus far, only one, the École Nationale Supérieure d'Architecture de Bretagne (ENSAB), did not provide 3rd cycle education programmes as of 2017.

1.3. How can the doctoral student community be described?

The purpose of assessing the number and profiles of the students enrolled is to understand the diversity of the schools assessed and, thus, the critical mass potential of each scientific community. With this purpose in mind, we have tried to assess the quantity of students, the requirements to enter a PhD programme, and the international relations fostered by the programmes.

Regarding the scale of the doctoral student community measured in quantity of students, in 2017, there was an extreme gap between the school with the highest number of students enrolled, the Politecnico di Milano, with 1030 third cycle students enrolled, and the school with the lowest number, the University of Liechtenstein, Institute of Architecture and Planning, with only 6 students enrolled.

These 23 schools reviewed, with the exception of Politecnico di Milano, had an average of 691 students enrolled in the bachelor studies per school and 488 students in the Master studies per school. There was an average of 127 students enrolled per school in 3rd cycle courses in the 23 schools assessed; hence, just looking at averages, the 3rd cycle students accounted for only 10% of the total student population in the assessed schools, the Master students for 37% of the total student population in the assessed schools, and the bachelor student numbers account for 53% of the total student population in the assessed schools. It is also important to note that the average duration of the PhD studies was at 4.5 years from the register to the final completion, with a minimum of effective duration of 3 years and a maximum of 11 years.

The minimum enrolment requirement for students is the same for most schools: a Masters degree, even if some may accept candidates if they provide exceptional previous experience (in research or practice). This common ground in third cycle requirements falls in line with the three cycles of study, which arose from the Bologna Agreement.

Of the schools reviewed 10, of the 23, provide a double degree with another university for 3rd cycle education, mostly considering a specificity of the research topics, and of these double degrees, most of have less than 10 students.

In synthesis, on one hand, there is a great disparity in scale, between schools with less than 10 students enrolled in doctoral training and schools with more than 1000, and on the other hand, there is a common understanding of the minimum requirements. It is also important to note that the third cycle students provide for an average of one tenth of the total number of students in the schools.

1.4. Who is supervising the research?

The criteria to become a PhD supervisor within the PhD programmes are also diverse within the range of school reviewed. Of the 23, 10 schools state that supervisors must hold a PhD degree and 13 of the 23 schools require that the main supervisor must be a member of the school staff (full and/or associate professor). Only 2 of the 23 reviewed schools state that an expert in field can be a supervisor, even if he/she is not the holder of a PhD degree.

Regarding the scale of the possible supervisors within the faculty, of the 23 schools reviewed there are schools with as little as 4 possible supervisors (University of Liechtenstein, Institute of Architecture and

Planning) and as many as 147 (Universitat Politècnica de València). In 16, of the 23, reviewed schools a third cycle diploma is formal requirement for achieving a senior position in the faculty.

If there seems to be a majority of consensus around the need to have at least one of the supervisors as a PhD holder, and/or member of the Faculty, some diversity of the supervisors' profile is still present. For some schools, the PhD degree is the only requirement to be a supervisor, while, for other schools, supervisors must prove they hold both a PhD and significant body of research in the field (such as articles published in peer reviewed journals, or experience teaching in postgraduate studies).

1.5. How much does it cost?

The average of the 20 schools that have provided this information is a payment of around 1375 EUR of yearly fee per year of enrolment. There are some schools charging nothing to both national students and EU citizens and other schools charging 5000EUR a year (Delft University of Technology Faculty of Architecture and the Built Environment). The Royal Danish Academy of Fine Arts, Schools of Architecture, Design and Conservation, in Denmark, was excluded of these averages as it provided a yearly fee of 33000EUR per year, much above the general range of payment.

2.0 THE RESEARCH WORK

2.1. What are the main Areas of Research?

The focus areas of research in the 23 schools assessed are listed in Table 1, providing an overview of the diverse range involving research in Architecture, which is in line with the stated "fertile" ground for "trans- and inter-disciplinary endeavours" stated in the Charter (2012).

All of the schools include Architecture and most schools include Urban Studies in some form (Urbanism, Planning, Urban Design). The specifics of each school can be seen in Table 1, providing both a wide range of themes and an intentional interdisciplinary nature.

Some schools are closer to History, Heritage and Conservation (Politectico de Milano, Universitat Politècnica de València), other schools to the Social Sciences (Ecole Polytechnique Fédérale de Lausanne), to the Arts (The Royal Danish Academy of Fine Arts. Schools of Architecture, Design and Conservation) or to Technologies and Engineering (University of Pécs Faculty of Engineering and Information Technology School of Architecture) or to embracing a broad variety of methods and approaches (Delft University of Technology, Faculty of Architecture and the Built Environment, University of Ljubljana, and the Faculty of Architecture of the University of Lisbon). From the answers reviewed, we can assume these differences in the nature of the research work are initially related to the origins of each school, considering each school's emergence from either a Technical University or a Beaux-Arts Academy; nevertheless, some faculties manage to include both the technical and the Beaux-Arts traditions.

This comparative Table 1, describing the areas of research, aims to establish links between schools that share common (or complementary) interests and may possibly connect in future PhD programmes. It is important to note that English has established itself as the common language binding all programs, as most schools accept both English and the country's original language and some schools only accept English.

2.2. How can the Research Work be described?

Regarding the contents of the research work, training includes both course work and individual work, but mostly focuses on individual work. The majority of schools indicate that most of the work required (more than 50% of the research work) is divided between individual research work and the development of the delivery of a thesis. Only the University of Pécs Faculty of Engineering and Information Technology, in Hungary, indicates less than 45% of the workload for both these activities, having the rest of the research time divided by the Coursework, Course on Scientific Integrity, Generic skills, Course on Research Methods, the delivery of an exhibition, delivery of at least one peer reviewed paper, and a conference participation.

Only 3 of the assessed schools require teaching hours as a mandatory part of the 3rd cycle training and only 4 of the schools reviewed include a mandatory stay at another research institute.

Table 1: Focus areas of research. Source: 23 questionnaires

COUNTRY	UNIVERSITY / SCHOOL / FACULTY / INSTITUTION	FOCUS AREAS OF RESEARCH
Belgium	KU Leuven, Faculty of Architecture	Architecture, Interior Architecture, Urban Design, Landscape
Belgium	KU Leuven, Faculty of Engineering Science	Architecture, Urban Design, Planning
Czech Republic	Czech Technical University in Prague - Faculty of Architecture	Architecture, Urban Design, Planning, Product Design, History of Architecture and Monument Conservation,Architecture, Building and Technology
Czech Republic	Brno University of Technology, Faculty of Architecture	Architecture; Urban Design; Planning
Denmark	The Royal Danish Academy of Fine Arts. Schools of Architecture, Design and Conservation (KADK)	Architecture, Interior Architecture, Urban Design, Planning, Landscape, Product Design, Design, Conservation
Denmark	Aarhus School of Architecture	Architecture, Urban Design, Planning, Landscape
France	Ecole Nationale Supérieure d'Architecture de Bretagne (ENSAB)	(no 3rd cycle course)
Hungary	University of Pécs Faculty of Engineering and Information Technology (PTE MIK) School of Architecture	Architecture, Interior Architecture, Urban Design, Planning,Heritage protection, Building Energetics
Italy	Politecnico di Milano	Preservation of the Architectural Heritage: Culture and Practice; Diagnostics of Materials and Structures and Rehabilitation of Historic Buildings; Methods and Themes of Historical Research; Construction History;Historical Territory and Cultural Landscapes
Italy	University of Ferrara, Department of Architecture	Architecture, urban design, planning, product design, landscape
Liechtenstein	University of Liechtenstein, Institute of Architecture and Planning	Architecture, urban design
Lithuania	Vilnus Gediminas Technical University, Faculty of Architecture	Architecture, urban design, product design, landscape
Netherlands	Delft University of Technology,Faculty of Architecture and the Built Environment	The Architectural Project and its Foundations, Computation & Performance, Design & History, Geo-information Technology & Governance, Green Building Innovation, Housing in a changing society, Innovations in Management Built Environment, Urban and Regional Studies, Urbanism
Poland	Cracow University of Technology / Faculty of Architecture	architecture, urban design, planning, landscape
Portugal	Faculdade de Arquitetura da Universidade de Lisboa	Architecture, Urban Design, Planning, Product Design
Portugal	Faculty of Architecture / University of Porto	Architecture; Urban design; Planning; Product Design
Slovakia	Slovak University of Technology, Faculty of Architecture	Architecture, interior architecture, urban design, product design
Slovakia	Faculty of Architecture, Slovak University of Technology, Bratislava, Slovakia	Architecture interior architecture, urban design, product design, monument and cultural preservation
Slovenia	University of Ljubljana, Faculty of Architecture	Architecture, interior architecture, urban design, digital design, architectural technology
Spain	Universitat Politècnica de València	Architecture; Urban design; Planning; Landscape; History, Theory, Heritage; Graphic Expression in Architecture; Building Engineering
Switzerland	Ecole Polytechnique Fédérale de Lausanne - EPFL	Architecture, Urban Design, Planning, Landscape
Turkey	Yıldız Technical University, Faculty of Architecture, Department of Architecture	Architecture; History & Theory of Architecture; historic preservation; project and construction management; building physics; building construction
Turkey	Atılım University / Graduate School of Natural & Applied Sciences / Architecture Department	Architecture

2.3. Is there Research by Design?

As stated in the introduction, Voyatzaki (2014) claims we have entered an “Ambivalence” phase, where practice and academia cross-over; however, design work is only obligatory in one of the 23 schools (Slovak University of Technology, Faculty of Architecture, in the Product Design Programme) and a practice based experience throughout the research is not required by any school.

This can be interpreted in three ways: that design has not yet found its place in the schools reviewed, that the programmes are open and not exclusive to research by design, or that any kind of inquiry in which design is the substantial constituent of the research process is referred to as research by design. At this stage, conclusions should be supported by a further inquiry into each school’s proposed research methods.

CONCLUSION

This paper stands at the beginning of a systematic PhD survey, promoted by the EAAE and thus developed at European level, which hopes to become thorough in order to identify common ground, without overlooking the diversities and specificity of each culture. The initial results arising from the questionnaire, stated in this paper, do not aim to provide definite conclusions, but hope to initiate a debate on architectural research based not on general assumptions, nor on the characteristics of a few specific PhD programmes, but on actual data collected from as many different countries and programmes as possible.

The purpose of this first paper is to disseminate these original findings in the ARCC EAAE 2018 conference in order to invite a broader group of schools and researchers into this discussion. These results can later be used, on one hand, to support a further global interconnection and research network and, on the other hand, to promote a European policy paper in support of the doctoral training in architecture, identifying good practices and strategic possibilities within a global architectural research community that is, today, united in diversity, safeguarding local culture while seeking a common ground for dialogue and change.

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David M. Breiner

Expanding Study Abroad in a Global Context: Nexus Abroad

Expanding study abroad in a global context: Nexus Abroad

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ABSTRACT:
Architecture programs in the U.S. have incorporated study abroad experiences as a means of exposing students to geographical and cultural diversity. This paper analyzes and promotes an innovative approach to study abroad called Nexus Abroad. A summer 2016 iteration involving a group of faculty and students from varied disciplines serves as a case study. The three-week-long course combined geographical and cultural diversity with a collaborative, transdisciplinary structure, providing students with a more integrated global perspective. It accomplished that not through a studio project, but by focusing on a common theme in which architecture was studied as one of many components that constitute a society. The course united liberal-arts-derived goals of global awareness, resourcefulness, and openness to other cultures with discipline-specific goals, in this case four National Architectural Accrediting Board student performance criteria. The benefits of and potential improvements to this short study-abroad course are revealed by examining student deliverables and focused interviews, comparing pre- and post-course surveys, and evaluating students' grades before and after their participation in Nexus Abroad.

KEYWORDS: Study abroad, Architectural education, Transdisciplinary, Nexus Abroad

INTRODUCTION

When educators debate approaches to improving architectural pedagogy, often the issues involve how to expose students simultaneously to societies beyond their ken and to disciplines beyond architecture. Though architecture programs in the U.S. expose students to geographical and cultural diversity through study abroad experiences, they typically isolate architecture and the built environment from the broader culture. Even when cultural literacy and intercultural professionalism are added as supplemental outcomes, courses can miss an opportunity to give students an integrated global perspective. This paper demonstrates an alternative solution: the value of a collaborative, transdisciplinary[1] model for study abroad. In the three-week Nexus Abroad[2] course at Jefferson (Philadelphia University + Thomas Jefferson University), participants focus collaboratively and intensely on a single transdisciplinary topic, and the summer 2016 experience serves as a case study for this paper. Among the many benefits of this model, it can address several student performance criteria articulated by the National Architectural Accrediting Board (NAAB), including professional communication skills, investigative skills, history and global culture, and cultural diversity and social equity.

1.0 HISTORICAL CONTEXT

The discussions aimed at creating a transdisciplinary, global education have their roots in the beginning of academic programs for architects in the United States. The father of American architectural education, William Robert Ware, founder of architecture programs at the Massachusetts Institute of Technology and Columbia University, fought to make architects well-rounded generalists in the liberal arts tradition with excellent skills in posing difficult questions, thinking analytically, and solving problems (Plunz 1990). At the turn of the 20th century, under the influence of Charles McKim, the liberal arts emphasis was eclipsed by a more strictly architectural menu of graphics and design courses. McKim also expanded the opportunity for the best graduates to travel and study in Europe. American architecture students were being exposed to primarily European precedents, largely through books and images (Wright 1990), and – for a select few – by studying in Paris and taking the Grand Tour. Starting in the 1960's, study abroad became possible for a larger segment of architecture students (Costanzo 2012) and the pedagogy of those programs appears to have largely copied the mono-disciplinary approach of architectural education at home.[3]

Since the late 20th century, educators rethinking architectural education have prompted renewed discussion. At the time, architectural studio was recognized as an excellent method of learning by doing, a "reflective practicum" (D.A. Schön 1991). Yet other voices proposed replacing superficial curricular ties to fields such as the liberal arts with more intense multidisciplinary investigations of architecture's political and cultural context (T.A. Dutton 1991; H.A. Giroux 1991). This concern was highlighted in Ernest L. Boyer and Lee D. Mitgang's landmark *Building Community* (1996, esp. 60, 81-82, 85), which posited that collaborative, multidisciplinary work was academe's most important challenge, important due to its deep connections to ethical decision-making and communication skills.

More recently, writers with diverse agendas have continued to recommend multidisciplinary and cross-cultural approaches as means of improving architectural pedagogy and, ultimately, the standing of architects in society. One motivation is to provide architecture students with the rigorous and systematic approach they require to apply their discipline-specific "definable body of knowledge,"[4] along with critical thinking and analysis, to their designs and thereby challenge the status quo (A. Orbasli and M. Vellinga 2008; N. Coleman 2010). Another perspective recommends that architectural curricula address large environmental problems by working on real-world projects (A. Tzonis 2014), which by necessity calls for architecture students to collaborate with those in other fields. Such an approach to education, in conjunction with the recasting of the architectural profession from a career focused on status and profit into a "calling" aimed to benefit humanity, would help overcome society's skepticism of the field. This would be accomplished by mastering the practicalities of how space is used by people in a diverse world (T. Fisher 2001). At least one writer anticipates that these goals will be advanced by the current shift of architectural education to synthesizing varied "specialized knowledges," namely technology, history, theory, and sociology and culture (J.W. Robinson 2001). Other research emphasizes how experiencing a culturally or geographically different place can fundamentally expand students' perceptions, making them more globally minded, inquisitive, self-reliant, and adept at cross-cultural communication (K.B. Jones 2001; L.D. Culver 2011); however, those studies continue to deal with study abroad though a purely architectural lens, concentrating on issues like scale, architectural history, and how people use the environment they live in. Conventional study abroad does not address the concern raised by a few writers (L. Groat and S. Ahrentzen 2001) that architectural studios are not always successful in integrating allied disciplines.

2.0 NEXUS ABROAD

2.1 Premise

Jefferson's Nexus Abroad program responds to these criticisms and recommendations by presenting an alternative format for study abroad. While there are many advantages to semester-long study away experiences, there are also advantages, particularly for younger students, in using a short course to instill a different way of thinking about architecture. The Nexus Abroad curriculum aims to provide an interdisciplinary, global educational experience for all students, including architecture students, asking them to become creative problem solvers outside of the venues they are familiar with. The course recognizes that architectural effort, by itself, typically does not solve significant underlying socio-economic, cultural, or ecological problems. Instead, architecture students can be encouraged to develop the convergent and divergent thinking needed by the brain to move in new directions (T.S. Hamza and D.K. Hassan 2016)[5] and the history of architectural pedagogy as well as recent scholarship indicate that students can and should learn to be creative beyond the studio environment.

2.2 Course characteristics

Nexus Abroad is a collaborative, transdisciplinary learning experience for students in which a three-week, three-credit study abroad course is organized around a common theme. In the summer of 2016, the common theme was the co-existence of Jewish, Christian, and Muslim communities across Southern Europe since antiquity: how they impacted one another as well as how they interacted with forces beyond the European sphere. The itinerary included locations in four countries: Sarajevo and Mostar in Bosnia; Dubrovnik in Croatia; Madrid, Seville, and Cordoba in Spain; and Florence and Prato, with an optional trip to Lucca, in Italy. Together, the group explored the common theme in terms of the socio-economic, political, and cultural environments (including architecture and urbanism) in their historical setting as well as their impact on contemporary society.

Over the previous year, the three faculty – from architectural history, fashion design, and human geography – had collaboratively developed a shared syllabus, which would allow students to integrate their experience from multiple perspectives.[6] In 2016, of the 33 students who participated, 45% were rising sophomores (the target audience), 30% rising juniors, and 25% rising seniors. Their majors included business, fashion merchandising and fashion design, mechanical engineering, textile and industrial design, physician assistant, psychology, and occupational therapy, along with students in the College of Architecture and the Built Environment, representing the five-year accredited bachelor of architecture program, four-year pre-professional architectural studies program, and four-year accredited interior design program.[7]

The schedule consistently balanced common activities with discipline-specific activities. Providing an orientation to the host country and city as well as to the theme of co-existence, common activities included brief presentations and specialized tours of pivotal sites. On the other hand, discipline-specific activities permitted students to see connections to their own field of study. This was structured by subdividing the course into three discipline-specific smaller groups, each emphasizing a different realm within the larger topic: “History Takes Form” with the architectural historian; “Fashion Studies Abroad” with the fashion designer; and “Contemporary Europe” with the anthropologist. This way, the architecture and interior design students explored the built environment in greater depth, specifically honing their visualization skills while visiting domestic, religious, and civic architecture associated with each of the three monotheistic religions. Meanwhile, the other two groups pursued their own secondary subjects. The alternation between the two kinds of activities prepared students to work in four-person transdisciplinary teams on assignments consisting of two digital postcards and a final project in the form of a film responding to a prompt that connected to the course theme.

One version of a common activity was for the entire group to participate in a guided tour. In Sarajevo, this included tours led by clergy or docents of a Serbian Orthodox church, an Ashkenazi synagogue, and a Sunni mosque, each historically significant but typical enough for students to understand more about that religious community and how it interacted with the larger society. A subsequent smaller group activity for the architecture and interior design students was to visit residences associated with a prosperous family in each religious community – a 17th-century Ottoman house in Sarajevo, a 14th-century house of Sephardic Jews in Cordoba, and a 14th-century palace of a Christian family in Florence – where the group examined built environment issues in greater depth.

Another version of the common activity was for each of the three faculty to give a 15-minute presentation related to the topic of the day. For example, in Madrid when the daily topic was “Globalization,” the students heard about how urban planning helped to create the global city, how globalization impacts Spanish fashion, and how the global city copes in a world of strife. That was followed up by smaller group activities: the architects and interior designers visited three museums designed by internationally acclaimed architects. The required reading for the day – typical of the varied perspectives discussed – was a brief article that focused on the complex economic impact of “Starchitect-designed” monuments, reconnecting the discussion of space, form, and material to larger issues in Spanish society (Holleran 2013).

Interdisciplinary experiences occurred through planning and by happenstance. An example of the former occurred in Seville, where attendance at a professional flamenco performance was preceded by a group lesson (faculty included!), an event that addressed the goal of “getting out of one’s comfort zone.” An example of the latter happened in Florence, when students were able to join a small disciplinary group not their own. Some of the architecture and interiors students visited the Museum of Torture in Lucca with the anthropology professor, while the remainder of the built environment students benefited from having a textile design student with them as they examined lace-making equipment on display in the mercantile family’s palace.

3.0 STUDENT OUTCOMES AND THEIR EVALUATION

3.1 Overview

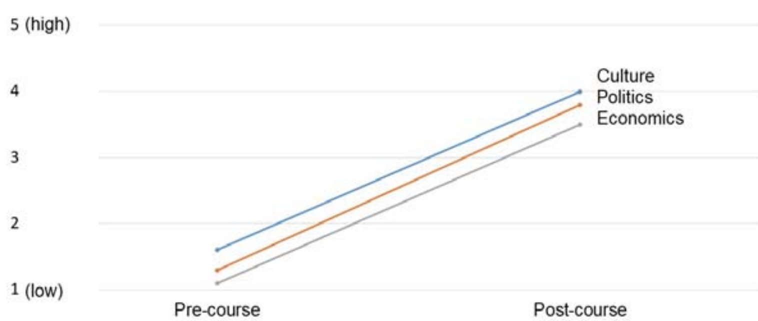
The value of our Nexus Abroad course is demonstrated by examining student learning outcomes, which addressed both Nexus Abroad goals and, for architecture students, NAAB mandates. For Nexus Abroad, the goals were to: (1) document how social, economic, political, and cultural developments contribute to the evolution of form in architecture, landscape architecture, and design; (2) apply resourcefulness and openness in adapting to new cultural environments; (3) exhibit diagramming and photographic skills by discerning 2- and 3-D organizational patterns and representing them graphically; (4) exhibit visual-analysis and contextual-analysis skills by identifying significant elements in design; and (5) develop oral presentation skills. The benefits of a transdisciplinary and global experience of this type for design students can be identified by evaluating several tools. All students completed the pre-course/post-course surveys and the team transdisciplinary assignments. Another set of tools was limited to the architecture and interior design students: interviews conducted a year after the course concluded which asked them to reflect on the impact of Nexus Abroad on their perspective, and a comparison of grades in studio and history of architecture and interiors courses before and after Nexus Abroad.

The pre- and post-course surveys addressed the overarching goals of the Nexus Abroad experience. The students typically had limited exposure to, but cautious interest in, the international world. Although they gave varied answers on the pre-course survey spanning the spectrum from “never” to “often,” the majority of answers were clustered. In the pre-course surveys all but one of the built environment students said that their personal goals “mostly” matched those of the Nexus program, which were to demonstrate: global awareness, specifically knowledge of political, economic, and/or cultural developments of a geographic region; resourcefulness and flexibility while adapting to new cultural environments; and openness to people, ideas, and activities from other cultures as a means of personal development.

3.2 Global awareness

Due to the goal of increased global awareness, students were surveyed about their general knowledge of the history or current events in the countries they were about to visit, with results shown in Figure 1. 63% admitted to “rarely” reading, watching, or listening to news about the countries they were about to visit, and would be unable to give a general account of their political and economic situations. When asked to give examples of cultural contributions from host countries they could discuss with peers, the examples spanned from sports (soccer and bullfighting), to culture (flamenco), to famous architects (Brunelleschi to Gaudí) and artworks (“Mona Lisa”), to popular culture (“Game of Thrones” television series) and cuisine (Turkish coffee, olive oil, and gelato). One student was unable to provide any examples, and several incorrect examples were omitted. They “rarely” or “occasionally” watched a movie or show filmed in another language and “rarely” visited a non-U.S. news or info website. On the 2017 post-course survey, students reported a substantial increase in their current knowledge of the host countries in terms of contemporary cultural (2.4/5.0), political (2.5/5.0), and economic (2.4/5.0) developments. Students responded with “extremely high” when asked about their desire to continue learning about this material, the likelihood they would recommend the course to a friend, the overall quality of course, the effectiveness of the instructor, the amount they learned, and the value of what they learned. These responses demonstrate success in regard to improving students’ global awareness.

Figure 1: Self-reported global awareness (current knowledge of host country), 2017 cohort

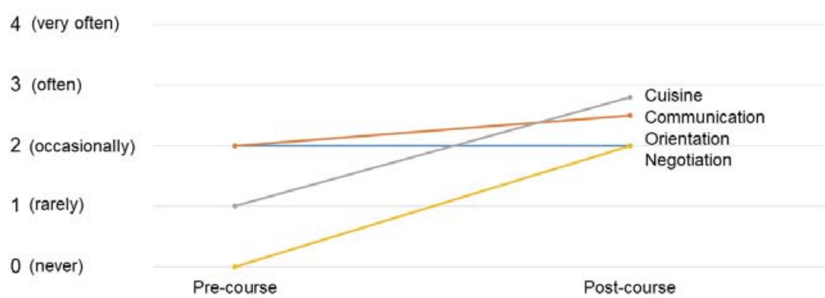


3.3 Resourcefulness and openness

The course goals of expanding students’ resourcefulness in new situations and their openness to other cultures were matched closely by the students’ personal goals, as reported in the pre-course survey. Students indicated that they wanted to: “try new things,” “experience different cultures,” “try a lot of new foods,” “step out of my comfort zone,” and “see and experience as much as possible.” Figure 2 illustrates the changes students reported before and after the course regarding their resourcefulness in new situations and openness to other cultures. “Orientation” (how often they found their way in an unfamiliar city, or experienced homesickness or culture shock) remained constant. Since students did have opportunities to find their own way in the cities visited, an improvement to the course could include a reflection making them more aware of what they were already doing but possibly not appreciating. “Communication” (how often they tried to speak a foreign language; conversed with or worked in a group with students from another culture; or liked a film, music group, or sports event originating outside the U.S.) increased modestly. This suggests that planning for increased interaction with natives could improve the course. “Cuisine” (how often they tried new cuisines) and “Negotiation” (how often they dealt with a store clerk who did not speak English) both rose dramatically. Given the cities visited in southern Europe, those changes were expected.

Due to the transdisciplinary nature of the course, students were asked in the pre-course survey to give an example of adjusting their way of thinking or acting to accommodate another student’s input. Some comments addressed working with others in studio or debating in a liberal arts course an issue such as civil liberties versus national security, and others mentioned changing opinions about abortion. All of them had worked in a group at the university either “sometimes” or “often,” typically in an interdisciplinary team. They enjoyed this because they learned new things and shared the workload; however, they disliked unreliable partners and dealing with peers who had a different work ethic. When they discovered that this course would require teamwork, they were positive. Their comments included a few cautious ones about the collaboration (“Ok, but hope we get to pick partners.") but were mostly enthusiastic ("… projects seem like fun and everyone seems awesome," "excited to meet new people," etc.) They were even more positive about the transdisciplinary requirement ("everyone will have a different perspective" was written by three students, "good resource to have a mixed group," etc.) Only one response was unenthusiastic ("Wish it was limited to [my] major in order to go into greater depth about architecture.")

Figure 2: Self-reported resourcefulness and openness, 2016 cohort



During the course, all students were evaluated on the work they produced as part of a transdisciplinary team. For example, to create a digital postcard each team of four students was assigned a site not otherwise covered by the itineraries. They briefly researched the site online in advance of the excursion, and then visited it to record personal observations, photograph it, and film brief interviews. Each team then posted their analysis on YouTube and linked it to the course Facebook page, in order to share it with the rest of the course as well as their loved ones back home. Faculty assessed each project on its merits, including the extent to which the built environment and fashion were discussed in the context of their socio-economic, political, and cultural realms. The culminating assignment was also a transdisciplinary challenge. Each team had to use its digital postcards, sketches, photos, video clips, and other resources to make a seven-minute film addressing one aspect of the entire trip, such as "Volition and Compulsion" or "Invisible and Visible." The teams incorporated lessons learned in the varied disciplines and from the multiple locations they had visited to produce insightful and entertaining responses to the prompts they had been given, and were assessed in a similar manner to the previous assignments. Faculty judged six of the seven films as outstanding and the seventh as very good.

In the post-course survey, the majority of students responded that during the course they had "always" been self-motivated, asked for help, invested enough time and energy to meet/exceed course requirements, participated actively, and gave their best possible effort. They felt that the assignments "always" contributed to learning and that the amount of work was "always" appropriate. They responded that they "usually" were well prepared and that the intellectual challenge of the course was "usually" high. In addition, students reported that they felt the course was well organized and executed.[8] Students were then invited to write additional comments. One observed that completing a reading in advance and then experiencing the topic the next day was very useful. Another said (unsurprisingly) that she had learned a lot from walking through a building and asking the professor questions on site compared to sitting in a classroom. Another student appreciated that faculty presentations were integrated and that he had heard from each instructor. In short, with regard to the Nexus Abroad goals, the course was successful in many ways.

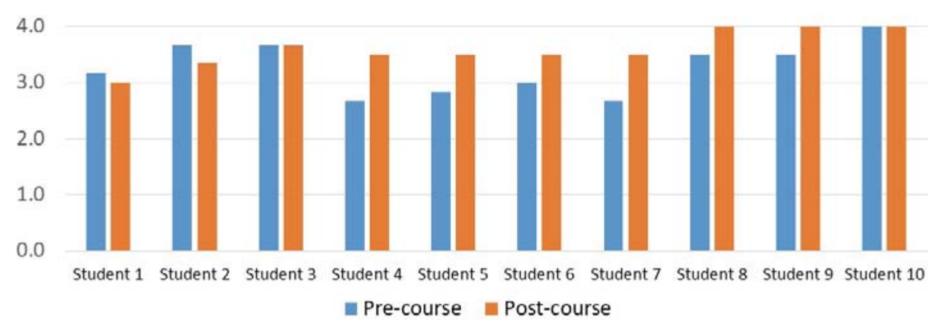
3.4 Discipline-specific and NAAB student performance criteria

Sixteen months after the 2016 course ended, architecture and interior design students completed post-course interviews that asked them to reflect on the course's impact on their subsequent year of studies and its relationship to four identified NAAB student performance criteria. Regarding the course in general, all respondents said that they would recommend it to a friend. Minor concerns included one recommendation to provide more time at the beginning to adjust and another more time at the end to complete the final film. Unanimously, they felt that the influence on their subsequent education was very positive. One student said that his immersion in a foreign culture made him feel more connected to global courses in the general education curriculum. Two others noted the connection to history of architecture and studio courses. Another mentioned that seeing sites first hand gave her a "different eye." All were favorable about the transdisciplinary aspect. One respondent thought there could have been more interdisciplinary work within the smaller group activities and another was impatient that interdisciplinary work wasn't happening more frequently back on campus.

The second set of questions regarded the four NAAB student performance criteria assigned to the course (which overlapped with the Nexus Abroad goals discussed above): (6) communication skills, (7) investigative skills, (8) history and global culture, and (9) cultural diversity and social equity.[9] Regarding professional communication skills, students agreed these were honed, though one complained that the pace was too fast, and another that they should have prepared even more diagrams and sketches for the final film. One comment praised working with non-designers as a way of integrating other perspectives when completing a task. For investigative skills, while a student mentioned needing more information on the host countries, two others said they learned a lot about particular sites and social issues in Bosnia. One student wrote that it was good training for the programming studio back on campus. Finally, students were moved by sites that were memorable for historic events (the assassination of Archduke Franz Ferdinand in Sarajevo), religious conflict (the Great Mosque/Cathedral in Cordoba) or their association with nationhood (Plaza de España in Seville). Any international trip naturally addresses the history and global culture criterion, and students recognized this consistently, though their comments were still instructive. One called seeing the role of religion in other countries "eye opening," a second recognized the impact of history on architecture today, and a third appreciated staying in centrally-located hotels which facilitated convenient exploration of the locales. Not every course can deal with cultural diversity and social equity to the same extent, but in this case every student mentioned the impact the recent war had on Sarajevo's architecture, its power hierarchy, and its population. Students' digital postcards and films required clear graphic and verbal communication based on research from a variety of sources, and, furthermore, on their assessments of multiple cities visited. These deliverables revealed that the students had addressed the NAAB criteria. The results of the post-course survey and interview confirm that students acknowledged their enhanced skills and knowledge bases.

The long-term impact on the students' success in post-trip courses also provides some informative data for students in the College of Architecture and the Built Environment.[10] For the 13 architecture and interior design students who participated in Nexus Abroad from 2014 to 2016, and were enrolled in studio courses both before and after the experience, there was no discernible impact on studio grades. That outcome is not surprising, since there is no studio component to Nexus Abroad. Since educators would want study abroad to enhance subsequent studio performance, this issue is worth further investigation. On the other hand, exposure to the history of art, architecture, interior design, and urbanism is an important part of the experience for students, and there we do find an impact, as demonstrated in Figure 3. Six of the ten students who were midway through the required sequence in History of Architecture and Interiors courses increased their grade in those courses (while two students' averages remained steady), with the pre-course average of 3.32/4.00 rising to 3.60/4.00 after Nexus Abroad. Compare that to the grades of a control group of ten students who did not participate in Nexus Abroad, but were demographically and academically similar to the Nexus students: three increased, four remained steady, and three declined. Furthermore, for the four students who began the history sequence after Nexus Abroad (not shown in Figure 3), two earned a 4.00 average and another student a 3.89. This is a small group of students from which to draw broad conclusions; however, the data show high achievement in history courses after the international experience.

Figure 3: Change of grades in History of Architecture and Interiors courses, 2014-16 cohorts



4.0 CONCLUSION

Nexus Abroad is in its infancy, but it has much potential to enrich the education of architecture students. Being an elective course, it is dependent upon students' interests, budgets, and desire to try a short study away experience. It also relies on faculty expertise and willingness to invest the many hours needed to craft a successful transdisciplinary course. This investigation of and participation in Nexus Abroad in the European context suggests that a short-term, international, and transdisciplinary course enhances the education of architecture students in terms of global awareness, resourcefulness, and openness even when studio is not part of the curriculum. One goal of Nexus Abroad is to encourage students to undertake a traditional study-abroad semester, which at Jefferson, like many institutions, requires studio and therefore exposes students to professional issues in the global context. In a few years, there will be enough data to examine whether rising sophomores participating in Nexus Abroad continue to benefit from its global, transdisciplinary basis and whether it entices more students to choose a semester-long experience as a senior. Future iterations will also provide the opportunity to experiment with the suggestions identified in section 3 as well as the opportunity to diversify the locations and populations involved, as several educators have advocated (Dutton 1991; Groat and Ahrentzen 2001; et al.) Demonstrating that spirit, the 2018 Nexus Abroad course will tackle India.

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ENDNOTES

[1] For this study, the following terms are used intentionally: multidisciplinary (involving multiple disciplines collaborating in an additive way, so they remain separate), interdisciplinary (involving multiple disciplines collaborating synergistically), and transdisciplinary (involving multiple disciplines collaborating from the onset of an activity to form a new holistic approach, which can have a long-term impact on each discipline). Linder, 291-98, provides an historical account of interdisciplinarity and transdisciplinarity in architectural education.

[2] Created by Philadelphia University four years ago, Nexus Abroad has no connection to the Forum-Nexus Study Abroad program that provides European experiences for students from institutions worldwide.

[3] A review of the websites of multiple prominent Architecture departments implies that their study away programs are still largely mono-disciplinary in practice.

[4] Coleman, 204. This issue touches on the debate of whether architecture truly is an independent discipline. Robinson, esp. 62-63, discusses whether architecture is a distinct discipline. Based on her clarifications, it is reasonable to continue identifying architecture as a distinct discipline for the purpose of this article.

[5] Those authors incorporate lessons from E. de Bono, *Serious Creativity: Using the Power of Lateral Thinking to Create New Ideas* (New York: HarperBusiness, 1993) regarding “lateral thinking,” and T.J. Howard, S.J. Culley, and E. Dekoninck, “Describing the Creative Design Process by the Integration of Engineering Design and Cognitive Psychology Literature,” *Design Studies* 29, no. 2 (2008) regarding the differences among original design, adaptive design, variant design, and routine design.

[6] In addition to the valuable suggestions from his peer reviewers, the author owes much gratitude to colleagues Prof. Catherine Casano and Dr. Steve Dinero for their collaborative efforts and sharing their disciplinary expertise in the 2016 iteration of the course. In other years, the organizing themes for the course have been: the Legacy of Nazism in Central and Southeastern Europe, Modernity and Post-modernity in Europe, and Modernism in Central Europe between the World Wars. The theme for the 2018 course in India is Politics, Power, and Presentation, combining comparative legal systems, global economy, and the built environment.

[7] The author is indebted to colleagues Dr. Phil Tiemeyer, former faculty coordinator of Nexus Abroad, Prof. Lisa Phillips, current faculty coordinator, and Dr. Madeleine Wilcox, director of International and Domestic Study Away Programs, for sharing surveys and discussing the broader program goals. In 2015-2018 students enrolled in Nexus Abroad shifted from primarily rising sophomores (almost 50% for two consecutive years) to primarily rising seniors (67% one year and 44% the next). The majors represented also varied to include graphic and animation design, business marketing, construction management and landscape architecture, health science, biology, law & society, and environmental sustainability, while losing some others.

[8] Specific to the small-group experience, students responded with “always” when asked if the instructor connected the course objectives to activities, assignments, and assessments; encouraged them to connect their experience to the course; provided clear, useful feedback to improve learning; inspired interest in the material; was available and helpful; communicated ideas and information clearly and effectively; graded fairly; treated students and their ideas with respect; and used required texts/other materials effectively.

[9] For full descriptions, see National Architectural Accrediting Board, 16.

[10] Acknowledging the transdisciplinary mission of Nexus Abroad, it would be valuable to examine how students perform in their general education courses before and after Nexus Abroad, but that topic was not considered as part of this study. Continuing to collect data from future cohorts of students would also be crucial to the study and improvement of the program.

Robert Holton

La Ville du Bien-Être Collectif: A Prototype Sustainable Community for Disadvantaged Caribbean Regions

La Ville du Bien-Être Collectif:

A prototype sustainable community for disadvantaged Caribbean regions

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ABSTRACT:

Objectives:
To provide a strategic framework for the utilization of under developed rural land with the intent of enhancing the economy, creating work opportunities, and strengthening the general wellbeing of the population. The goal is to provide a community infrastructure that allows for equal access to resources and opportunities for each citizen.

Methodology:
The development of a master plan for the community of Gressier Haiti, a coastal town near the capitol Port-au-Prince. La Ville du Bien-Être Collectif is distinctive in the way it responds to the community development goals of the Haitian government in a single unified plan. The plan's transformative approach is designed to overcome the extensive economic and social problems of the country. The organizing principles are founded on reconstructing the economy, re-growing the middle class, stabilizing the physical context, and reducing the impact of natural disasters. The primary economic driver of the community is the defining of an educational and commercial center focused on value-added agriculture. A vocational college is at the core of the center with a social agenda to educate a new generation of agro-entrepreneurs in techniques leading to improved crop production through sustainable practices.

Achieved outcomes:
The master plan is organized around a compact center surrounded by residential neighborhoods and a buffer of green agricultural fields. The neighborhoods, oriented towards middle-income inhabitants, are developed at a pedestrian scale and each have a social communal core. The entire community responds to the natural environmental conditions and is supported by sustainable practices which promote self-sufficiency. The master plan presents successful strategies to expand the middle class in the current socio-economic conditions of Haiti. It is capable of adaptation to other sites and has the potential to be transferred as an innovative planning technique throughout the Caribbean.

KEYWORDS: sustainable, community, prototype, reconstruct, re-grow

1.0 CONTEXT

1.1. Geography

La Ville du Bien-Être Collectif, a prototype sustainable community, is planned around the geography of the south central region of Haiti at approximately 18 degrees north latitude and 72 degrees west longitude (Fig. 1a). Haiti is one of the most populated countries in the Caribbean and the third largest in land area (*World Population Prospects* 2017). The topography is diverse with the most mountainous terrain in the region, but is also composed of small coastal plains and long river valleys. The country has a hot and humid tropical climate with an average winter temperature of 74 degrees and an average summer temperature of 88 degrees. Annual rainfall averages around 60" with rainy seasons in the spring and fall. The country is at times impacted by both water inundation and scarcity, both of these types of meteorological occurrences are often heightened by a deforested landscape leading to severe soil erosion.

The proposed site for the community is near Gressier, a coastal town of approximately 25,000 inhabitants (*Mars 2015 Population Totale* 2015). This is an area to the west and in close proximity to the capitol Port-au-Prince, around 12 miles. The parcel is composed of 150 hectares with an irregular geometric shape and a predominately non-orthogonal perimeter boundary (Fig. 1b). The existing natural surroundings are a variety of flat, shallow, and steep terrain with expansive views to the north coastline and the sea beyond. The minimally sloped topography is mostly open farmland. At the higher elevations, steeply sloped topography is covered with dense pockets of vegetation. Flora Indigenous to the area includes acacia, rosewood, cedar, and palm trees. The natural fauna is mostly small mammals, reptiles, and birds. Cows and goats make up the majority of common domestic farm animals. The site has a network of streams that flow downhill across the topography from the south to the north. These streams have the potential to expand into small rivers depending on the season. Environmentally the site experiences a high amount of annual rainfall, solar exposure, and cross winds. The region is a high-risk area for natural disasters and has a recent history of earthquakes and hurricanes.

Figure 1a & 1b: Site location. Source: (Author)

1.2. Socio-economic

One of the most populated countries in the Caribbean, the health and wellbeing of Haiti's citizens has been severely impacted by both political and environmental catastrophic events. Political upheaval has significantly undermined the general population over the last half a century and is often noted as a contributing factor to unstable food and fuel prices (*Haiti's government falls after food riots* 2008). A history of human rights abuse has also been documented in the same period (Buss, Terry F.; Gardner, Adam 2009). Since the beginning of the 21st century the Haitian environment and citizens have been significantly effected by natural disasters. In 2008 three major hurricane storm events hit the country leaving almost a million individuals in need of humanitarian assistance (UN seeks almost US$108 million for Haiti floods 2008). In 2010 a magnitude 7.0 earthquake struck Haiti. Over 300,000 people lost their lives in the event and over one and a half million individuals were homeless without basic food and shelter. Post disaster waste contamination added to the spread of disease ending the lives of another 10,000 people and leaving around one million sick (Sontag, Deborah 2012). Then again in 2016 another hurricane hit the country, the largest in half a century. This series of human initiated and natural disasters left the resources of the country depleted or completely destroyed. A fragmented infrastructure and the severe reduction of available basic human amenities, such as health care, caused thousands of individuals to be displaced across the country.

2.0 OBJECTIVES:

2.1. Strategic framework

La Ville du Bien-Être Collectif provides a strategic framework for the utilization of under developed rural land with the intent of enhancing the economy, sustaining the environment, and heightening social bonds. The primary objective of the sustainable community is to strengthen the general wellbeing of the population. Economically the ambition is to nurture a group of agricultural entrepreneurs in the direction of sustainable farming practices, promoting future generations and enduring communities. The immediate objective is to employ thousands of citizens in food, energy, and construction trades with a long-term goal of developing independent private businesses. Environmentally the response intends to protect and supplement local ecosystems through sustainable agriculture, energy, and building practices. The implementation of water management strategies, renewable energy harvesting, and resilient building techniques can help reduce the risk of cultural and natural disasters. Socially the plan envisions to enhance social stability by providing income appropriate housing, pedestrian scaled neighborhoods, primary and vocational education, and easily accessible commercial areas. The goal is to provide a community infrastructure that allows for equal access to resources and opportunities for each citizen.

3.0 METHODOLOGY:

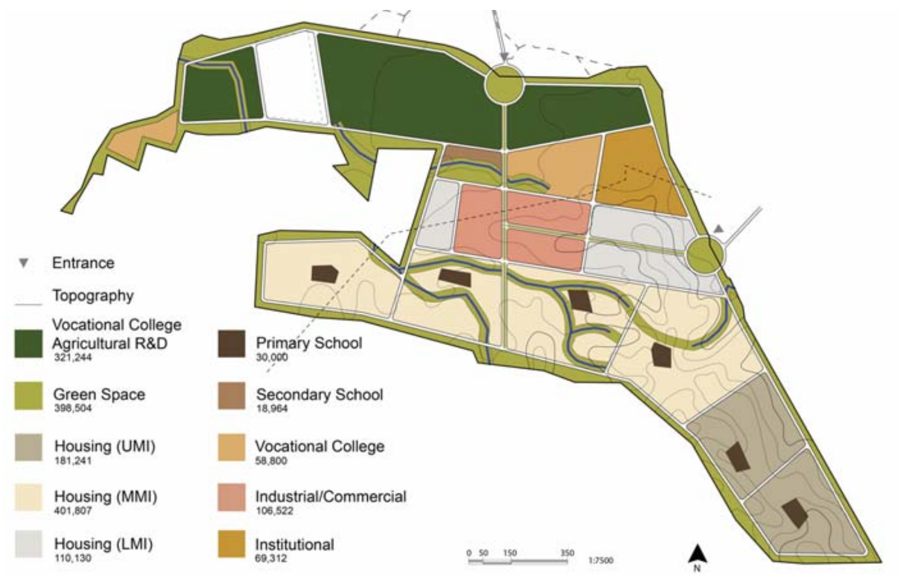

Figure 2: Master plan zoning. Source: (Author)

3.1. Master plan organization

La Ville du Bien-Être Collectif is composed of three primary elements that include agricultural fields, public commercial and educational centers, and residential neighborhoods. Inspired by the organization of Italian hill towns, settlements with a similar topographic condition, the master plan is based on five primary principles; clearly defined entry sequences, surrounding green buffers of agricultural fields, compact commercial town center and educational quarter, clustered hillside dwellings, and communal gathering spaces. Two points of arrival at the north and east perimeters establish thresholds that initiate the entry sequences leading to the town center. This vehicular boulevard and pedestrian greenway passes through the surrounding buffer of planted fields, proceeds along the educational quarter, and culminates at the commercial town center. At a finer grain, the promenade continues to the more remote clustered hillside dwellings. The agricultural fields are the first zone in the entry sequence and form a buffer between the town and the coast to the north. They are predominately on shallow sloped land enriched by soils deposited from a river to the west. The educational quarter is located between the perimeter green fields and the commercial town center. These adjacencies allow for a layering of social interactions that promote an exchange critical to developing economic prosperity. At the confluence of the two primary entry sequences is the core of the master plan. Infused with a mix of commercial, civic, and residential programs the town center is a unifying agent for the community. More remote, the hillside dwellings are grouped into neighborhoods and located on the steeper sloped terrain. Communal gathering spaces are a recurring element in the master plan and take the form of market squares in the town center and smaller school or church plazas in the neighborhoods.

3.2. Master plan zoning

With an area around two million square meters the master plan zoning is divided into ten distinct areas (Fig. 2). From the almost flat shallow topography of the northern parcels to the steep landscape of the southern lots the master plan gradually transitions from more public open spaces to private living areas. The agriculture research and development zone at the northern edge comprises approximately 350,000 square meters, spanning the entire distance between the eastern and western site perimeters. Shifting to the south, the educational and institutional zones comprise an area of around 150,000 square meters and are strategically situated between the agricultural zone and the commercial zone. At the center is the 100,000 square meter commercial town center. This zone is flanked by low-middle income housing to both the east and the west with an area of 110,000 square meters. Moving toward the southern housing parcels about 400,000 square meters is allocated to middle-middle income housing and 110,000 square meters for upper-middle income housing. The housing zone along the southern perimeter is divided into six neighborhoods each with a primary school located at the center. The total primary school area is approximately 30,000 square meters. The center of each zone is located within 400 meters of an adjacent zone allowing for easily traversed pedestrian distances accomplished within a 5 minute walk. The proposed total combined building area within all zones is around 500,000 square meters. Surrounding the master plan along the entire perimeter and woven through the different zones is 400,000 square meters of green space. This buffer zone is a critical component in sustainable planning and environmental resilience.

3.3. Master plan sustainability

Several strategies for sustainable community development are incorporated into the master plan (Fig. 3). The project site has many natural waterways that are an enormous natural resource with potential for energy production and water filtration treatment techniques. At the higher elevations, where the dwelling units are located, hydro-power is harvested through a series of micro-dams as a means to offset the energy needs of each neighborhood. Wetlands water treatment areas are located at the lower elevations near the edge of the agricultural fields. After filtration, this water can be reused for crop irrigation. Along the various waterways that travel from the residential slopes to the farming fields catchment areas are located to accommodate increased flow naturally occurring with seasonal changes in precipitation and from extreme weather events. At the edges of the catchment areas and following the topography of the steeper residential slopes gabion retaining walls are located for soil retention and erosion prevention. In conjunction with the proposed hydro-power at the higher elevations, micro-solar power is deployed throughout the residential zone as a renewable energy source. These sustainable planning strategies play a critical role in providing a stable physical context and reducing the potential impact of natural disasters.

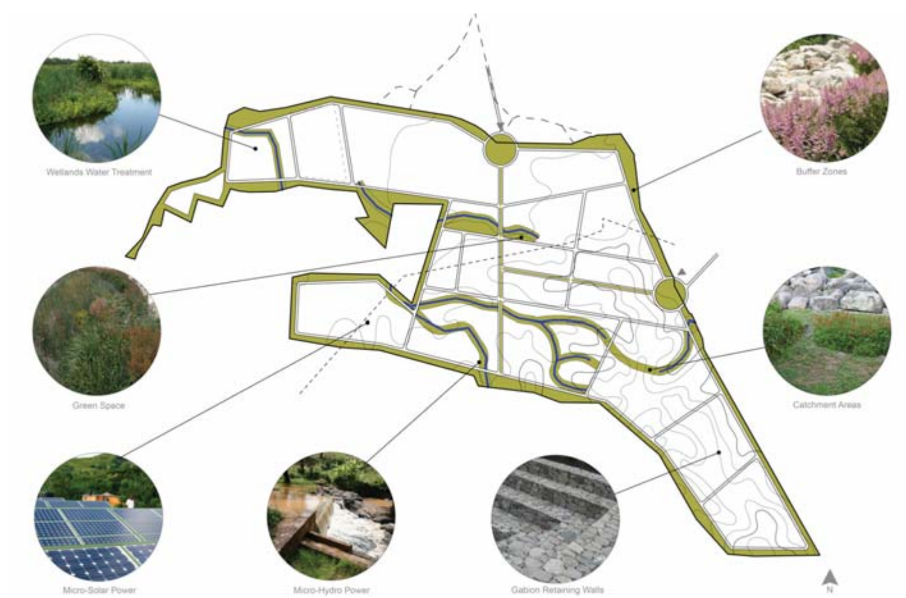

Figure 3: Master plan sustainability strategies. Source: (Author)

3.4. Commercial center

The commercial town center, located at the core of the master plan, is designed to be the social and economic hub of the community. Basic planning elements include pedestrian green ways, a focal cultural plaza, multi-use central courtyards, and an institutional square (Fig. 4). The two main pedestrian greenways provide a primary means of access between planning zones while simultaneously engaging citizens as thoroughfares of commerce lined with commercial businesses. These commercial parkways culminate at the location of a unifying cultural plaza surrounded by hierarchical structures capable of reinforcing local heritage and identity. Flanking the pedestrian greenways are a series of multi-use central courtyards that promote temporary markets and impromptu social meetings. The structures surrounding the courtyards are composed of shops on the ground level and apartments on the upper levels, contributing to a sustainable entrepreneurial live/work lifestyle model. Institutional services are equally accessible and planned around a similar town square typology. In whole, the town center zoning is comprised of over 50,000 square meters of ground floor commercial space with the capacity to increase by 100% through a daily expansion into central public areas open to everyone.

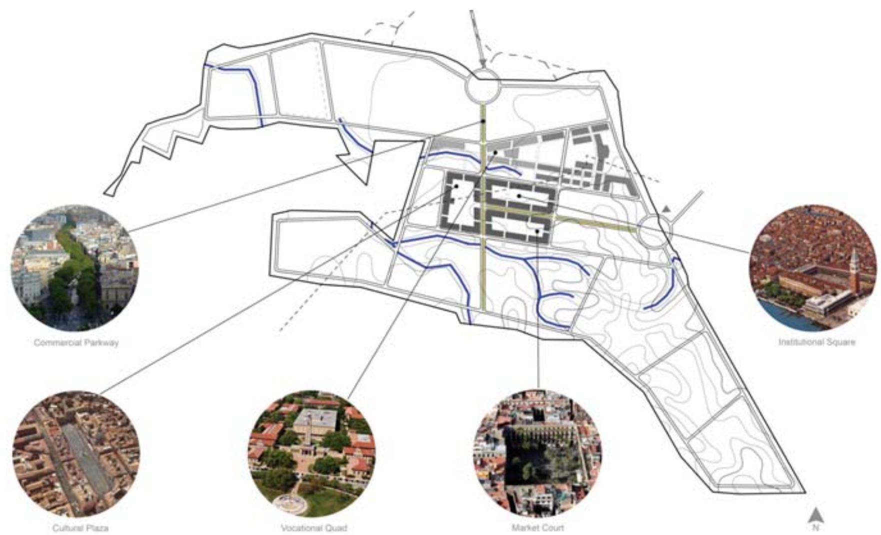

Figure 4: Town center planning strategies. Source: (Author)

3.5. Educational center

Along with the town center, the educational center is the primary economic driver of the community with a focus on value-added agriculture. The educational center includes a vocational college, secondary school, and research & development facilities within the agricultural zone. Both the vocational college and the secondary school are sited in an area south of the agricultural fields, north of the town center, and flank one of the primary pedestrian greenways that connects the northern site periphery to the town center. The low-middle income housing neighborhoods are also in close proximity to the educational center and provide necessary student housing. The vocational college and secondary school comprise 40,000 square meters of building area over three levels and surround a centrally located, five level, iconic structure. Including the agricultural facilities and fields, the center occupies close to 350,000 square meters of land. Crops traditionally cultivated in areas around the project site include millet, cassava, banana, coffee, maize, and sugar cane. The goal of the educational center is to train local citizens in the practices of value-added agriculture with the intent to develop a new generation of economically stable farmers. The system of progressing through primary school, secondary school, vocational college, and then practicing in the agriculture research facilities defines a clear path towards a stable way of life for the community. The concept of value-added agriculture is critical to rethinking traditional farming techniques, it allows a greater percentage of harvested crops to survive the transition from the farm to the market and ultimately the consumer. Through education, research, and practice the citizens of La Ville du Bien-Être Collectif have the opportunity to develop an environmentally and economically stable society.

3.6. Residential neighborhoods

A Key aspect to strengthening the general well being of a population is the availability of suitable and affordable housing. The master plan is organized to accommodate individuals and families of various middle income financial means by providing low-middle, middle-middle, and upper-middle income housing. Arranged into neighborhoods, the design for each of the residential areas has been developed to address the needs of a wide spectrum of individuals at various stages in life.

3.6.1. Low-middle income housing

Located in the middle of the master plan adjacent to the town center and vocational college, the low-middle income housing is the most densely planned neighborhood. Intended occupants include students attending the vocational college, recent graduates establishing new businesses, and young business owners. The town of Jacmel, a Haitian community along the southern coast, was an important planning precedent. Jacmel is a town of around 40,000 inhabitants that has maintained it's rich architectural heritage with many well preserved French colonial townhouses dating to the early 19th century. The town has been labeled 'City of Light' being one of the initial settlements in the Caribbean to have electricity in the early 20th century (Leeder, Jessica 2012). Culturally the town has a vibrant art scene and uses it's distinct architectural background to stage film and music festivals. Critical components of this model include; mixed use buildings, entrepreneur homes, market plazas, covered walkways, and exterior covered terraces. In this neighborhood of the master plan, mixed-use buildings are positioned around central open market spaces. These buildings allow for both residences and a variety of businesses to exist within a single structure and encourage the development of individual driven commerce. Similarly, entrepreneurial homes that help facilitate new business types based on the expertise of each citizen are located along the edge of the neighborhood at the commercial center. Townhouses make up the majority of the residences and are typically 50 square meters in size with four units per each 200 square meter plot. Market plazas, located at the center of the residences and businesses, provide an open space for temporary vendors, leisure activities, and entertainment events. Architectural elements, such as covered walkways and exterior terraces, line the streets to help foster a pedestrian environment. The low-middle income neighborhood is comprised of over 2,000 dwellings that include around 1,250 townhouses and 750 town center apartments on three levels for a total building area of over 100,000 square meters. The primary goal of the neighborhood design is the promotion of social interaction as a means to enhance economic opportunities and the prosperity of the citizens.

Figure 5a & 5b: Housing neighborhood plans. Source: (Author)

3.6.2. Middle-middle income housing

The middle-middle income housing neighborhoods are located to the south of the town center on terrain with a gradual slope. The medium density of the neighborhood planning makes it suitable for new families of 3-5 members. This housing area incorporates many of the organizational strategies found in Petion-Ville, a suburb near the perimeter of Port-au-Prince Haiti. Petion-Ville is a mostly residential area with around 300,000 inhabitants (*Mars 2015 Population Totale* 2015). It is known as a safe, stable, and prosperous area supported by many businesses and social amenities. Elements vital to the identity of this precedent include hillside dwellings, vegetation lined streets, open green spaces, and a centralized school with community shared playing fields and an open plaza (Fig. 5a). The residences are composed of clusters of attached houses. Each house is 75 square meters in size with three units per 250 square meter plot. The gradually sloping landscape allows for privacy between the densely sited dwellings and a network of tiered walkways provides pedestrian access to the center of each neighborhood (Fig. 5b). Near the center of each middle-middle income neighborhood civic programs and spaces are located. These programs include a primary school, small church, plaza, and open green playing fields. The neighborhoods are scaled based on the distance an individual can walk in five minutes. This allows the central communal programs and spaces to be easily available to the citizens of each neighborhood. The four middle-middle income neighborhoods are made up of almost 4,000 dwellings on two levels for a total building area of almost 300,000 square meters. The objective of these neighborhood plans is to provide a range of easily accessible resources for each family composed of individuals at various stages in life.

3.6.3. Upper-middle income housing

Similar to the middle-middle income housing, the upper-middle income housing is planned based on design principles found in the Petion-Ville precedent. Distinguishing neighborhood features include clustered hilltop dwellings, open views, lush vegetation, open green spaces, and public plazas. The two upper-middle income neighborhoods are located in the southeastern area of the site on the steepest terrain. These are the least dense neighborhoods with the largest dwellings and plots. The houses are grouped in two adjacent units of 120 square meters each on 350 square meter plots. Further developing the terraced housing strategies of the middle-middle income neighborhoods, the steeply sloping landscape provides greater privacy for individual families and expansive open views of the coastline. The higher elevation also naturally provides a more lush landscape adding to the sense of personal space. Public amenities are located at a central plaza and include a small market, a chapel, and spaces for temporary vendors. A large open green space is also placed adjacent to the plaza for community events. The two upper-middle income neighborhoods comprise over 750 dwellings on two levels that make up a total building area of around 100,000 square meters. These neighborhoods are designed to offer families a greater independence while still providing valuable social amenities.

3.6.4. Housing typologies

Responding to the socio-economic needs of the citizens in each neighborhood several housing types were developed. Four townhouse prototypes were developed for the lower-middle income housing to address varying plot shapes and setbacks. The middle-middle income housing has seven prototypes to accommodate both linear and compact plots as well as the sloped topography. Six multi-level tiered prototypes were developed for the upper-middle income housing as a response to the steep slope of the higher location where they are sited. For all income categories an inventory of roof designs were developed that included shed, gable, hip, and flat configurations with varying overhang dimensions to address the unique orientation of each housing cluster. Sustainable building strategies incorporated into the dwelling structures include solar panels for electricity and hot water production, roof ventilation for convection cooling, green roofs for insulation and vegetable growing, roof top rainwater harvesting, extended overhangs for solar shading, and landscaping with indigenous plants (Fig. 6). The housing designs are capable of being constructed with predominately local labor and materials. They are intended to be simple yet meet the needs of a growing middle class society.

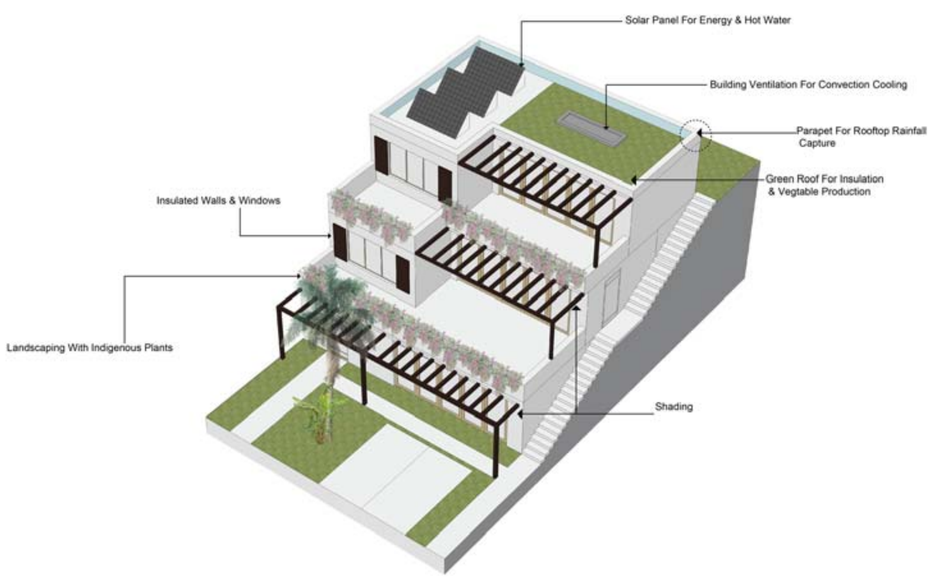

Figure 6: Building sustainability strategies. Source: (Author)

4.0 ACHIEVED OUTCOMES

4.1. Concluding results

The master plan of La Ville du Bien-Être Collectif is organized around a compact center surrounded by residential neighborhoods and a buffer of green agricultural fields. The organizational adjacencies encourage an open social society and promote a sense of equality paramount to establishing economic stability. The master plan zoning clearly defines a balance between public and private areas for communal living appropriate to citizens across a wide range of ages. The incorporation of sustainable strategies fortifies physical, economic, and social environments through the utilization of renewable natural resources and helps establish an economically independent middle class population. Located at the heart of the community, the commercial town center is an easily accessible hub of social and economic activity. By providing a place of exchange for individuals to sell and purchase merchandise the central business area promotes commerce and supports financial self-reliance. Designed to accommodate the developing needs of the population, the housing neighborhoods offer secure and socially engaging environments conducive to developing economic independence and broadening the community collective. Each of the neighborhoods, oriented towards middle-income inhabitants, are developed at a pedestrian scale and each have a social communal core that promote interaction and civic discourse. Over 7,000 sustainably built and environmentally resilient housing units are planned in 8 neighborhoods. The educational center expands future generations of prosperous farmers and entrepreneurial citizens through teaching, researching, and developing environmentally sensitive agricultural practices based on the region's natural resources. In the short-term around 15,000 new jobs are established in food, energy, and housing production. The entire community responds to the natural environmental conditions and is supported by sustainable practices promoting a self-sufficient society. The master plan presents successful strategies to expand the middle class in the current socio-economic conditions of Haiti. It is capable of adaptation to other sites and has the potential to be transferred as an innovative planning technique throughout the Caribbean.

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Poster Abstracts

Building Simulation Tools and High Performance Design

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It is usually to observe a new type of computational tools were utilized by architects and students. Especially, building performance simulation tools are more easily accessible to users.

More architecture schools are giving courses in the area of computational design courses. One of the new course related environmental design is the class offering computational building simulation tool as a methodology to measure their design's quantitative performance. However, it is not clear how this tools helped users. This paper is to understand computational tools impact on current design.

To understand how user changed their design process by computational tools. This paper conducted the survey before and after they take a class on using modeling and simulating building performance tools.

The graduate level course is monitored for the experiment. The class consisted with diverse background undergraduate in architecture and engineering. Three domain tools were introduced to the students; they are energy, light, and airflow. At the first day of the class, students are asked to redesign the small residential building to improve its performance in terms of Energy, Daylight, and Airflow without using any simulation tools. During the 16 weeks, the class introduce simulation tools. As final project students were asked to revisit the first assignment and use simulation tools to redesign the building.

By comparing these two design proposals with the survey to students, this paper like to discuss observation of various relation about students background, simulation tools, and there understanding of high-performance design.

A Framework for Systematizing Airflow Behavior in Natural Ventilation Strategies with respect to Climate Zones

Homeira Mirhosseini, Ute Poerschke
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The vast expansion of mechanical air conditioning in buildings since the 1960s has severe impacts on the environment. In the United States and other developed countries, the amount of energy consumed by buildings for mechanical air conditioning is steadily growing. Reducing building energy use and improving indoor air quality by increasing passive cooling mechanisms seems to be an appropriate solution for achieving sustainability.

Passive cooling is an effective approach for building design that focuses on improving indoor thermal comfort with low or zero energy consumption. Using the energy sources from the natural environment combined with designing the building components provides passive cooling for the building. The objective of passive cooling is to maximize the energy efficiency of the building by minimizing the heat gain from external sources as well as helping heat reduction. There are several passive cooling strategies that can be incorporated into the design of a building for achieving this objective. Natural ventilation is one of the passive cooling strategies that removes heat from a building using the physical processes of air movement such as buoyancy, gravity, and wind, and of subtracting/adding humidity to air. The natural ventilation strategies have diverse functionalities and are applicable to specific climate conditions within a definite time span (daily or seasonally). Each strategy has specific characteristics which can be combined to different technologies.

This paper tries to systematize natural ventilation strategies with a focus on factors like air movement behavior, causality of natural ventilation strategies, techniques used in each strategy, time of use, and the climate in which the strategies are operative. The outcome is a comprehensive tool summarizing all natural ventilation strategies and their characteristics to allow for easy selection of appropriate strategies in diverse climates during the design process.

Feasibility Study of High Performance Shipping Container Schools in Developing Countries

Laura Lee Battaglia, Jeehwan Lee
Hampton University, United States of America

There is a need for durable, low-cost and sustainable school facilities around the globe, especially in developing nations. Recycled shipping containers are potential solutions to this need due to their materiality, portability, and flexibility for future expansion. As for economic aspects, shipping container constructions are 20 -50 percent cheaper compared to traditional school construction methods. In addition to research on the physical and tangible outcomes of shipping container classrooms, rigorous study of how cultural values and norms may affect the success of this project, is equally important.

Architectural Research: An interdisciplinary team of students and professionals are tasked to explore the technical and programmatic feasibility of modifying a single unit as well as studying the implications of expansion. This research begins with prototype development of a modular classroom for not only spatial layout but also students' comfort and energy performance. A prototype of a modular classroom focuses on sustainability in passive heating and cooling, natural ventilation, daylight performance, and renewable energy generation, providing students with an ideal learning environment.

As a preliminary study for prototype development, this research employs a mixed-use research method including simulation study and mock-up test. The first phase of the simulation study is designed to explore the possibility of wind-driven ventilation using computational fluid dynamic (CFD), and daylighting performance and solar energy generation using energy simulation software. Depending on several control variables such as container orientation, window size, window position, 10', 20', and 40' long shipping containers are simulated for airflow patterns, air velocity (m/s), indoor temperature distributions (˚C), illuminance levels (lux), and solar energy generation (kWh). Based on findings from simulation study, second phase of mock-up test for validation is planned to test its performance using HOBO sensors in and around shipping containers.

Planning Research: The same interdisciplinary team is simultaneously tasked with understanding the cultural and social impacts of global design. Questions that will be addressed include: how to achieve community engagement with the project, and how to meet specific local educational needs. The potential for connecting container schools around the globe through a learning management system and central data servers is one aspect that may be studied as one solution to addressing educational needs.

The Impact of Academic Library's Indoor Environment on Students' Behavior: The Example of Langsam Library, University of Cincinnati

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At present, Modern library plays an important role as work, study and meeting spaces. Although scholarship on how the indoor environment in academic library affects students' behavior abound, most of these studies are restricted to being qualitative studies. This paper would however explore what factors will influence the behavior of students in library by using mixed methods, combining the data analysis and qualitative methods. The focus will be to assess behavior, not as the activity type but rather as the time spent by students in academic library. Based on the regression analysis between the environmental factor variables and the time spent variable, noise will be shown to be an important factor influencing the amount of time spent by students in an academic library. While the remaining factors, including temperature, relatively humidity and illumination, won't affect students' time- stay. Evidently, this paper will show that the design of libraries should focus on creating a quiet environment to prolong the students' learning time. Thus, the library will be more effective as a learning space. It is hoped that this article will be a reference for the designers who are interested in the environment design of academic library.

Designing a Responsive Acoustic Surface to Optimize Disruptions in the Academic Design Studio

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The academic design studio is traditionally an open-plan environment. This studio typology contributes to effective collaboration, learning, visual connection, as well as disruption. Our goal is to study the effects on how student behavior, learning, and productivity, can positively change with the design and implementation of a responsive acoustic surface.

The open-plan academic studio culture is built on inherent verbal communication from both professors and students. With multiple conversations taking place simultaneously, noise from desk critiques and presentations lead to a distracting work environment. Empirical evidence suggests that noise disturbances effect productivity, speech intelligibility, and overall well-being. Additionally, studies show that exposure to noise generated within the building can lead to reduced concentration and mental arithmetic performance, and increased distraction due to reduced speech privacy.

Our research begins with the question of whether or not the academic design studio can contextually and autonomously respond to its occupants. Artificial intelligence is changing the way many industries function and perform, from information gathering, to self-driving cars. Algorithmic approaches to informed and autonomous decision making is becoming the new normal, and what we should expect for the future. We want to understand how these principals can lead to better scenarios in the design studio typology.

The aim of our work is to focus on how to optimize the studio for academic performance. By responding to their immediate interior environment, self-regulating surfaces have the ability to increase student performance and overall well-being. To contextualize interior elements that can become autonomous systems, we use computational analysis and parametric interfaces to collect and filter real-time data to provide feedback to our design approach.

Our responsive surface seeks to reduce fatigue and distraction in the academic design studio by controlling disrupting noise, while also serving as an adjustable separator that maintains a sense of the traditional open-plan environment. With this framework in mind, our research explores a responsive surface design that is intended to mitigate disruptions in the design studio.

Understanding the Impact of Anthropogenic and Natural Causes of Diurnal Urban Heat Island Phenomenon using Heat Stress at the Pedestrians-level in the City of Chicago

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Urban Heat Island (UHI) has profound effects on the thermophysiological responses of residents. Our recent research on the City of Chicago has validated the definition of the open-field UHI phenomenon when compared to the city's surrounding areas. Despite being on the waterfront, Chicago maintains a temperature profile similar to that observed in cities such as Barcelona and London, especially when compared to their surrounding areas (Moreno-Garcia 1994; Bohnenstengel et al. 2011). Focusing on the diurnal behavior of UHI, the contrast between the city and its surrounding becomes less clear. As a result, weather conditions at the local levels may vary from the open-field UHI profile. The authors of this paper have tested the hypothesis that pedestrian' heat stress experience at the tract level differ according to specific neighborhood physical characteristics described in Mayer & Höppe 1987 and Oke 1988. These physical traits are identified to be; proximity to large bodies of water, the degree of the overshadowing in the various urban canyons, levels of ground coverage by vegetation, asphalt, or concrete pavings. This paper focuses on comparing the different anthropogenic and natural environmental taits on heat stress at the pedestrian level. We collected weather data for the hottest day of the year (June 11th, 2016) from O'Hare airport weather station. This data was used to simulate the local environmental conditions on fifteen blocks representing a series of contiguous census tracts forming a 14-kilometer urban transect from the waterfront to the rural peripheries of the city. Envi-MET, a three-dimensional non-hydrostatic simulation program was used to model the buildings-air-vegetation-ground-water interactions along the transect. The outcomes of the simulations runs were further transformed using the BioMet module to calculate the Universal Thermal Climatic Index (UTCI). This index is developed partly by the International Society of Biometeorology and supported by the European Union (Fiala et al. 2012). It uses the concept of equivalent temperature relevant to a reference environment (Bröde et al. 2012). UTCI algorithm uses meteorological data such as air and radiant temperatures, wind speed, and water vapor pressure together with metabolic rate and clothing levels. (Błażejczyk et al. 2010). The literature links the different stress levels experienced to a UTCI level. The result of the Envi-MET simulation showed that the temperature profiles of the most of the census tracts followed the pattern of O'Hare airport profile closely (Figure 1). Other closely resembled the profile of the rural area. During the peak hour, there was a noticeable difference in the air temperatures estimated at the urban tracts. These variations of peak temperature can be attributed to the general anthropogenic and natural features dominant in each tract. On the other hand, the difference in the diurnal UHI among the census blocks along the transect was much clearer (Figure 2). The paper details these features and connects them to the observed thermal characteristics. In conclusion, the paper emphasizes that through studying the heat stress predicted at the pedestrian levels we may be able to identify the impact of anthropogenic and natural elements in each tract.

Quick Construction Cost Estimate Tuned to Architectural Quality

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By using a quick cost estimating method attuned to the quality of various building system, Architectural Quality Cost Estimating (AQCE) can help students gain understanding and control over construction costs as a critical factor for achieving sustainable designs at the conceptual and schematic stages of architectural design.

Architectural Quality Cost Estimating drives the estimate from simple Gross Building Area. It makes use of widely available data for cost of basic building systems to achieve a cost estimate that is sensitive to architectural design while being fast and easy to apply. The breakdown is aligned with the assemblies estimating top-level categories published by R.S. Means. Given a building type and its typical cost per square foot of area, the cost of categories of substructure, shell, interiors, services, and sitework is apportioned as a percentage of total cost. A weighting factor is then applied by the user to each of these categories to adjust the cost by a qualitative classification as Utility, Average, Premium, and Super-premium. The construction cost is then summed from these categories and special assemblies and site work added. The method accounts for increased construction cost of green construction, complex form, fine materials, and elaborate sitework. However, in a full optimization system appropriate to support design decisions, these added cost items also add value by reducing operating cost, increasing tenant rents and retention, or increasing social value. In conjunction with other performance assessments, such as expected income of tenant space, energy consumption, lighting adequacy, and visual assessment, AQCE can enable a student to gain awareness of economic factors and trade-offs.

Analysis of sensitivity and accuracy is being conducted with reference to Means square foot estimating, Means assemblies, and Means item estimating. These other estimating methods require a level of detail that is invariable overwhelming to architecture students, but can lead to acceptable accuracy. The goal in the comparison is not to show that AQCE is useful for industry for project cost control, but instead to discover whether it is useful in educational settings to provide students with an awareness of major factors contributing to project cost in early stages of architectural design. The standard of validation is that the method will produce a “steerable” estimate that guides the student designer in the right direction when making design decisions.

As the cost estimate can easily be driven from quantities produced by a conceptual massing model in a CAD or BIM authoring software system, the method is well-adapted to aiding in cost control at the very early stages of design, the typical topic of academic design studios. It may also be useful as a design criterion in optimization algorithms or a fitness function in genetic algorithm applications. AQCE is also expected to be useful for land developers who need a “back-of-the-envelope” method to gain a construction cost estimate that is sensitive to architectural quality factors. As such, it may be a crucial contribution to achieving a powerful method for “triple bottom line” analysis in support of sustainable development.

Revalorization Of The Use Of Raw Earth In Construction Practices In Kinshasa (Democratic Republic of Congo)

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Development is impossible without the realization of basic infrastructure and the construction of a quality habitat. Therefore, this project aims to contribute to the valuation of the clay resources of the Kinshasa region in order to develop the production of local, sustainable and energy efficient construction materials. The chosen region is justified by the abundance of clay raw materials and by important needs. The Kinshasa region is facing strong spatial and demographic expansion with, as consequence, the development of a suburban area in which the habitat quality is a critical problem.

Since the early 1990 and the bankruptcy of the Kinshasa Brickyard, the abandonment of building in clay materials was systematic in Kinshasa. Nearly the whole population turned to a local material: the concrete brick. It is a brick made by manual or mechanical compression by mixing grinding fines of a sandstone rock (the Inkisi sandstone) locally called “dust”, alluvial sands (alluvial deposits of the Congo River or the Mbinza, Kalamu and Ndjili rivers) and cement. These concrete bricks of 10, 15 or 20 kilograms cost on average 1, 1.5 and 2 $ the brick. Despite this high cost for most households, the concrete brick architecture is almost the only present in Kinshasa. Earth bricks (even in terra-cotta) are considered poor materials and low resistance materials. People prefer big concrete bricks, which they consider to be more aesthetic and stronger. In addition, the lack of masons trained to build with other types of materials complicates the implementation of another construction method in the region. This is a challenge that seeks to overcome a brickyard which has just been created in the nearby province of the Central Congo. I have participated in providing solutions to that challenge. The brickyard tries to diversify its products by offering a compressed earth block (CEB) made on earth-sand and earth-sand-cement to suburban and disadvantaged populations. The idea is to put forward the ecological, economic and comfort benefits of earthen habitat.

To achieve this, compressed earth blocks (CEB) were produced locally in Kinshasa by a manual press. The dimensions of the manufactured CEB have been adapted to be closer to those of concrete bricks. After a period of drying, the bricks were brought to a laboratory in Belgium to undergo durability tests (accelerated erosion test and accelerated aging test) and uniaxial compression test on CEB submitted to different rates of relative humidity.

This work will show how we manage to generate interest among the local population about the use of earth brick based on scientific researches aiming to produce a quality building material.

Exploration of Acoustical Design for Children with Special Needs

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This study explored the influence of acoustics on behaviors of children with Emotional Behavior Disorder and Developmental Coordination Disorder. Previous studies show environmental acoustics can influence a child’s learning, especially a child with special needs. However, there is a considerable absence of research pertaining to the influence of acoustics on the behavior of children with special needs in classroom settings. Findings suggest the need to develop a better understanding of classroom acoustical design specifically geared toward the unique learning experiences of these specialized populations to inform future design of special education environments.

Architecture for Elves: How Designers use ‘Pop History’ to Visually Construct Cultures

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Visual designers and artists in various forms of media capitalize on a shared understanding of international culture to illustrate attributes and characteristics of artificial societies. Through architectural metaphor and visual signification, these designers imbue their imagined cultures with elements of real history, communicating fundamentals of the fictitious culture through the shared language. This poster examines the architectural language of elves throughout contemporary media projects, identifying relationships to art nouveau, Frank Lloyd Wright, and feudal Japanese architecture. With these visual similarities established, the poster explores how the designers of the elven visual typologies use a ‘pop history’ understanding of these historical precedents to illustrate similar attributes: an exotic air, a comprehension of the natural environment, and a feeling of timeless elegance. By grasping how designers in entertainment exploit this ‘pop history’ understanding, possibilities surrounding user interaction, comprehension, and expression within virtual worlds become clear.

Revitalizing Historic Cairo Through the Azhar Park

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Islamic Cairo is one area that truly captures the essence of Cairo during the Islamic dynasties. It still preserve its sense of place and identity with the bewildering fabric it is composed of and the confusing labyrinths that one experience when visiting this historic area. In 1995, the Aga Khan Trust for Culture made an initiative to refurbish this area and to restore its treasures, such as mosques, madrasas, houses and sabils. Besides this project, the Aga Khan Trust for Culture launched a proposal for a spacious park at the heart of Islamic Cairo, which acts as a lung in this congested area. The Azhar Park is considered one of the major vast open spaces nowadays in Cairo with an area of 30 hectares. This project revived this vital area of Cairo by acting as a catalyst for the other restoration projects in Islamic Cairo. The purpose of this paper is to explore the role of Al Azhar Park as a public open space in restoring, preserving, and promoting the Egyptian culture. It will analyze and evaluate the performance of the Azhar Park project in terms of creating a sense of place in this sensitive area in historic Cairo, whether it respected its surroundings and blended with them, and whether it succeeded in a mission to bridge the gap between the different social classes of Egypt. This evaluation will be conducted through a study of the project, an examination of the design elements and landscape and an assessment of the social and special attributes of this place.

The architectural expression of the invisible boundaries in Mecca

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How could the architect deal with the invisible border between the sacred and secular zone in Mecca? Is there any way that the architect might define the difference between the sacred and secular?

The city of Mecca is the center and a symbol of Islam in the hearts of Muslims around the world because it is linked to the three holy pillars of Islam. The holy book, the Quran, was revealed to Muhammad in Mecca. Allah's holy house, the Kaaba, is there. The Hajj and Umrah religious rituals must be performed in this holy area. All of these three elements make Mecca a holy city. And for this reason, the God (Allah) ordered his prophet Abraham (Ibrāhīm) to identify this land and to build clear pillars for his divine purpose.

Mecca is characterized by mountains of different heights that surround the central region, and this is why the prophet Ibrahim put these pillars in the mountains to clearly defined the holy area that is called the Haram. There are certain obligations that require this knowledge. The Hajj and Umrah, for example, include observances that should take place within the sacred borders. The border effects the cultural aspects that separate the Muslim and non-Muslim, and even the Muslims have some requirements in order to pass into this holy area. For instance, Muslims must respect the land. They are not allowed to cut trees or hunt. They may not harm other Muslims in this area.

The border is visible and invisible. The visible pillars are distributed on the edge of the city's entrances. There are up to 1104 pillars and they are different sizes and built during different historical periods. On the other hand, the invisible border is located between these pillars only recently shown on the map. According to the Islamic sources, the pillars were made by the Prophet Ibrahim with the angel Gabriel In different places by divine command. However, the invisible border was defined by Omar bin Al-Khattab's rule that depends on the slope of the land and flow of water. If the water flows toward the Kaaba it is considered sacred. However, the water that flows in the opposite direction is considered secular or unholy.

This thesis addresses the invisible border as the pilgrims during their Hajj and Umrah, and even the local people are not clear where the boundary is between the pillars. In addition, there are some towns, or homes that extend across the invisible border. The land within the sacred space is valued at 3 times or more than the land that outside of these borders. According to the Quran and Hadith, the good deeds and charity have done within the sacred space count for more than that done in secular space.

I propose the design of a religious/cultural building, part of which lies within the sacred boundaries and another part outside the holy area. It represents the “crossing” of space, and through its organization aims to define this invisible line.

Zhengti: Pursuing Heightened Sustainability, Design Innovation, Holism and Harmony in Chinese Architectural Education

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Our planet confronts a plethora of dramatic challenges moving forward, with few as threatening as implications of environmental degradation. As industrial progress generates wealth and raises living standards it concurrently ushers in widespread pollution, resource depletion and global warming. Cities are major vehicles for industrial machinery, with architects as primary players in escalating urbanity and glaring culprits in environmental decay. However, given central roles of design in shaping cities and creating buildings, there are outstanding opportunities to turn the tide. Fundamental to this opportunity is education's power to open eyes, instill values and enable society to move in alternative directions.

The authors have previously cooperated to develop new models for delivering architectural education China. This award-winning work, focused on international partnership and innovation in pedagogy, provided the framework for the current project. Considering rapid advance of environmental problems, the research aimed to provide students from Architecture, Planning and Landscape Architecture with deeper understanding of ways in which design can serve to lessen crises, reduce impacts and act in restorative ways. Overarching goals were to have students work in an interdisciplinary collaborative manner to develop awareness of environmental sensitivity, instill values around positive interventions, and design a center for sustainability at Guangzhou University that embodies the power/potential for positive change.

For over a week of immersive education in Guangzhou China, several dozen students participated in an intense workshop, led by educators from Canada and China, aimed at heightening understanding of sustainability. Using the potent term Zhengti, the workshop included precedent investigation, case studies and literature research to uncover emerging technologies and reveal best practices concerning responsible design. Process/product ingenuity was a pursuit, with all projects needing to embrace holistic approaches to design, construction and operations. An integrated framework for design + planning, developed by one of the authors, was at the core of design philosophy for the workshop. Throughout the workshop novel Western strategies for design were tested, including the use of 'parti' (i.e., principle, diagram, model) as drivers of design. While many dimensions of sustainable design are routine in Western education of architects, some of these concepts are without precedent within higher education in China. The authors, in light of China's growing awareness and increasing leadership in environmental matters, placed this charged topic at the workshop's heart.

The research, embedded within critical pedagogy of a high-energy design workshop, considered sustainability in a balanced and holistic fashion. The project involved critical reflection to adjust, test and refine work in play. While physical dimensions of sustainability are understood in China, there has historically been less emphasis placed on other qualities including social, cultural and spiritual aspects of environmental responsibility. Pedagogically the pursuit of a more fulsome embrace of sustainability was key. China's new five year plan incorporates attention to environmental quality as a major objective. This internationally-structured research resonates with such vital aspirations, serving to build awareness, knowledge and skills in design students with long-term enhanced quality of life front of mind.

Won't You Be My Neighbor(hood): Research, Collaboration, and Sidewalk Citizenship for Community Design Advocacy

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Frustrated by the limits of traditional design input a community and cross-sectional group of students from three universities departed on a radically bottom-up approach to community advocacy. The aim to bring together three different university classes and their North Philadelphia neighborhood to connect, reconnect, educate, document, display and dream about possible futures of their shared community. Challenged with leaving preconceptions behind, breaking stereotypes, making as-yet unknown friends, while proposing solutions for seemingly insurmountable issues of gentrification, eminent domain, and looming demolitions – all within the bounds of a semester. Along the way students and residents discovered a shared history of jazz, painting murals, newspapers clippings, vegetable gardens, bus stops, and the realities and responsibilities of being a 'good neighbor' are the bonds that link a community together.

Students and community members came together to organize themselves based on a disarmingly simple approach "Hello neighbor, my name is _______, and I'm a student in North Philadelphia, what can you tell me about our neighborhood?"

At the end of the semester – three universities, two civic groups, and a community garden got a meeting to present their shared vision of their community to the Philadelphia Housing Authority.

This paper seeks to demonstrate a model of community advocacy through engaging student and community groups through acts of altruistic design and neighborly citizenship to create new avenues for advocacy and community building.

Anchoring: Promoting and Sustaining a National Identity Through the Spice Industry

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Developing nations such as the Caribbean country of Grenada have been heavily dependent on agriculture for centuries not only for food but also as an economic stimulus. Grenada has been especially reliant on the success of their world-renowned spice production which has become a part of the national identity. However due to an increase in higher education, young locals are seeking alternative careers outside of agriculture. Therefore interest in the Spice industry has been on a steady decline.

The project goal is to use architecture as an instrument to rejuvenate a unique commodity and serve as a catalyst for the indigenous agricultural industry. The three major strategies are to: 1) Promote research and experimentation of spice varieties, encouraging innovation and entrepreneurship; 2) Actively engage locals, workers and visitors alike in the process of spice making; 3) Incorporate social and cultural opportunities for every user. Each approach will assist in nation building and strengthening Grenada's cultural identity on a global scale.

Grenada's rural parish of St. David, which has a rich agricultural history, was chosen as the area of study for this project. The intention is to decentralize economic dependence from the urban area and discourage migration from the rural areas. The project is also conceptualized as a model to encourage development of the environs into a thriving social and agricultural zone. This master plan includes the adaptation of an old sugar mill into a rum factory, the expansion of an existing research farm, the improvement of an adjacent athletic field and the creation of fruit/ vegetable picking fields encouraging community farming and economic incentives.

“Unlike music, painting sculpture, film and literature, a construction is intertwined with the experience of a place.” “Building transcends physical and functional requirements by fusing with a place, by gathering the meaning of a situation. Architecture does not so much intrude on a landscape as it serves to explain it” - Steven Holl

The idea of anchoring not only focuses on the physical siting of the project but involves the conceptual and experiential rooting of the architecture. This is done by framing landscapes, providing symbolic views through the building, capturing panoramic scenes and creating moments which anchor the facility to the site. Inspiration is taken from the rhythmic flow of water of the adjacent creek flowing from the mountains to the Atlantic Ocean. The water which symbolizes rejuvenation and the connection between Grenada and the world is used to bisect the building connecting the historic sugar factory with the athletic field. One portion of the building concentrates on the circumstantial human conditions such as street orientation, spice production and research and development. The second part responds to the pre-existing, universal conditions such as the solar orientation, water flow and mountain views.

Also, the cyclical nature of spice making is symbolic and manifests itself into the aesthetic and volumetric treatment of the structure. The roofscape: 1) Accentuates the repetitive nature of spice production 2) Relates to traditional architectural forms 3) Complements the topography of the mountains.

Seeing Through the Eyes of Another: Architecture, Advocacy, Truth & Reconciliation Considering Aboriginal Culture & Community

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For thousands of years North America has been inhabited by indigenous peoples. Their practices, philosophies, cultures + communities have been shaped by the land, with an overarching belief that they are of the land not merely upon it. The beauty, strength & meaning of connections to place prove undeniable. Over recent centuries, with arrival of newcomers, much of this world turned upside down. A path of abuse, oppression + cultural assault defined relationships between aboriginals and colonizers. Only recently have steps been taken to illuminate conditions and find paths forward that are considerate, compassionate, fair & just. In Canada the Truth and Reconciliation Commission navigated uncharted waters in its endeavor to identify/understand complex issues, and to point in promising directions for building respect, affording honor and initiating journeys to healing. The author has experience with and understanding of Canada's indigenous people –servin on numerous initiatives tackling indigenous issues and having been conferred numerous Aboriginal names.

The present research focuses on an innovative, inventive and bold design studio conducted in concert with Aboriginal communities to explore issues, reveal culture, foster partnership and open head + heart. Realized within the context of Comprehensive Studio, in an accredited school of Architecture, the research examined pedagogical dimensions of a project for indigenous healing. Sited on historically meaningful land in Canada, the studio project was the 2000 M2 Moh-Kins-Tsis community center embracing education, support and wellness. The client was a local aboriginal support group intent on exploring a new home that would welcome both indigenous and non-indigenous populations into a place of dialog, sharing and reconciliation. Advisors included players within the Aboriginal community including Elders and leaders. A range of communities, including First Nations, Metis and Inuit were involved. From learning perspectives, teaching included immersive experiences in culture (e.g., ritual sweat lodge), guest lectures by residential school survivors, spiritual teachings by Elders, open discussion in sharing circles, and feedback on design by Aboriginal partners. All students spent time with Aboriginals on the site – learning about the history of place, feeling energy of nature and critically 'listening to the land'.

While accreditation dictated attention to development of professional knowledge/skills, broader educational/societal expectations warranted concurrent consideration of 'charged' topics. As a society we find ourselves at a critical juncture in our relationship with North America's indigenous people. As educators we find ourselves presented with potent vehicles to foster conversation, understanding and healing. The studio offers opportunities for challenging conventions, charting new waters, and most critically to examine tough topics in safe, open, intriguing ways. Methods included precedent examination, case studies, literature + archival work, and logical argumentation. Through collaboration with Aboriginal communities research catalyzed pedagogy that permitted students to see through the eyes of another. Cultural sensitivity, awareness and empathy prove essential as design for one population is entertained by another. Rather than a climate of arrogance & imposition, studio pedagogy cultivated conditions of shared discovery, humble acceptance and openness to new ways to seeing, thinking and acting.

The Challenges of Incorporating Passive Energy Strategies into Developer Single-Family Suburban Housing

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To achieve measurable success with integrating sustainable energy systems into buildings will require application on a sizeable scale. In terms of construction volume single-family suburban developer housing starts account for a huge percentage of construction, recently averaging around a million per year, and single-family homes consume around 80% of residential energy use. This market presents a prime opportunity for applying passive strategies on a scale great enough to have a significant impact on energy use. Yet developers typically build entire subdivisions with little to no regard to orientation to sun and wind and most architects appear uninterested in becoming involved with the 'lost cause' of suburban housing design. But a million passive house starts a year could have profound effects on ecosystems at the macro scale well beyond the boundaries of the subdivision. With the looming specter of climate change and its potentially catastrophic impact, can architects ethically continue to ignore the suburbs with their significant potential for sustainable change? This research first investigates the reasons why architects and suburban developers both seem uninterested in incorporating sustainable energy strategies at the scale of the subdivision and then identifies potential design strategies for improvement through the form of a potential model house and subdivision designs.

Research reveals surprisingly few passive single-family housing communities, and none on a vast scale. Passive houses have been around for decades so why haven't they made the leap in scale? This research/design project considers the biggest obstacles to passive developer housing then tests these ideas through potential design solutions of a prototypical house (based on the Charleston typology) and a neighborhood master plan. This objective, to reveal the major challenges and the potential for bringing passive energy to the massive scale of developer housing, produced two main questions; how do we apply passive energy strategies to the pre-manufactured suburban house and how do we make passive houses marketable in a well-established industry?

The Challenge to Making Developer Houses Passive - Current developer housing is designed with little to no relation to the direct sun, wind movement, daylight or thermal efficiency. Houses in a typical subdivision are oriented towards the street regardless of cardinal direction. How can we adapt these non-directional houses to maximize natural environmental benefits such as:

• Orienting Towards the Sun

• Increasing Natural Ventilation

• Bringing Daylight to the Core

• Creating a Super-Insulated and Sealed Envelope

The Challenge of Making Passive Houses Developable - None of the changes above will matter if the houses won't sell. The typical developer house is primarily concerned with presenting a nostalgic image of house as "home" because that is what their clients want, but most architects are not interested in reproducing repetitive, historical kitsch. So any design for passive suburban developments must be financially feasible and marketable and address the following issues:

• Conveying an Authentic Image of "Home"

• Making Passive Construction Cost Effective

• Avoiding Repetitive Communities and Houses

Cloudforest impact: a cross-sectional study of an interdisciplinary design service learning study abroad program in Costa Rica

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Study abroad programs generally, and service learning programs specifically, have been studied for their impacts on students. Some have linked study abroad to student intellectual or cognitive development and academic success, changes in attitude, international and intercultural awareness, self-efficacy, civic engagement, employment/career opportunities and spiritual growth. Some have examined students' perceptions of their impacts or effectiveness. While the potential negative economic, social, and cultural impacts of tourism, a related but distinct practice, are well documented, there is less written about the impact of study abroad on host communities. Small but positive economic impact has been seen in host communities from study abroad programs, but there are some potential tensions with study abroad. Community-based engagement may reinforce students' preconceived ideas, and benefits to host communities may be questionable or short-lived. This study makes a unique contribution by investigating the impacts of the Sustainable Futures study abroad program in Monteverde, Costa Rica not only on its participating students, but also on host community members.

Through the Sustainable Futures program, participating community non-profit clients in Monteverde propose projects of various scales, including scenario planning, master planning, building design, and installation construction. Sustainable Futures students of architecture, landscape architecture, and planning take on these projects, providing design services in a curricular structure loosely hybridizing academic research and professional practice. For the duration of the 10-week, 12/13 credit program, students stay with homestay families from the Monteverde Community.

This paper describes impacts on professional and lifestyle decisions assessed through a questionnaire-based cross-sectional study of a sample of students, clients, and homestay families who participated in the Sustainable Futures program between 2008 and 2017.

ReFigured Bass: A New Architectural Formalism

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An essential question under a multiplicity of guises remains what will replace modernism in all of its guises. Wolf Prix, during recent critiques at SCI-Arc, expressed the widespread attempts to discover what is 'next' as a desire for "finding Nemo." This research project supports seeking this goal through what can be conceivably understood as wrong turns in the discipline including a return to science and a return to formalism, collectively employed with the philosophical thinking of object-oriented ontology. Our understanding of the world in which we live informs what we build. Static conceptions through enhanced digital capacities have evolved our understandings of the world as dynamic interconnected webs and our built environment has responded. Acceptance of this response, as with the relationship with early modernists and the societal issues of their time, aligns with the consensus of global thinking of dynamic interconnections as both cause and solution to the global crisis for the human species of climate change. For example the campaign slogan: "Stronger Together." There exists credible evidence through the geometricization of emerging physical theories that, in essence, reality is actually much weirder than fields and webs of dynamic interconnections.

Advances in theoretical physics define our world as varying patterns of vibrating strings of energy embedded within dimensions numbering far beyond those familiar. Fields and webs yes, but now nested offer conceptions of connections folded within connections. It is argued that these new conceptions of reality, even if not able to be "seen," suggest new organizational potential for densification and depth leading not to prescriptive form making strategies but rather to a new series of formalisms. As with earlier scientific theories operating at realms beyond the human sensorium, contemporary theories of science and philosophy, postulating new connections between the living and inert, bring new ontological and epistemological possibilities for questioning corporeal concepts of matter and mental concepts of sympathy and subject/object relationships. Re-readings of works by Peter Eisenman and Greg Lynn from the 1990's become enhanced as are readings of contemporaneous works including The Miller House by Atelier Wylde-Oubrerie, works by the Balliet Studio and Preston Scott Cohen, Inc. as expressing ideas of depth and simultaneity of densities. Within the area of identity politics, 'intersectionality' creates frameworks for making multidimensional conceptualizations for examining the multiplicities of agencies blending together to create a particular identity. Rosalind Krauss's response to Colin Rowe's analysis becomes newly instructive: "The reality of deep space is constantly opposed to the inference of shallow, and by means of the resultant tension, reading after reading is enforced…Through these "fluctuations" the building's surface is experienced, then, not as a thing - a mute object of stone or concrete - but as a ground of meanings, multiple, changing, addressing itself to the process of cognitive differentiation."

[1] Wassily Kandinsky's formalism term: Figured Bass.

[2]Rosalind Krauss, "Death of a Hermeneutic Phantom: Materialization of the Sign in the Work of Peter Eisenman," Houses of Cards, (New York: Oxford Univ. Pr., 1987).

Integral Living Research: Architectural Research, Advocacy, and Healthy Living

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Integral Living Researchis a novel and collaborative design research method that melds the disciplines of architecture, interior design, and STEM (Science, Technology, Engineering and Math fields). Developed through deep experience in human-centered design research that focuses almost exclusively on advocacy and urban living space, the overall goal of Integral Living Research is to help transform such urban space when it fails to promote optimal living for underserved families. Improved health and living spaces for underserved communities is a proven area of urgency in our current world.(WHO, 2016) Often families' health is detrimentally affected by the type of housing one has access to.(Reddy, Amanda & Jacobs, 2016) This collaborative and interdisciplinary research, thus far, has focused on the urban house, the discoveries will be deployed to develop a "case study house," both virtual and actual, that tests some of Integral Living Research's innovative methods to improve the health of families. Including a "hard-science" technological and transdisciplinary design approach to green or biophilic materials. This team has developed a novel approach to optimizing interior space for health and advocacy for those in need of such spaces. The work includes both technological advancement and the exploration and documentation of current advocacy in service to the needs of urban families.

Overall, this research suggests that such a "case study house" will become an innovative example of how the human-centered design method can drastically improve the health outcomes of urban dwellers. This work is also anchored in the scholarship of teaching and learning through the mentorship of beginning designers and researchers in the developing technology and advocacy processes of Integral Living Research. This paper will document and discuss the design research, trans-disciplinary design and human-centered research thinking involved in creating healthy urban interior living environments. The work discussed will examine the urban house and living as a structured experience that is part of our overall health as urban dwellers. In the 21st century, all architecture is part of health care, all architecture is advocacy and housing is the nexus of these pressing issues.

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A New Vision for Midtown: Place-making Connecting Space, Property, and Value

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A research and design project translated the College Park City-University Partnership's objectives for redevelopment serving needs of campus and community into a new vision for the Midtown District. This project serves as a case study example of public engagement architecture in the social setting of a contested space where an automotive corridor slices between campus and two marginalized neighborhoods. Baltimore Avenue, aka Route 1, is becoming an attractive location for higher density development. The project methodology linked research and design connecting space, property, and value. Higher density development has already begun in Midtown, largely focused on student-oriented residential and retail uses. Recent development includes residential slabs rising along the west side of Baltimore Avenue in the form of a wall dividing community and university. The Paint Branch river further reinforces the town/gown separation. The Partnership challenged the master planning team to envision a future for the Midtown District that would connect community to campus, while offering attractive opportunities for developers to implement projects that would enhance the sense of place.

The multi-disciplinary team grounded place-making in research methods of their respective disciplines. Designers gain empathy for users by immersing themselves in the design space, observing, and interacting. They perform context analysis, identifying key site factors and combining the different variables to discover meaning and opportunity. Real Estate Developers conduct market analyses to study demographics, income, employment, socio-economic context, and growth trends, looking at the potential for student housing, office, and retail.

With an understanding of context, market, regulatory context and development processes, the team was ready to design. We came together in a design charrette, inspired by insights gained through meetings with community groups and informed by our research. We implemented key place-making concepts from meetings with civic: (1) Connect to the ecology of the region with a river walk along the Paint Branch, (2) Create mews linking Baltimore Avenue to the River Walk and providing views of the Paint Branch, (3) Create a market square offering retail to neighborhood residents, campus community, and hotel guests, (4) Barn dance street crossings for enhanced pedestrian access, (5) Campus connection, (6) Lively retail/entertainment offering "third places" for community gathering. The design charrette led to a schematic design proposal suggesting long-term vision at the scale of the district and near-term vision for the creation of a neighborhood with a sense of place to catalyze future development.

The multi-disciplinary team brought architecture, urban design, and real estate development expertise to the project, anchoring creative place-making in market research and financial analysis. The design team was asked to envision a healthy, walkable district that fulfills the mandate of the partnership to tie together University and surrounding communities with sustainable mixed development. This project shows prospective developers how they can realize their economic objectives while building a sustainable community that transforms the lives of Midtown District residents and remakes an automobile strip into a healthy, walkable community This master planning study serves as a guide to developers initiating new projects within the Midtown District.

Housing And Wellbeing: Does Design Effect Us?

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An increasing body of evidence suggests that some of the contemporary forms of the physical environment have a negative influence on the wellbeing of its inhabitants. This paper presents a literature review on the impact of the built environment on the inhabitants' wellbeing in the residential context. The paper reviews recent literature from various interconnected fields such as psychology, physiology, and sociology in the built environment context. Previous research has shown that the characteristics of the built environment can influence all aspects of human life. The effect of the built environment on the physical and psychological wellbeing is well investigated. However, there is limited research on the relationship between the residential built environment and social wellbeing, as measured by social integration and cohesion which suggests the need for more exploration, particularly in the context of the Middle-East.. This research will be focusing on the cultural context of the Middle East and in particularly on Qatar, for where there is a dearth of research that investigates the above relationship between wellbeing and the built environment. The lack of understanding results in a disconnection between the local communities' socio-cultural needs and actual design and supply of housing.

The relationship between housing and wellbeing is complex and multidimensional. Moreover, behavioural, biological, cultural, social, physical and political factors are considered, as variables that affect the relationship between wellbeing and the residential built environment. In considering the relationship between physical environments and users, various theories and concepts were found to overlap with wellbeing research, such as quality of life, happiness, life satisfaction and sustainability. This paper, through an in depth literature review, aims to distinguish the relationships between different concepts by defining the idea of social wellbeing and exploring how to evaluate them. A review of previous methods and indicators were used to measure and evaluate wellbeing and the quality of residential built environment, organised to help architects and planners to analyse the impact of their designs on the wellbeing of people.

Bibliography
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Louis Kahn’s User Responsive Enclosure for the Weiss Residence

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The modern movement encapsulated in the International Style as defined by Philip Johnson and Henry-Russell Hitchcock was characterized by lack of ornament, and large expanses of glass permitted by structural advances that rendered the load-bearing wall obsolete. Arguments for modernism, before Johnson and Hitchcock aestheticized the movement, were buttressed by a stance against excess in the face of needs prompted by population gain and urban concentration in an industrialized economy. Modernism promised greater equality through efficiencies, and increased wellbeing due to advances in public health underpinned by science. When social problems persisted after World War II and the subsequent period of prosperity, confidence in modernism and rational planning waned. Belief in the health benefits of natural light remained, but architecture perceived as providing universal solutions was susceptible to a critique of callousness reflecting underappreciation of the depth of cultural realities.

Within architecture, brutalism and post-modernism represented a return to craft, and a retreat from the enlightenment project that propelled modernism. While modernists sought to address problems beyond those generated within the discipline, post-modernists saw limits in the discipline’s ability to solve social and environmental problems, focusing on the communicative function of architecture. After the ebb of post-modernism, a new modernism has emerged drawing on imagery of early modernism. There is less concern with structural honesty, and expression of structure, yet still a heavy emphasis on glass. Despite the emergent green-building movement, glass is commonly used with little regard to heat gain from specific orientations, glare, and privacy. Liabilities resulting from the former are typically addressed with frits or coatings, while the latter issues when addressed, are typically mediated with interior shades.

Flat facades with highly repetitive elements, common in modern architecture, have been cited as alienating and banal, evidence of a technocratic, as opposed to human orientation. This paper relates social science research to shortcomings of modern architects when addressing human comfort, both physical and psychological. Visual signifiers play a role in the latter, but are not limited to overt syntax emphasized by Robert Venturi whose critique of modernism has deeply impacted architectural culture. The focus of this study is a house designed by Louis Kahn and Anne Tyng in the late 1940’s for the Weiss family that exemplifies how modern design can support human needs through implementing an innovative widow wall system that mediated light, privacy, ventilation and thermal comfort with integrated adjustable panels, horizontal louvers, and heating elements. Aspects of the system translated to sliding panels that control light and views at perimeter study carrels in Kahn’s Exeter Library, one of his later works. Analysis of the Weiss House is situated in a larger project that utilizes digital models for analysis of solar control devices and their impact on building performance.

The "architect's responsibility": Towards an understanding of ethical practices

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In the face of pressures of an increasingly de-regulated capitalism that emphasizes "wins" above all else, is it possible for the architectural profession to mount an independent effort to promote an ethical stance in the design and construction of our built environment?

The architectural profession today is weakly regulated. Despite the global scope of many firms, the sole international professional organization, the International Union of Architects, provides only academic opportunity for critique, while national organizations such as the AIA (American Institute of Architects) or NCARB (National Council of Architectural Registration Boards) in the Unites States, or RIBA (Royal Institute of British Architects) in Britain provide codes of conduct largely limited to contractual issues and the architect-client relationship. As large architecture firms increasingly work internationally in countries with poor human rights records, the lack of overarching legal and ethical guidance has resulted in controversies such as the razing of historical housing structures and displacing of residents to make way for ambitious design work for the 2008 Olympic Games in Beijing (for example Herzog and de Meuron's National Stadium), or the use of unpaid and ill-treated labor for status-laden design opportunities (such as in Zaha Hadid's Heydar Aliyev Center in Azerbadjan). Such examples are not limited to countries with autocratic rulers; more recently, David Chipperfield's firm was harshly criticized for its luxurious and award-winning Fayland House design, in which the staff bedroom is windowless. As clients demand with impunity, the architectural profession has turned to the client's satisfaction and their own artistic and business opportunities, with general ethical concerns seemingly swept by the wayside in the quest for "memorable" architecture; or, as Patrik Schumacher rationalizes, "the supposed 'architect's responsibility' is an empty, self-engrandizing [sic.] sham […][that distracts from] the responsibility [the discipline] has actually been entrusted with, by the legitimized social actors that are its public and private clients."[i]

This paper examines ethical ideals as they relate to architecture, and systematically maps them into a network of approaches, in the process providing an analytical overview of current ethical debates in architecture. From Sam Mockbee's call to "Help those who aren't likely to help you in return, and do so even if nobody is watching,"[ii] to questions of how ethics and aesthetics are related as postulated by William Taylor and Michael Levine; from critiques of the continuing patriarchal decision-making process in architecture as outlined by authors as varied as Dolores Hayden and Barbara Hooper to the empowerment of people to access and freely use attractive and functional spaces , this paper presents a systematic framework of ethical demands as well as illuminating examples where architects have successfully taken an ethical stand. In doing so, this paper contributes to the question of the "architect's responsibility" and an understanding of ethical practices in the profession.

[i] "What are architects responsible for?" published July 11, 2015. https://www.architectsjournal.co.uk/culture/what-are-architects-responsible-for/8685996.article

[ii] Samuel Mockbee in Wiggelsworth, Sarah and Jeremy Till, eds. The Everyday and Architecture. London: John Wiley & Sons, 1998.

Rewilding Pallets: Revealing Diverse Ecological Values in Urban Wood Waste through a Didactic Garden

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This design research project considers how pallets and their end of life infrastructures can be expanded to elicit more ecological – non-human – benefits. This project utilizes a widely available pallet type to demonstrate how urban waste materials – if designed with more diverse ecological values in mind – can directly benefit both humans and non-humans. These concepts challenge the current centralized and automated industrial waste practices as well as to encourage designers to define new inspirational end-of-use infrastructures.

Resourceful hobbyists have long deployed pallet reuse as a method to disrupt waste cycles to the point of cliché. More academic and professional applications such as Hiroki Tominaga's "Shitomito Pallet Office" or the temporary "Meditation Pavillion" by Duchesneau and Allard share how pallets are also part of expressing a sophisticated and complex architectural language if appropriately arranged and situated. However, amongst the ubiquity of reused pallet designs, there are few examples of its direct non-human ecological use in the urban landscape.

Pallets are now indispensable to industry, they are the rafts and barges of land-based transport infrastructures that help to connect distant communities. It is estimated that over 4 billion pallets are in service each day just in the U.S. and help to generate billions of dollars.[1] Although the diversion from landfills is increasing, recaptured materials also remain confined to the typical waste recovery practices of grounding and chipping into finer parts, which results in commercial products like mulch (52%) and fuel (23%).[2] This rather abrupt and idiosyncratic particalization ignores broader ecological applications and bypasses more meaningful transactions back to wilder systems.

This garden project directly challenges current practices by first retaining the "whole" material supplied by the pallets and thereby valuing the extension of material decay. Secondly, the pallets are deliberately reconsidered for their ecological values beyond carbon storage, embodied energy, or nutritional values. The ecological functions as observed by forest scientist reveal processes such as water retention, places for perching, soil retention, shelter and countless other latent benefits that aggregate to the deeper and less visible merits of the entire project. Specific wildflowers were selected to attract local pollinators and were arranged to sustain human participation and delight. The generous seating area, also made from pallets, marks the human "perch" from which to reflect ecological activities of the garden.

Materials, as compared to topics of energy and nutrients, are more entrenched in cultural subtleties that challenge our resolve to simplify it. New, fresh, unspoiled materials draw the muse of designers because they have the power to easily transform our direct experience, while its waste is often passed off to automated infrastructures because we are no longer charmed. However, the non-human world could benefit from materials – once so thoughtfully appropriated for human use – to also be creatively re-appropriated back to allow for broader ecological functions. Such should be a requirement for all borrowed materials.

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