ABSTRACT

ISLEY, CHRISTOPHER G. Examining Integrated Design Workflows that Support Building Performance Integration in Small Architectural Firms. (Under the direction of Dana Gulling and Dr. Traci Rider)

In recent years, society has become more focused on the environmental, social, and economic impact of buildings. This emphasis has placed increased pressure on architects to actively include building performance in their designs. The diversity of performance considerations associated with these high-performance buildings requires practitioners to manage an increasing amount of information, leading to an associated increase in project complexity. As demand for higher-performing buildings continues to increase, architecture firms are experiencing related challenges as the Architecture, Construction, and Engineering (AEC) community seeks to embrace a more performance-conscious approach. With less financial resources and flexibility, small firms are particularly sensitive to these increased responsibilities, facing greater challenges in addressing building performance. The purpose of this three-article dissertation is to establish an understanding of the term building performance in practice and then explore the challenges that small firms face when considering building performance in design and the methods they use to overcome these challenges. Through this exploration this dissertation will establish a framework for future research and increase the understanding of building performance in practice.

In the absence of a unified definition of building performance in the AEC community, the first article combines a literature analysis and a survey of architectural firms in North Carolina to explore definitions of building performance in practice. The building performance definitions of practitioners were then evaluated against three building performance themes identified in literature: building-oriented, occupant-oriented, and blended perspectives. Patterns within the

definitions reveal trends in the prominence of the building-oriented perspective, the presence of ambiguous terms, and variations between the expression of design elements in the definitions and those that the participants identified as part of building performance.

The second article explores the conditions that create hardships for small firms as they strive to incorporate building performance into their workflows. This article covers one portion of a case study of three small architectural firms in North Carolina to create a shared understanding of the processes and the development of issues within the research participants workflows relating to the consideration of building performance. Conducting interviews with individuals familiar with the firms' workflows and design processes, this article identifies 33 challenges within three themes and increases an understanding of how these challenges may be influenced by the firm's incorporation of building performance, project types, and workflow.

The third article explores the ability of integrated design (ID) workflows to overcome the challenges associated with building performance in design. Continuing the case study of three small architectural firms in North Carolina, this article explores how ID workflows help these firms to overcome the challenges with building performance considerations. Using replication logic, the study interviewed individuals within the three firms, one firm using a traditional design workflow and two firms using integrated design workflows were studied, to gain insight into their design process. Eight themes were identified that aid the small firms using ID to actively and meaningfully support building performance in their designs.

This dissertation increases the understanding of building performance in practice. This dissertation provides insight into the current understanding of building performance definitions, the challenges small firms face when addressing it, and how components of ID can help overcome these challenges.

Examining Integrated Design Workflows that Support Building Performance Integration in Small Architectural Firms.

by
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A dissertation submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the
requirements for the degree of
Doctor of Philosophy

Design

Raleigh, North Carolina
2021

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BIOGRAPHY

Grey Isley grew up in a small, rural town in central North Carolina where he gained his love of family, the environment, and design. He earned his bachelor's degree in Agriculture and Environmental Technology from North Carolina State University. During his time at the university, Grey worked part time for a disaster mitigation company in their environmental department. After graduation, he would continue to work for this company as their environmental specialist and eventually manage all their indoor air quality projects. Grey would continue to learn about the indoor environment, building science, and energy management. He would eventually become an independent building science consultant, holding several licenses and certifications. During this time Grey would earn a Master of Science in Architectural Studies, concentrating in sustainable design, from the University of Florida. He credits the faculty at the University of Florida for encouraging him to continue his education in architecture. After completing his degree, he would return to North Carolina State University to earn a Master of Architecture. This degree expanded his knowledge of design and provided him with a greater understanding of how design influenced the outcomes he had experienced in buildings throughout his career. With this understanding Grey continued at North Carolina State University to pursue doctoral studies. These studies helped him expand his understanding of the links between design and building operations.

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CHAPTER 1: Introduction

Over the past century, new technology has evolved architecture's design process, building form, and our understanding of the built environment, changing how architecture is created and viewed. During this same time, the building's environmental, social, and economic conditions (Göçer et al., 2015) have gained greater emphasis. These new areas of emphasis have increased the complexity of the design process by requiring the synthesis of an enormous amount of information and knowledge and have extended the number of disciplines involved in the design (Negendahl, 2015; Østergård et al., 2016). The complex design process, an extension of the Architecture, Engineering, and Construction (AEC) disciplines, and an institutional framework that often leaves the definition of building performance implicit (Rahim, 2005) have contributed to forming a gap between the expected and operational performance of buildings.

Problem Background

The AEC industry acknowledges the need to reduce the gap between expected and operational performance (Fischer et al., 2017) of buildings. Still, research has not addressed the complexity of the gap. Current research tends to ignore or downplay the documented performance gap, overlooking the operational feasibility of proposed design processes. Multiple approaches to improve building performance have been evaluated, ranging from the use of predictive parametric optimization (e.g., González and Fiorito (2015); Zani et al. (2017); Gadelhak (2013)) to the collaborative assessment of building systems (e.g., Ku (2009); Mesa, Molenaar, and Alarcón (2016); Rohracher and Ornetzeder (2002)). However, completed research focuses on individual design elements, such as energy use or daylighting, and their optimization, or the benefits of specific techniques, such as collaboration or Building Information Modelling (BIM). The research often has a limited perspective – frequently from the lens of an engineer or

building scientist (Lin & Gerber, 2014). Findings repeatedly support the adoption of the evaluated method, whatever it may be, without providing a clear explanation of the method's integration and impact on the design process (Idi & Khaidzir, 2018). The limitations of existing research are attributed to the detailed research focus and reductive methods; however, this does not preclude the need to understand the use of the proposed techniques in practice and their ability to reduce the gap in building performance.

Addressing the gap in building performance requires an understanding of building performance expectations and workflows that are feasible in practice and allow for the consideration of building- and occupant-oriented performance factors. A unified definition of building performance is the only way to truly address expectations of building performance. The lack of a common definition results in targeted performance standards varying between projects, designers, owners, and municipalities (Aune et al., 2009; Bordass et al., 2001; de Wilde, 2019). Variations between stakeholders' definitions, and therefore expectations, can cause conflict and contribute to building performance gaps. Understanding the multiple perspectives of building performance is critical in unifying expectations.

It is also critical to understand the ability of a workflow to incorporate building performance in practice. The ability of a workflow to reduce the gap in building performance hinges on the workflow's 1) ability to address the expected performance outcomes and 2) its feasibility under real-world conditions. Integrated design (ID) workflows address both criteria. ID's focus on collaboration, process, and technology (Hjelseth, 2017) provides it the flexibility to address various performance considerations (Liu et al., 2017). Further, firms can optimize ID workflows to address operational factors, such as firm size, financial status, team compositions, project cost, timelines, and employee knowledge, that influence the workflow's feasibility.

Further understanding is needed of how practice views building performance. This understanding will help work toward a unified definition and narrrow expectations. However, research must also explore the challenges firms face when addressing building performance during design and how their workflows may be shifted to address these challenges.

Study Purpose

It is the purpose of this dissertation to explore how architectural firms perceive building performance and how they can meaningfully incorporate thinking about building performance in the design process. This research focuses on small firms; the architecture profession is primarily composed of firms employing less than 50 people. Small firms have fewer resources available to modify workflows and face difficulties uniquely related to their size (American Institute of Architects, 2018). This exploration will extend across three articles.

The first article will explore the understanding of building performance in practice. The absence of a unified definition of building performance in the AEC industry can lead to misunderstandings and conflicts among stakeholders. A literature analysis and a survey of architectural firms in North Carolina is combined to evaluate definitions of building performance in practice. In this initial phase of the research, representatives of participating architectural firms were asked in open-ended fields to define building performance as seen in their daily practice. The definitions were evaluated against three building performance themes identified in the literature: building-oriented, occupant-oriented, and blended perspectives. Definitions were further evaluated for their expression of design elements. The analysis compared this list of design elements to a list of performance considerations specifically identified by the participants as part of a second question around strategies addressing building performance. The article uses the findings from these two approaches to defining building performance to explore how

practitioners conceptualize building performance, focusing on how their definitions may not fully reflect all the design elements that they themselves consider to be part of building performance.

The second article explores conditions that create hardships for small firms as they strive to incorporate building performance into their workflows. A comparative case study of three small architectural firms in North Carolina is used to create a shared understanding of their design processes and the development of issues within their workflows around the consideration of building performance. Purposeful selection of participants identified firms based on their consideration of building performance and their design workflows. One firm using a traditional design workflow and two firms using integrated design workflows were studied using replication logic. This inquiry aimed to identify challenges with building performance consideration through each firm's perspective by conducting interviews with individuals familiar with the firms' workflows and design processes. Challenges were compared across the firms, resulting in the identification of 33 challenges within three overarching themes.

The third article continues the case study of the three small architectural firms to explore how ID workflows help these firms to overcome the challenges with building performance considerations. Small firms, making up the majority of firms nationally, are susceptible to changes in their workflows and increased responsibilities due to fewer financial resources and flexibility. The interviews with the firm representatives were used to understand their workflows and how these processes impacted their thinking around building performance. The workflows were mapped and discussed with a focus group within the firms to confirm these understandings. This analysis identified eight themes that aid the small firms using ID to actively and meaningfully support building performance in their designs.

Study Significance

This dissertation contributes to understanding how architectural firms perceive building performance in practice, the challenges small firms face in considering building performance during design, and how the small firms in the study have modified their workflows to include building performance evaluation. The AEC industry and firms of all sizes can benefit from this new knowledge on how conditions in practice can impact the understanding and implementation of building performance measures during design. This dissertation highlights patterns within the definitions of building performance and illustrates how components of ID workflows can be used to overcome challenges in considering building performance during design.

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CHAPTER 2: Article 1

Building Performance in Architectural Practice: Assessing Building Performance Definitions

Abstract

Building performance is an ambiguous term that is often left implicit by the architecture, engineering, and construction (AEC) industry. Most frequently associated with a building's energy use, the term can also include other design considerations relating to occupant social, health, and psychological needs. The absence of a unified definition of building performance in the AEC industry can lead to misunderstandings and conflicts among stakeholders. In the absence of a unified definition, this research combines a literature analysis and a survey of architectural firms in North Carolina to evaluate definitions of building performance in practice. This research asked representatives of participating architectural firms to define building performance as seen in their daily practice. The definitions were then evaluated against three building performance themes identified in literature: building-oriented, occupant-oriented, and blended perspectives. Building performance considerations were then identified within the definitions and compared to a list of considerations identified by the participants. This paper uses these findings to explore how practitioners understand building performance and how their definitions may not fully reflect all the design elements that the designers themselves consider to be part of building performance.

Introduction

Architectural practice and society have become increasingly focused on building performance (Göçer et al., 2015; Hwang & Tan, 2012). As demand for higher-performing buildings increases, architecture firms are experiencing increased challenges as the architecture, construction, and engineering (AEC) community seeks to embrace a more performance-conscious approach (Rezaee et al., 2019). One of these challenges is the formation of a documented gap between the expected and operational performance of buildings (Augenbroe & Park, 2005; Maslesa et al., 2018; Tweed & Zapata-Lancaster, 2018).

This documented gap between expected and operational performance is attributed to many factors across the design and operation of a building (Cohen et al., 2001; Hay et al., 2018; Pauwels et al., 2011). One of these being, variations between stakeholders' (design team, contractor, owner, operator, users, etc.) definitions of building performance. Current research establishes that inconsistencies in performance definitions between stakeholders establishes an uneven landscape of performance-related issues (Clarke & Hensen, 2015; Gerrish et al., 2017; Leaman et al., 2010) and often excludes occupants' wants during design, such as energy savings, comfort, productivity, environmental performance, and user satisfaction (Leaman & Bordass, 2001; Zavei & Jusan, 2017). Furthermore, performance standards frequently vary between individual projects, designers, owners, and municipalities (Aune et al., 2009; Bordass et al., 2001; de Wilde, 2019), making it difficult to establish a definition through collaborative team experiences. Without establishing a unified definition or growing tacit knowledge through repetitive experiences, stakeholders frequently act on their personal assumptions when addressing project objectives and expected outcomes. This assumption can result in stakeholders excluding or misrepresenting performance-related considerations based solely on personal

experiences and expertise, leading to discrepancies between the design's expected and operational performance. Ultimately addressing these discrepancies later in the design phases can result in additional project cost, liability, and reputational damage for AEC team members.

The presence of various definitions within the design process can be attributed to the complexity of modern buildings requiring an increased number of stakeholders to be involved in the design process (Maslesa et al., 2018; Preiser, 1995; Sackey et al., 2015). This inclusion of additional stakeholders has fragmented the architecture, engineering, and construction (AEC) industry into an industry of specializations (Sackey et al., 2015), resulting in the absence of a single 'master builder' to oversee and standardize design development. This splintering creates isolated environments in which specialized and disparate definitions of building performance develop (Preiser, 1995). Differing definitions of building performance are often influenced by a stakeholder's role in the building process, with each specialization having a different lens through which they view building performance (Maslesa et al., 2018). As a result, a clear definition of building performance remains elusive and is often left implicit in practice (ALwaer & Clements-Croome, 2010), contributing to a gap between expected and operational performance.

Unifying building performance expectations and enabling designs to meet those expectations requires a cohesive understanding of building performance, at least within the design and operation of each particular project. Therefore, it is important to better understand how practitioners perceive and address building performance within their designs to mitigate the gap between expected and operational performance. This paper focuses on evaluating constructed definitions within architectural firms to increase the industry's understanding of the differences in definitions. Using insights from firms in North Carolina, this paper explores trends

within firm definitions of building performance and their expression of building performance considerations. Comparing these two elements – stated firm definitions and expressions of building performance - suggests a structure for future research to evaluate building performance definitions and expands the discussion around a unified definition of building performance within the AEC industry.

Background

At its most basic level, building performance is "the measurement of achievement against intention" (Hartkopf et al., 1986, p. 232). However, without further clarification, a stakeholder's particular perspective influences both the interpretation of a project's intended goals (intention) and the successes or failures (achievement). Depending on the stakeholder's perspective, performance objectives may focus on quantitative goals relating to the function of the building, qualitative goals around occupant needs, or a combination of both (Bordass et al., 2001; Leaman et al., 2010). A stakeholder's role in the design process, and their relationship to the building's use, influences their perspective and definition of building performance. For example, occupants may be more concerned with their health and productivity while an owner may emphasize energy costs, and an HVAC designer may focus on maintaining industry-established temperatures.

Existing literature identifies three primary perspectives towards performance considerations: building-oriented, occupant-oriented, and blended. The building-oriented perspective focuses on technical, quantitatively measured performance considerations that often focus on the building, such as energy consumption. The occupant-oriented perspective recognizes the importance of the occupants' perception, focusing on qualitative evaluations related to occupant comfort, health, and wellbeing. The third perspective draws from the other

two, recognizing the importance of the building systems and the occupants' perception. These three different perspectives provide a foundation for understanding how an individual or firm may discuss building performance.

The building-oriented perspective frequently discusses building performance in terms of quantifiable data related to building systems such as energy use, daylighting, and interior climate control. Achievement of project goals is often expressed through measurable components, such as insulation values, energy use intensity (EUI), equipment efficiency, lighting levels, and ventilation rates (Rohracher & Ornetzeder, 2002). In this perspective, the occupant is not ignored but instead considered through the objective measurement of building systems and standardized building-related targets, such as acceptable building temperatures.

The expression of building performance under the building-oriented perspective is not uniform. Douglas (1996) frames his discussion of building performance through five categories that define a good building: adaptive, durable, energy-efficient, habitable, and secure. While helpful in quickly identifying critical performance areas, these categories also contribute to the vagueness associated with building performance definitions. For example, without clarification, daylighting might be considered under energy efficiency. It could also be linked with habitability by addressing the user's ability to perform work. Finally, it may not be acknowledged at all as a performance consideration since it is not explicitly acknowledged in Douglas's five categories.

Others do not recognize categories. Clarke and Henson (2015) focus on the larger category of energy efficiency and express building performance through quantifiable elements such as economics, climate change mitigation, life cycle analysis (LCA), fossil fuel replacement, codes, and perceived value. Others follow a similar pattern, relating building performance to specific metrics such as noise control, fire safety, thermal efficiency, and indoor air quality

(Støre-Valen & Lohne, 2016). Regardless of minor differences, these approaches commonly understand building performance through 1) measurable systems like economics or requirements for construction such as code, 2) easier calculations during design, and 3) not considering the occupants' subjective perspective in evaluation.

Occupant-oriented perspectives, on the other hand, concentrate on the experience of the building users. The perspective focuses on design quality, social considerations, and the building's environmental benefits. This approach stresses the importance of the occupants' behavior in evaluating the performance of the building (Göçer et al., 2015; Leaman et al., 2010). Characteristics seen in this perspective are derived primarily from literature relating to Post Occupancy Evaluations (POEs) and similar evaluations of occupant needs. Markus et al. (1972) state that the "understanding of design, and as a consequence, the performance of its products, must start with an understanding of people" (p.1). Here, the occupants' needs and perceptions take precedence over other building-centric considerations. For example, instead of evaluating occupant comfort through an HVAC system's ability to maintain established temperatures, an occupant-oriented perspective evaluates the occupants' perception of comfort. Preiser and Vischer (2005) relate the occupant perspective to an understanding of Maslow's (1943) hierarchy of human needs - physiological, safety, love, esteem, and self-actualization. They posit that Maslow's hierarchy of needs can be redefined as building performance criteria; occupant-oriented perspectives focus on the building's social, cultural, economic, and environmental benefits rather than the operational performance of a building system (Bordass et al., 2001). Evaluation through the occupant-oriented perspective typically addresses the building's ability to improve the health, safety, and comfort of the occupants and the wider community (Göçer et al., 2015). Contrasting with the building-oriented perspective, occupant-oriented performance

considerations typically 1) relate to the occupant and their needs; 2) may be qualitatively evaluated based on occupant perception; and 3) relate the success of the performance of the building's systems to occupant perception. This occupant-centered evaluation of performance often requires interaction with the occupants to understand their needs, wants, and perceptions. This interaction can occur during design but is more important after occupancy to understand how design decisions have impacted building performance from the user's perspective. Given the need for interaction, considering occupant-oriented performance is more difficult for firms during the design process. In partnership with the disengagement of firms after the building is occupied, these user-centered considerations are underrepresented in design.

The blended perspective on building performance combines aspects of the building-oriented and occupant-oriented perspectives, leading to a large range of performance considerations and evaluation techniques. Strong examples of the blended perspective includes Hartkopf and Loftness (1999) in which they identify six performance categories for a building: spatial performance, thermal performance, air quality, acoustical performance, visual performance, and building integrity. Within these categories, physiological, psychological, sociological, and economic needs and their relationship to performance considerations are recognized, effectively blending the first two approaches. For example, the authors acknowledge that thermal performance can be evaluated through the occupants' sense of warmth and the building's energy conservation. Similarly, Leaman, Stevenson, and Bordass (2010) suggest a balanced range of performance considerations, both measurable and subjective, to blend occupant and building evaluation criteria. Performance is discussed as a focus on occupants and their needs, with environmental performance focusing on energy, water, and economic sense. The other two perspectives clearly influence this duality.

Still, other literature in this balanced perspective classifies considerations as relating to basic needs or concerns within a building. ALwaer and Clements-Croome (2010) organize performance into three categories: people (owners, occupants, and users); products (materials, structure, facilities, equipment, control, and services); and processes (maintenance, performance evaluation, and facility management). Likewise, Prieser and Visher (2005) propose a hierarchy of (1) health, safety, and security performance; (2) functional, efficiency and workflow performance; and (3) psychological, social, cultural, and aesthetic performance. Regardless of the specific approach, discussing building performance under this holistic perspective unifies evaluation by recognizing the importance of the building, its systems, and the occupants' perception. This blended approach will 1) consider elements of both the building-oriented and occupant-oriented perspective; 2) evaluate performance using a combination of qualitative and quantitative methods; and 3) consider the relationship between building systems and occupant perceptions. These three properties make the blended approach the most inclusive of the three perspectives and more capable of assessing holistic building performance across considerations (Douglas, 1996; Invidiata et al., 2018).

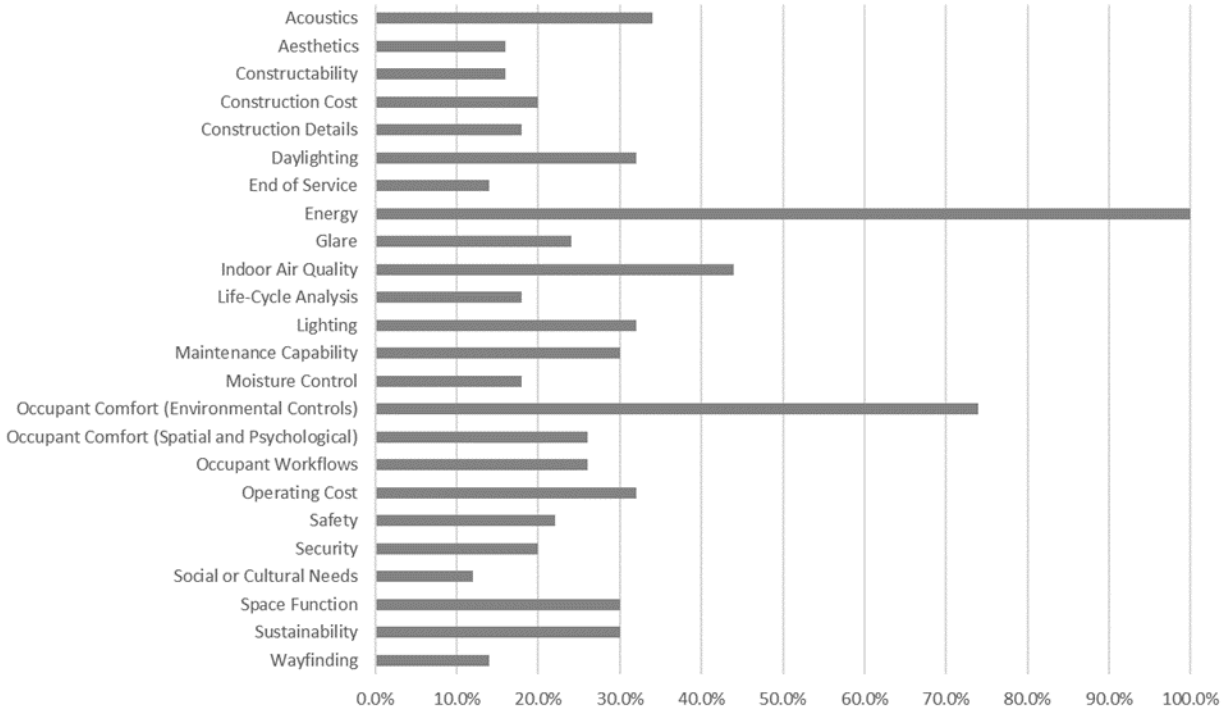
Methods

This paper outlines one component of an exploratory case study that evaluates the understanding of building performance and how it is considered within architectural practice. The case study methodology was chosen due to its strength in analyzing processes in their real-life context. As part of the larger study, a survey was administered via email to North Carolina-based architectural firms to explore how the term 'building performance' is currently interpreted in practice, as well as what strategies firms most connected with the use of the term. The survey was hosted through QualtricsXM and contained 40 questions in four categories: 1) firm

description, 2) building performance definitions and considerations, 3) difficulties associated with considering building performance during design, and 4) workflows. This paper analyzes results from the second category, building performance definitions and considerations. Questions in this category explored the participants' understanding of building performance through both open-ended and multiple-choice questions. Questions first asked participants to define 'building performance' and then identify design elements that their firms considered part of building performance.

The question asking participants to define defining building performance was open-ended, allowing participants to provide an unrestricted definition reflective of their firm processes. Another question provided a list of 24 design elements and asked participants to select those elements that they felt related to performance. The list of elements was created by reviewing literature that focused on building performance design strategies. Literature reviewed included journal articles, conference papers, and books. The strategies mentioned in these sources were coded, allowing the design elements offered in the survey to emerge from the existing literature. Design elements that were addressed in literature but could not be validated through multiple sources were not included in the survey. This process resulted in an offering of 24 design elements associated with building performance. Figure 2.1 shows a complete list of the elements and the frequency of their occurrence in the reviewed literature.

FIGURE 2.1
Identified Building Performance Considerations and Their Frequency of Occurrence Within Selected Literature.



Considerations are listed alphabetically on the left with the percentage of literature sources in which they were identified across the bottom.

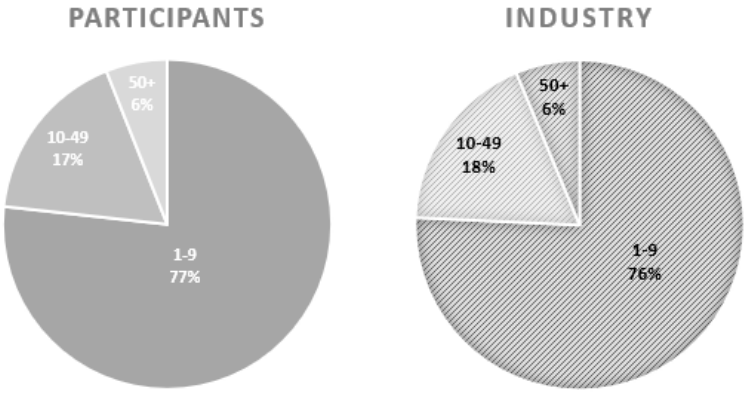
A total of 765 North Carolina architectural offices were identified through a North Carolina Board of Architecture database. One participant from each firm was identified as the point of contact through the list and solicited to participate in the survey. Surveys must have been completed by someone directly involved in or knowledgeable about the company's design workflow and building performance perspectives, such as management positions or project architects. Participants were given a 35-day response window. A total of 116 firms participated in the survey and provided full or partial responses by appropriate individuals. Incomplete surveys were reviewed, and completed questions were accepted if the participant's position was included. Ten respondents did not define building performance, resulting in the analysis of 106

responses to the definition question. All 116 participants selected design elements from the given list that they identified as building performance considerations.

Analysis

Of the 116 participants, 110 identified themselves as firm principals, three identified as department or senior-level managers, and three identified as project architects. Responding firms were of various sizes, with 76.72% employing less than nine people, 17.24% employing between 10 and 49 people, and 6.03% employing 50 or more. This composition of firm size resembles the industry's firm size composition as reported in the 2018 American Institute of Architects (AIA) firm survey (American Institute of Architects, 2018) (Figure 2.2).

FIGURE 2.2
Distribution of Firm Sizes Between Survey Participants and Industry as Reported in the 2018 AIA Firm Survey.



Participant Definition of Building Performance

To organize the range of participant definitions, the three building performance perspectives established in the literature were used as categories: building-oriented, occupant-oriented, and blended. The participant-established definitions were coded for alignment with one of these three perspectives based on properties identified through the literature and listed in the background section of this paper. Definitions that emphasized building systems, the building's impact on the environment, or quantitative measurements were classified as building-oriented.

Definitions focusing on occupant wants or needs, or qualitative measurement were classified as occupant-oriented and finally definitions containing a mixture of these elements were coded as blended.

Definitions that did not provide enough detail or express any identified building performance considerations were initially eliminated from further evaluation. However, upon further review, a pattern in these vague definitions emerged that expressed building performance through ambiguous terms such as ‘project goals’ or ‘stakeholder needs’. This pattern displayed properties associated with Integrated Project Delivery (IPD), in which the project team members define project objectives, goals, and metrics at the beginning of the project. Recognizing this pattern within the participant-given definitions, a fourth perspective emerged that was not identified through the literature: Integrated Approach.

After classifying the participant-given definitions into one of the four perspectives, definitions were coded again for the expression of design elements relating to building performance. This process was similar to the one used to identify the 24 elements within the literature. The coding process used the 24 elements identified through literature as a guide, allowing additional elements not already present to emerge from the definitions. The design elements found in the definitions were then tallied for comparison purposes. During this process, patterns emerged within definitions around the identified design elements.

Once the two-step coding process was complete, two comparisons were made. The first compared definitions within each of the four perspective groups looking for patterns relating to the expression of design elements and emergent themes within groups. The second comparison analyzed responses across three areas: participant-given definitions, the 24 building performance considerations identified within the literature, and the elements selected by the participants as

relating to building performance. This second comparison looked for variations in the identified elements between the sources and the frequency at which the elements were identified.

Findings

The findings explore how the participant-established definitions 1) aligned with the three perspectives on building performance (building-centered, occupant-centered, and blended) as identified in literature; 2) expressed design elements associated with building performance; and 3) were different from or aligned with the design elements selected by the participants from the given list rooted in existing literature.

Survey Findings: Perspectives in Definitions

Table 2.1
Alignment of Participant-provided Definitions within the Four Identified Building Performance Perspectives.

Definition Perspective	%
Building Oriented	49.5
Blended	33.3
Occupant Oriented	10.5
Integrated Focus	6.5

Building-oriented Focus. As shown in Table 2.1, the building-oriented perspective was prominent in the participants' definitions, with 49.5% of the definitions focusing on technical considerations and building systems. Responses under this category repeatedly referenced energy efficiency, the function of the whole building, or the building systems; these items were often related to a quantifiable measurement or standard. For example, one participant stated that building performance is:

> An approach to building design that looks at the entire building as a system to achieve the best efficiency in its individual systems, including HVAC, electrical, etc., with the object of creating a building that performs at some benchmark level better than code required minimum.

Similarly, another participant indicated that building performance as:

> How well a building is insulated, its energy consumption and the efficiency of building systems all the three main things that we think of when it comes to building performance.

Patterns emerged during the review of the participant-given definitions, establishing three subcategories: efficiency and system function, environment, and economic value. These subcategories support elements of building-oriented perspectives identified by Leaman et al.(2010) where environmental performance, mainly energy and water efficiency, and building economic sensibility (i.e., construction and operation cost) are stressed in measurable and quantitative terms.

Definitions in the *efficiency and system function* subcategory identified energy or water efficiency as an important consideration but also recognized the proper function of the building systems. One participant defined performance as:

> The systems that outline & reinforce the working envelope & systems of a building. They can be both 'active' and 'passive', and be integral to the envelope/structure or the engineering that makes the interior habitable.

While another defined performance as:

> Degree to which a building system or combination of systems achieve specific design goals and metrics, which could include energy and water conservation, energy production, water harvesting, thermal effectiveness and comfort, air quality, etc.

As seen in these examples, participants in this subcategory typically separated efficiency from broader environmental concerns such as sustainability, differing from Leaman et al.'s (2010) inclusion of energy and water efficiency under the larger topic of environmental performance. The separation of the two aspects of performance within the definitions distinguishes between the two subcategories of efficiency and system function and environment.

Definitions in the *environment* subcategory placed less emphasis on efficiency and instead focused more on the overall environmental impact of the building. Definitions under this heading often referenced sustainability or material life cycles, for example defining building performance as the "use of sustainability technology/materials that offer a reasonable return on investment" or "life cycle of all products and systems integrated. We look to design buildings that work well under current conditions but are designed flexibly to be sustainable and re-purposed if necessary." While some of these definitions reference energy efficiency, topics such as materials, sustainability, and life cycle cost were more prominent, stressing environmental impact.

Definitions associated with *economic value* often referenced construction and operational cost, function, building lifespan, and other value-related elements that establish the building as a commodity. For example, one response noted:

> Building performance is the resulting summation of all design and construction activities, and includes strategies, planning, schedule, budget, products, components, assemblies, systems, cost, preparations, installation, coordination, craftsmanship, maintenance, and life-cycle replacement.

Similarly, another definition in this category defined building performance as:

> The cost of building operation is important to clients. The building codes determine minimum energy standards; exceeding those standard often make a building more cost efficient to operate. A building performs better if the design results in cost-savings for a client.

Since performance considerations are often measured using financial metrics, there was some overlap between *economic value* and the other two subcategories of *efficiency and system function* and *environment*. This overlap stresses the complexity around these subcategories, illustrating that even in expressing definitions aligned with the building-oriented perspectives, definitions can include variations that may influence the interpretation of the term building performance.

Blended Focus. The blended perspective of building performance was the second most prominent, with 33.3% of the definitions providing evidence of this approach. Definitions here contained complex references to multiple performance considerations, similar to the definitions associated with the building-oriented perspective. These blended focus definitions commonly referenced both qualitative and quantitative considerations that include occupant needs. For example, one participant shared:

> Building performance is both scientific and aesthetic. The building needs to control water and water vapor, insulate occupants from extreme temperatures, and use the least amount of energy to run its systems. But it also needs to provide enough daylight and views to create a sense of wellbeing and be organized in a way that flows and functions easily for daily living.

Building systems and occupant experiences are important; however, these elements were not always presented equally in the blended perspective definitions. While many definitions balanced the user's needs with operational efficiency, some of the definitions emphasized either the building or its occupants. An example of this imbalance is:

> How well the building meets the needs of the user is the most important measure of performance. But, of course, there are economic performance factors, energy performance factors, and many others, as well.

This definition emphasizes the occupant, while another participant emphasized the building:

> Holistically it would reflect how a building ages and how it serves its users. It more typically is used to describe how the building envelope and systems perform throughout the year as exposed to natural elements. How much energy is expelled to keep building occupants comfortable.

While most of the definitions supported a balance within the blended perspective, there were several definitions that represented this tendency to lean towards building- or occupant-oriented considerations under the larger blended-perspective heading. The definitions representing this lean towards one of the other perspectives were equally distributed between the two tendencies.

Occupant-oriented Focus. The occupant-oriented perspective was the least represented of the three perspectives found in literature, with only 10.5% of the survey definitions aligning with this approach. These definitions were often concerned with design quality, social considerations, and the environmental benefits for the occupants, commonly basing the evaluation of these concerns on the occupant's or owner's expectation. For example, one participant defined building performance as "client and user satisfaction. [A building that] provides a meaningful experience for users that elevates their perspective." Similarly, another defined performance as a "measurement of the degree in which the building meets the owner's use and expectations." Some definitions focused on the occupant while linking their needs or wants with quantitative considerations like budget or maintenance. For example, one participant explained performance as a "quality facility that meets owner's needs within their operational and budgetary restraints." While another defined performance as "how well a building supports the environment required by the end-user upon occupancy and with consideration to minimizing maintenance issues over time." This trend is important to note as these definitions illustrate an uncertainty that can come with relating building performance to user or owner needs. These needs can sometimes be quantified even though they are based on the subjective perspective of the user.

Integrated Focus. An integrated approach perspective was not identified in the existing literature discussing building performance, but instead was identified by analyzing definition results, and only comprised 6.7% of the respondents' definitions. The participant-provided definitions within this emergent category used an individual project or process perspective that relied on stakeholder input to define building performance characteristics. This approach to building performance has similarities with the integrated design process (IDP) in which

stakeholders help define project objectives (Ku, 2009; Negendahl, 2015). However, these definitions are vague on what design considerations are included when addressing building performance, making it difficult to establish a unified definition of performance within this perspective.

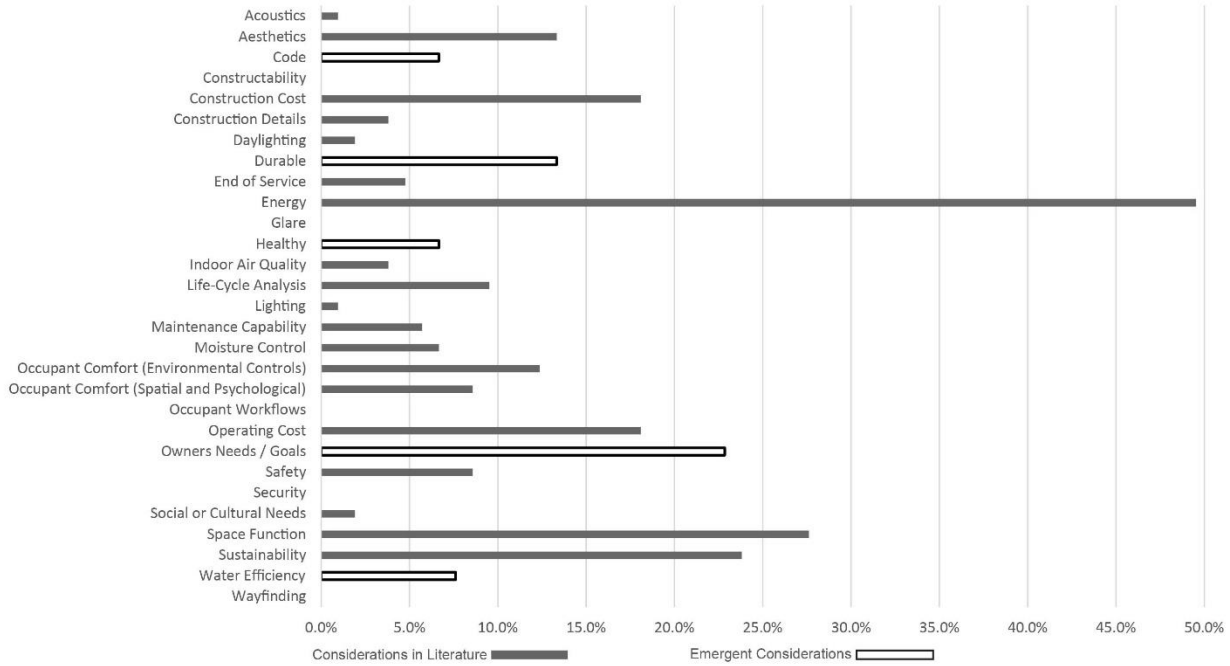
Examples of these definitions included ‘The measure of a building's ability to meet a given set of goals’ or ‘how well a building performs its function based on standards set in place in design.’ Defining building performance as it relates to goals or standards restricts the interpretation of these definitions, relying on the establishment of performance criteria during design. Furthermore, using terms like ‘expectations,’ ‘building function,’ and ‘established criteria’ introduces a level of ambiguity to the definitions that enable misinterpretations. While this ambiguity limits the ability the classify these definitions into one of the other three perspectives, the notable trend of project-established criteria clearly justifies the creation of this fourth category. These integrated focus definitions can address building-oriented, occupant-oriented, and blended perspectives depending on the project goals while also recognizing IDP trends that highlight the role of the project team in defining those building performance goals.

Survey Findings: Performance Considerations

Overall, 19 of the 24 elements identified in the existing literature were found in the participant-given definitions of building performance. Five of the design elements identified in the literature were absent from the participant-given definitions; *wayfinding, constructability, glare, security,* and *occupant workflows* were not mentioned by participants. However, an additional five elements were identified during the analysis (Figure 2.3). These include *durable, water efficiency, healthy, building code,* and *client’s needs/goals*. Components like *durable, healthy,* and *client’s needs/goals* are ambiguous but considered important due to their frequency

within the participant-given definitions. Of the identified elements in the definitions, *energy* was the most prominent with almost 50% of the definitions expressing it as a performance consideration. The remaining elements were identified at a considerably lower rate with *space function* being the 2nd most identified at around 27%.

Figure 2.3
Identified Building Performance Considerations and Their Frequency of Occurrence Within Participant-given Definitions.

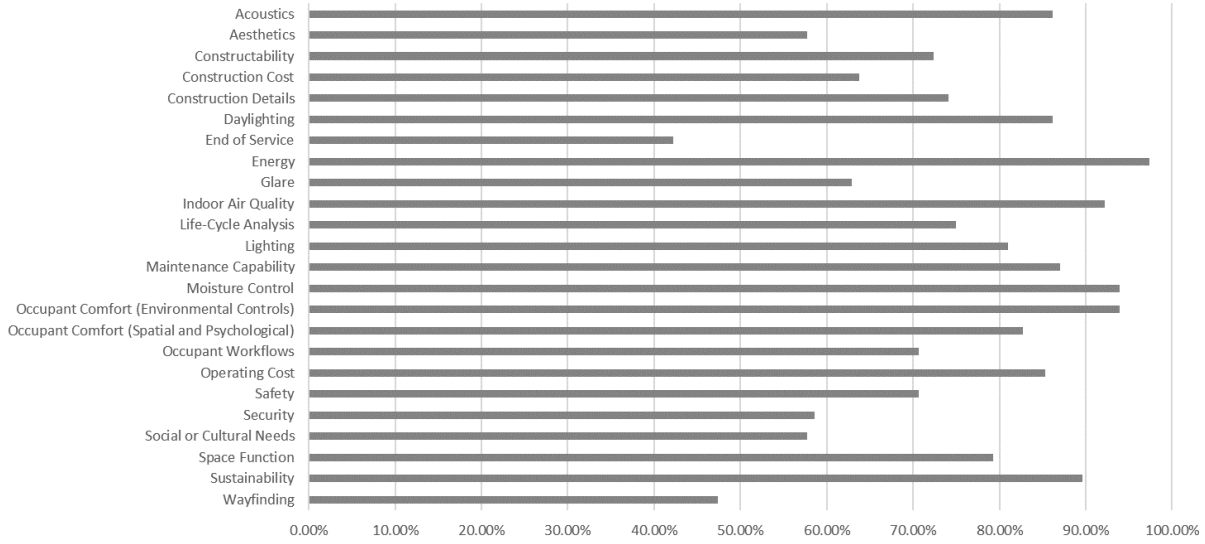


Building performance considerations found in literature listed alphabetically on the left, with the percentage of occurrences found in participant-given definitions across the bottom.

When asked to specifically select design elements felt to be associated with building performance, the participants selected a broader range of elements than those that they included in their definitions (Figure 2.4). Elements including *energy*, *indoor air quality*, *lighting*, *acoustics*, and *sustainability* were still selected from the list more frequently than *social and culture needs* and *end of service* similar to patterns found in the definitions. However, the participants also frequently selected other elements, including *wayfinding, constructability, glare, security,* and *occupant workflows*, though these terms were not evident in the participant-

provided definitions. The rate at which the elements were selected was overall greater throughout and the patterns were dissimilar to that found in the definitions.

Figure 2.4
Participants Selected Design Elements.



Elements are listed alphabetically, with the percentage of the participants that identified them as building performance considerations across the bottom.

Discussion

The survey findings highlight how definitions of building performance can significantly vary between practitioners, supporting discussions in literature. All three building performance perspectives identified in literature – building-oriented, occupant-oriented, and blended – were present in the definitions given by practitioners, and a fourth perspective emerged. However, the frequency of these perspectives was not uniform; the building-oriented perspective was evident in more definitions than the other perspectives. Furthermore, energy was identified as a performance consideration in 49.5% of the participant definitions, with 97.4% of the participants identifying *energy* as a performance consideration when presented with the list of 24 design elements. The prevalence of both the building-oriented perspective and the identification of energy as a performance consideration reinforces discussions in the field that energy-related

design elements receive greater attention than other design elements in discussions of building performance (de Wilde, 2019).

Although energy and the building-oriented perspective receives the most attention when discussing building performance, over half of the participant-given definitions (50.5%) were classified into one of the other three building performance perspectives. This spectrum of participant-given definitions mirrors discussions in literature regarding the inconsistencies around definitions of building performance. Across the participant provided definitions, building performance was expressed using various terms and focuses, sometimes highlighting building systems and at other times concentrating on the users' perspective. These inconsistencies can establish an uneven landscape on which to evaluate building performance (Clarke & Hensen, 2015; Gerrish et al., 2017; Leaman et al., 2010). For example, when addressing comfort, defining building performance as the "design of [the] building and systems for optimal performance of building envelope and heating/cooling systems" differs from "providing space and comfort that meets the needs of the client, staff, stakeholders, and their customers." Comfort may be considered under both definitions, but the two perspectives may evaluate the outcomes differently. The first definition focuses on performance from the aspect of the building and its systems with comfort evaluated based on HVAC's ability to maintain prescribed temperatures. Conversely, the second definition emphasizes the occupants and their needs which may be evaluated from the individual's perspective, such as their perception of a comfortable temperature or the space as psychologically pleasant. The presence of these types of variations within the participant-provided definitions reinforces discussions in existing literature. In the absence of a unified definition of building performance, variations in how it and its elements are

interpreted can result in misunderstandings and/or the exclusion of occupant wants or needs during design (Leaman & Bordass, 2001; Zavei & Jusan, 2017).

Even within an identified perspective, the participant definitions were not always in agreement. As seen in the building-oriented perspective, three subcategories emerged. These categories reflected various focuses within the larger perspective. While these definitions centered around quantitative building-focused design elements, the definitions were not consistent in expressing their importance. Similarly, in the blended perspective, some definitions leaned more towards the building- or occupant-oriented perspectives when expressing building performance considerations. These differences demonstrate that even within a shared perspective, the participants in this study expressed building performance differently. Research should continue to evaluate these differences within and between the perspective to identify how they may influence the interpretation of building performance and its application.

Ambiguous terms in definitions such as comfort, durable, or owner/user needs also support different interpretations of building performance based on a person's role within the design process, as seen in literature (Alwaer & Clements-Croome, 2010; Maslesa et al., 2018). Terms such as energy efficiency are often tacitly understood within the AEC community, providing a foundational awareness of intent. However, terms found in the participant-given definitions such as comfort, building function, project goals, owner needs, and operational efficiency have greater ambiguity. For example, healthy can be interpreted as relating to physiological needs like indoor air or lighting quality, or it can be interpreted as psychological, addressing social or cultural needs, space functionality, or acoustics (Hartkopf & Loftness, 1999). When accompanied with more context, terms like these can be specifically linked with more concrete performance considerations like indoor air quality, maintenance capability, or life-

cycle analysis. However, without additional context, the terms are left open to interpretation within the definitions. The use of these terms suggests that there are more layers of ambiguity around building performance in the AEC industry than currently studied.

Definitions given by participants for the occupant-oriented and integrated approaches used ambiguous terms more often, referencing items such as user's needs, owner's needs, comfort, satisfaction, or project goals. Each of these unclear terms can be broken down further. Participants' definitions of building performance did not clarify or operationalize these terms, supporting arguments that interpretation of building performance may differ among stakeholders (Alwaer & Clements-Croome, 2010). For example, from an owner's perspective, satisfaction may be a building that remains occupied and results in little maintenance or operational cost. On the other hand, from an occupant perspective, satisfaction may be a building that is easy to access, allows for work-related activities, and is perceived as comfortable. Finally, from a design standpoint, satisfaction may be an aesthetically pleasing building that maintains comfortable temperatures and is easy to construct. Presenting building performance in terms of occupant satisfaction or project goals, as seen in these definitions, reinforce discussions of how the lack of a common definition of, or clarity around the use of, the term building performance can result in performance standards and expectations varying between designers, owners, and other stakeholders (Aune et al., 2009; Bordass et al., 2001; de Wilde, 2019). Future research should evaluate the use of ambiguous terms to understand how these terms are interpreted between individuals, evaluating within and across perspectives of building performance.

It is reasonable to consider that a certain level of ambiguity will persist in practice, even when using robust definitions. Definitions can be considered brief overviews of a practitioner's interpretation of building performance. Individuals may not fully express all the design elements

they consider part of building performance through a definition. This misalignment between the internalized definition and considerations for building performance was evident in the discrepancy between the elements identified in the given definitions and the elements selected from a list. When prompted, the participants selected a larger range of design elements than what was conveyed through their definitions.

Additionally, the frequency of some elements selected from the list rivals energy, indicating that while energy efficiency and related topics are more prevalent in literature and more frequently expressed through definitions, other design elements such as acoustics, moisture control, and indoor air quality are garnering more attention and effort. For this reason, it is important to continue to expand our understanding of how building performance is understood and applied throughout the AEC industry, including building users. Additional research into other stakeholders beyond architectural firms and their view of building performance will help inform this understanding.

This study provided insight into how design practitioners understand and express building performance through their definitions and how their expression of design elements within these definitions may differ from what elements they consider part of building performance. This insight is presented within the context of the limitations of this study. The participant-provided definitions in this study were gathered in the limited context of a survey from a small industry subset and is assessed only through the researcher's perspective. This process highlights only one side of the design process when design teams can have any number of stakeholders. The definitions and their interpretation within this study are subjectively based on the researchers' perspectives and knowledge in the research area and the participant perspectives. Further, the design elements presented to the participants were based upon the

evaluation of the literature. They may not reflect a full range of design elements that the participants consider part of building performance. Additionally, the context in which the definitions were presented may not reflect actual discussions of building performance in practice. Despite these conditions, recognizing the presence of the various building performance perspectives and the influence that they may have on application is important. Future research should consider how the perspectives influence design, how variations in stakeholder perspectives may influence the challenges firms face when including performance considerations into their designs, and how forming a unified definition of building performance would influence practice.

Conclusion

This research evaluated design practitioners' definitions of building performance in practice to contribute to the industry's understanding of building performance evaluation and expectation. This research 1) supported the organization of building performance perspectives into focus areas of building-centered, occupant-centered, and blended while adding a fourth integrated approach; 2) confirmed the lack of clarity surrounding building performance definitions; and 3) suggested possible variations between what may be expressed by practitioners in their definition and what they operationally consider elements of building performance. The emergence of a fourth perspective indicates that there may be additional perspectives toward building performance not yet recognized. The discrepancies between the building performance definitions and selected design elements also indicate that practitioners should be more cognizant of how they communicate building performance goals and strategies. Practitioners should identify areas where miscommunications may happen. In identifying these areas, designers should modify their design process to communicate building performance goals and strategies

more thoroughly, potentially reducing miscommunication. These findings help establish a foundation to build upon when discussing building performance.

Building performance in practice is complex. Additional research is needed to understand how building performance is interpreted by other stakeholders, including building owners and occupants. It is also important to explore where misunderstandings may occur within project teams and how ambiguous terms or the expression of perspectives may influence team members' understanding of project objectives. Patterns regarding the identified perspectives and ambiguity found in this research should be expanded to determine their presence in the wider AEC industry. Future research should include the recognition of the potential for additional perspectives of building performance within the AEC industry and building users. This study and following research can help improve building performance by breaking down assumptions and implicit understandings and supporting a greater clarity around building performance within the industry.

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CHAPTER 3: Article 2

Engaging Building Performance in Architectural Practice: Reviewing Challenges in Small Firms

Abstract

Building performance has become a critical consideration in the architectural design process as demand grows for buildings that consider environmental, social, and economic factors. This expansion of issues increases the breadth of knowledge required for architects, requires additional iterations and analysis, and often requires the involvement of other specialists. These conditions can create hardships for firms as they strive to incorporate building performance into their workflows. Small architecture firms, making up the majority of firms nationally, are particularly subject to these struggles as they lack the resources often available to larger firms. This research conducted a case study of three small architectural firms in North Carolina to explore a shared understanding of the processes and the development of issues within workflows that impact building performance. This study chose participants based on their consideration of building performance and their types of design workflows. Conducting interviews with individuals at the firms, this research aimed to learn from firm experiences to identify challenges with building performance consideration. As a result, this research identifies 33 challenges within three themes, contributing to a growing understanding of how a firm's consideration of building performance, project types, and workflow influence these identified challenges.

Introduction

The demand for buildings that consider environmental, social, and economic conditions has grown over the past few decades (Göçer et al., 2015; Hwang & Tan, 2012). These buildings are often regarded as sustainable, high-performance, or green buildings by operating at a lower cost and providing healthier and more productive environments (Zuo & Zhao, 2014). As part of their design, these buildings often integrate a wide range of performance considerations, including energy efficiency (de Wilde, 2019), life-cycle cost (Mostavi et al., 2018), operational efficiency (Fischer et al., 2017), environmental ergonomics (Hedge, 2000), sustainable materials, and construction methods (Zuo & Zhao, 2014). This diversity of performance considerations requires practitioners to manage an increasing amount of information, leading to an associated increase in project complexity (Hien et al., 2000; Olanipekun et al., 2018). As demand for higher-performing buildings continues to increase, architecture firms are experiencing related challenges as the Architecture, Construction, and Engineering (AEC) community seeks to embrace a more performance-conscious approach (Rezaee et al., 2019).

The challenges that an architecture firm encounters when addressing performance differ by project and firm. Difficulties can be tied to project objectives, project program, or firm composition and resources. The inclusion of building performance considerations in the design can require engaging additional stakeholders (design team, contractor, owner, operator, users, etc.) (Østergård et al., 2016), higher construction standards (Pulaski et al., 2006) and include considerations that extend beyond the commissioning of the building, like life-cycle impacts (Rekola et al., 2012). These high performance conditions require firms to manage both the fundamental design requirements and additional technical and social parameters relating to the stakeholders' interest and building performance (Sebastian, 2010). Incorporating these other

considerations frequently requires architecture firms to invest additional resources into technical evaluations, project management, and employee knowledge. Firms may be required to purchase additional software, hire knowledgeable staff or consultants, or invest in training. Small firms have limited resources and are less able to absorb the extra cost or time requirements associated with these extra demands (Brause, 2017). The challenges that the small firms face may differ from large firms due to their resource restrictions. These difficulties can impact a small firm's ability to adjust to the increased needs associated with building performance and limit the firm's ability to embrace performance fully during design.

As small firms make up the majority of architectural practice in the United States, it is vital to understand the challenges they face when trying to accommodate the industry's shift towards higher performance. The inability to properly consider building performance during any design phase can contribute to a gap between the expected and actual performance of the project (Augenbroe & Park, 2005; Maslesa et al., 2018; Tweed & Zapata-Lancaster, 2018). The inability to properly evaluate performance considerations and their scope in the project, or include all necessary parties during design, can exclude occupant's needs (Leaman & Bordass, 2001; Zavei & Jusan, 2017) and a breakdown in the building's usefulness (Islam et al., 2019). Due to their size and in-house capabilities, small firms must often choose between either satisfying the fundamental design requirements, such as structure, program, and life safety, and further exploring more specific performance considerations. The reduced ability of small firms to address building performance may result in the final building not meeting expectations. This research, therefore, believes it is essential to understand the challenges that small firms face when considering building performance and how workflows may impact or help alleviate these

challenges. To this end, this research conducted a case study to identify challenges within three small architecture firms in North Carolina.

Background

Literature indicates that when considering building performance, architectural firms may face challenges related to the design process, assessment methods, or interaction with stakeholders (design team, contractor, owner, operator, users, etc.). These challenges differ from those experienced during design less focused on building performance. Focusing on building performance can require new methods and tools for assessment, consideration of new materials or construction techniques, integration of additional stakeholders, additional competencies for design staff, and new workflows or procedures for quality control (Rekola et al., 2012). Introducing these new considerations and design techniques into the design process can burden all firms as they adjust.

At the fundamental level, traditional design workflows support the incorporation of building performance assessment. However, this nonsequential, iterative design process does not easily accommodate the additional consultants or procedures required to assess building performance (Aksamija, 2016). Performance evaluation needs to be included in early design phases when fundamental decisions are made to be the most effective (Aksamija, 2012; Turrin et al., 2011). Delaying performance evaluation into the later design stages results in unnecessary steps and can restrict performance decision. However, the early design stages are not typically structured to allow for performance evaluations. In the early phases, design is conceptual, with designers generating a range of scenarios followed by review and selection (Liu et al., 2003). Conceptual designs typically lack detail, limiting performance evaluation opportunities. Furthermore, the linear and fragmented nature of the traditional workflow can result in

miscommunication between stakeholders as disciplines are separated by design stages and do not always directly communicate with each other (Elvin, 2007). These conditions, and associated challenges, impact a firm's ability to incorporate building performance into its designs at the macro level of the workflow.

Additional challenges exist when evaluating the technical and social systems of the design workflows that support building performance considerations. Technical systems are most often associated with digital processes, such as modeling, document generation, and performance simulation (Hjelseth, 2017; Tropmann-Frick & Thalheim, 2015). Technical solutions, primarily performance simulation, are often seen as critical components for addressing building performance as they allow for the quick and accurate evaluation of building performance. However, these technical systems are typically limited to only addressing objective, quantifiable considerations (Sharma & Fisher, 2013). Also, architects often do not know how to use specific assessment techniques, like energy modeling, and do not consider it their responsibility (Denzer & Hedges, 2011; Fernandez-Antolin et al., 2020; Paryudi, 2015). Not taking responsibility for this task results in the overall absence of performance assessment and can cause complications, such as increased building and design costs and communication issues between stakeholders (Denzer & Hedges, 2011; Olanipekun et al., 2018). Further, simulation software does not always integrate seamlessly into the design process (Aksamija, 2016), and its use is not guaranteed to positively influence design (Deutsch, 2011). The complexity of the simulation programs often requires firms to hire individuals with knowledge of building simulation software or partner with outside consultants (Bleil de Souza, 2012). The software is also susceptible to improper inputs, resulting in calculation errors (Kim & Park, 2011). These technical conditions result in multiple challenges when addressing building performance.

The social systems support the communication and collaboration between stakeholders (Bostrom et al., 2009; Hjelseth, 2017). Collaboration is key to the design process; however, collaboration can also generate challenges (Elvin, 2007) and adversely impact building performance. A focus on building performance requires a more comprehensive approach to stakeholder inclusion, requiring the engagement of some that would not typically be involved in the design process (e.g., maintenance staff and occupants) (Olanipekun et al., 2018). These stakeholders may not be knowledgeable of the design process, creating confusion and other conflicts. Additionally, these stakeholders may not be initially comfortable providing details around habits or procedures, limiting their contribution. This increase in the number of stakeholders participating in the design process increases the burden on managing information and expectations, budgets, and project schedules (Häkkinen & Belloni, 2011). Failure to coordinate stakeholders and unify their perspectives leads to misunderstandings and uncoordinated actions (Valkenburg & Dorst, 1998), inefficiencies, reduced quality, slow progress, and reduced occupant satisfaction (Du et al., 2012; Kalantari et al., 2017; Meng, 2013; Negendahl, 2015). Under these conditions, the inclusion of additional stakeholders can hinder building performance, effectively reducing the benefits of collaboration.

Outside of the design process, challenges with building performance can be related to the programming, construction delivery (i.e., design-bid-build, design-build, construction manager at risk, integrated project delivery), and operation of the building. Higher-performing buildings can be more expensive to construct than conventional ones, as sustainable materials and efficiency techniques can be more costly (Kilbert, 2012) but have the potential to be more valuable over time for owners and tenants (Fischer et al., 2017). This increased cost can result in an unequal balance between the owner and tenants as they weigh the value of the building based on their

performance perspectives (Hwang & Tan, 2012). Tenants may have value design decisions relating to the function of the building, such as operational requirements. At the same time, the owner may be more interested in system-related performance and cost savings. These misalignments result in additional challenges as the architect balances expectations, budgets, schedules, and other factors like code compliance that influence a project outcome.

Methods

This paper outlines a qualitative exploratory case study that identifies challenges associated with the consideration of building performance during design in small architectural firms. This research was part of a more extensive study that focused on the challenges encountered when considering building performance and how a firm's workflow influences the firm's ability to overcome these challenges. This paper combines a synthesis of the existing literature to understand identified challenges related to the delivery of high-performing buildings and cross-referenced these established challenges with interviews, group discussions, and firm process diagrams from selected firms. This research did not focus on a single project but rather explored challenges the participating firms faced across their entire project portfolio. Complex processes, such as design workflows, result in multiple challenges which may not always be known or consistent between situations (Rekola et al., 2010). Focusing on a single project would limit the understanding of the challenges that the firms face to a single instance or situation.

Selecting Cases

Small firms were purposefully chosen for this research because they have fewer resources available and cannot freely invest in infrastructure, access technology, and hire specialized expertise to produce more complex projects (Brause, 2017) compared with large irms. Defined as firms that employ fewer than 50 people by the American Institute of Architect (AIA), small

firms comprise a large portion of the architectural community at 93.8% of all firms (American Institute of Architects, 2018). The large number of small architecture firms relative to all architecture firms, makes it essential to understand their specific challenges in addressing building performance.

A survey solicited 765 North Carolina architectural firms through email for their views on building performance. Fourteen of the 118 survey participants indicated a willingness to participate in an additional case study. Of those fourteen, eight were eliminated due to their firm size with either over 49 employees or being single practitioners. The researcher further evaluated the six remaining firms based on public information and short interviews to understand the firm's design workflows, availability, and regular consideration of building performance. This research sought firms using both integrated design (ID) and traditional design workflows for comparison. To be considered for the study, the firms needed to be available, willing to discuss their workflow processes, and demonstrate that they actively considered building performance during the initial conversations. Three were selected for the case studies, with two using ID workflows and one using a traditional design workflow.

Interviews and Focus Groups

The interviews and focus groups with the different firms collected insightful, context-based data regarding the firm's organizational structure, workflows, and challenges around building performance. Suggested by each firm's principals individuals with in-depth knowledge of the firm's workflow were approached for participation. A total of eleven people chose to participate in the interviews across the three firms: four in Case 1, three in Case 2, and four in Case 3. Eight were registered architects; seven acting as design principals/project architects, and one acting as an energy manager. The remaining three were design professionals: two junior

designers and one interior director. In light of COVID-19, this research conducted the interviews remotely using conferencing software. The interviews were semi-structured, lasting approximately 60 minutes, and performed using a casual tone with open-ended questions. Participants were encouraged to describe their experience with building performance considerations, the challenges that they have experienced, and how their workflows addressed these challenges.

After documenting and analyzing the individual interviews, a focus group was held within each of the three firms. These focus groups were open to other employees within the firm that wanted to participate, addressing building performance and workflows. Group discussions were intended to gain more context and insight into challenges and workflows for each firm, supporting the initial understanding established through the individual interviews. Participants were presented with the interview results from their firm and encouraged to provide additional insight or corrections.

Analysis

Data from the interviews and focus groups were analysed to better understand how the ID firms addressed building performance. In this analysis, this study considered the properties of the cases and their discussion of the challenges.

Introduction of Cases

Case 1 employs six full-time and two part-time designers with its office structured in a matrix hierarchy (Table 3.1) (Hayes, 2014). The firm uses a traditional workflow and works on various commercial and residential projects without a building type specialty. The firm considers a limited range of building performance considerations such as social programming and operational workflows while focusing on aesthetics. Other performance considerations, such as

life-cycle analysis, energy efficiency, and sustainable systems, are included in their designs when requested by clients. Case 1 performs a limited internal evaluation of these performance considerations, seeking outside consultants for more in-depth or complicated assessments as required. The evaluation of building performance can begin as early as schematic design when requested. Still, this evaluation typically occurs in later design stages, such as during late-stage design development or construction documents.

Case 2 employs 12 full-time employees: 11 designers and one support staff; and specializes in restaurants (Table 3.1). The firm's office is organized in a matrix structure and uses an ID workflow. Performance considerations focus on use and operational concerns, such as operational workflows, wayfinding, and maintenance. The firm employs designers with specialties in their focus areas but also relies on consultants as needed. Building performance is considered both internally and externally through all phases, with stakeholders involved as early as pre-design. The firm establishes objectives early to aid in the focus on building performance.

Case 3 employs 20 full-time employees, including support staff, and is structured into two studios (Table 3.1). The firm uses ID workflows and primarily designs institutional buildings, specializing in K-12 schools. Energy and maintenance efficiency are their primary performance considerations for designing low- to zero-energy buildings, with some secondary safety and educational workflow efficiency considerations. Case 3 employs an energy specialist in-house but works heavily with outside consultants to verify energy performance considerations. Building performance is considered early in the design process, including discussions with consultants, the formation of design objectives, and early-stage analysis during pre-design.

Table 3.1
Case Characteristics.

	Case 1	Case 2	Case 3
Workflow	Traditional	Integrated	Integrated
# of Employees (Total)	8	12	20
Structure	Matrix	Matrix	Studio
Project Types	Commercial and Residential	Resturant	Institutional (K-12)
Primary Performance Considerations	Social Programming and Operational Workflows	Operational Workflows, Wayfinding, Maintenance	Energy and Maintenance
Specialist	None	Multiple	Energy and K-12 Workflows/Safey
Consultants	Yes (As needed)	Yes (As needed)	Yes
Stage of Performance Consideration	Design Development or Later	Pre-Design	Pre-Design

Identifying Challenges

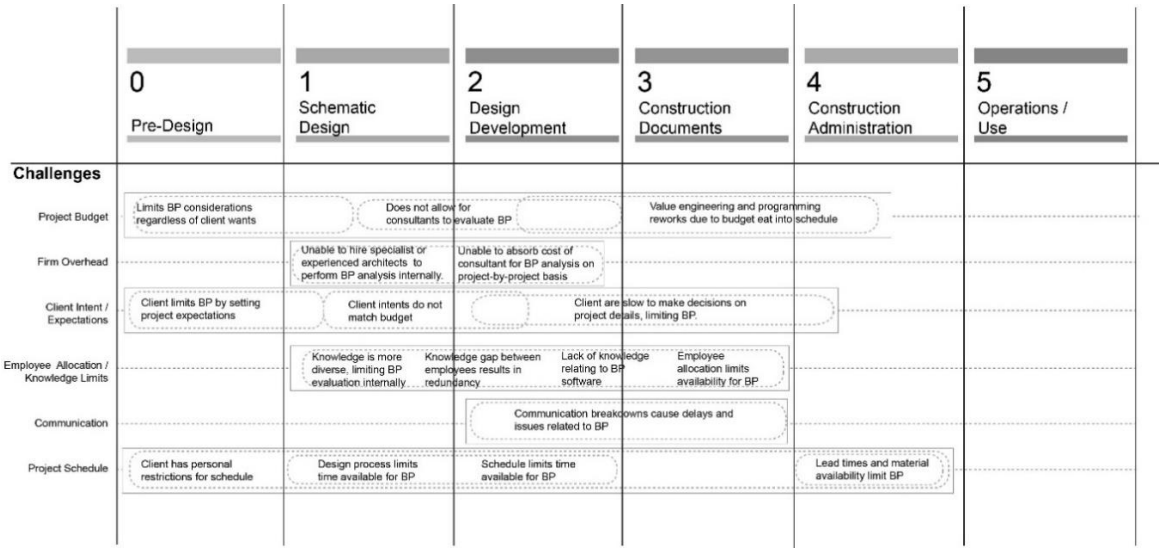
Building performance challenges were identified from interview data and coded based on their characteristics, such as referring to design process, client, budget, employee, knowledge, or other factors. Codes drew from those challenges identified within the existing literature, but new challenges were also allowed to emerge from the interviews. After coding the individual interviews, the challenges were compared across individual interviews from the same firm in a within-case comparison. Challenges expressed using different language but with the same intent across individual interviews were identified, combined, and distilled into a single phrase or idea. For example, a discussion the inability to hire consultants was coded as budget-related and employee-related. During distillation, this research summarized the discussion into two challenges; Project budget doesn't allow consultants to be hired, and Gaps in employee knowledge can require consultants to be hired. Once the challenges for each firm were established, a preliminary comparison was conducted across the three cases; the researcher identified challenges with similar meanings between the different firms. The researcher

addressed any difference in language or terms through the focus groups to further distill and confirm findings across the cases. A total of 33 challenges across the three firms were identified.

The challenges found across the three individual firms were further evaluated and coded, with nine categories emerging: project budget, firm overhead, client intent and expectations, employee allocation and knowledge, communication, project schedule, technology, exterior influence, and building performance complexity. There was evidence of these nine categories in each of the discussions with the individual firms. To better understand the context for these issues, the subset of challenges identified for each firm were mapped across AIA design phases: pre-design (PD), schematic design (SD), design development (DD), construction documents (CD), construction administration (CA), and operations/use. An example of this mapping is shown in Figure 3.1. Mapping the challenges of each firm identified relationships between the challenges, critical context, and connections to each firm's workflow. Given this, supported by the discussions of challenges within the firms, three primary themes emerged: Infrastructure, Process, and External.

After identifying the three primary themes, the challenges were restructured to explore them across the three firms. The 33 challenges and their 9 categories were reorganized under the primary themes and coded to indicate if all firms expressed the challenge or if it was only firms using integrated workflows or only the firm using a traditional workflow (Table 3.2). This structure helped identify similarities and differences in how the different firms discussed the challenges in light of the primary themes, the frequency of challenges, which phase they recognized the challenges, and the conditions surrounding the challenges when they occurred. This comparison uncovered patterns in how the different firms experienced and addressed the 33 challenges.

Figure 3.1
Mapped Challenges Associated with the Consideration of Building Performance for Case 1.



Categories are listed on the left with design and construction phase at the top. Dashed lines circling the challenge description indicate the experienced challenges across the phases.

Table 3.2
A Consolidated List of Challenges by Primary Theme and Category.

	CHALLENGES	PD	SD	DD	CD	CA	Use
	INFRASTRUCTURE						
	FIRM OVERHEAD						
1	Software needed to communicate or consider Building Performance (BP) is expensive	I	I	I	I		
2	Employee time needs to be billable, restricting BP research or evaluation	I	I	I	I		
3	Unable to hire specialist or experience architects to perform BP analysis internally		T	T			
4	Unable to absorb the cost of consultants for BP analysis		T	T			
	EMPLOYEE ALLOCATION / KNOWLEDGE						
5	Employee availability limits time available to resolve BP considerations		B	B	B		
6	Lack of employee knowledge can slow project development and require consultants		B	B	B		
7	Employees with specialties can be drawn away from work to help others.		I	I	I		
	PROCESS						
	COMMUNICATION						
8	Improper communciation / misunderstandings between stakeholders	I	I	B	B		
9	BP can require complex interactions between consultants		I	I	I		
	TECHNOLOGY						
10	Technology can be flawed and doesn't always reflect actual conditions	I	I	I	I		
11	Software can make the design process more complex, limiting time available for design.	I	I	I	I		
12	Software can automate some process, reducing knowledge gained through manual interactions.	I	I	I	I		
13	Technology can reduce personal interactions, increasing misunderstandings	I	I	I	I		
14	Interactions between compatible technology may not be seamless, causing communication issues	I	I	I	I		
15	Design process limits time available for BP		T	T	T	T	
	BUILDING PERFORMANCE COMPLEXITY						
16	BP must be actively considered at each design stage	I	I	I	I	I	I
17	Hard to quantify some BP considerations	I	I	I	I	I	I
18	BP is hard to define and client doesn't always have a big picture of performance	I	I	I	I	I	I
	EXTERNAL FACTORS						
	CLIENT INTENT / EXPECTATIONS						
19	Client limits BP by setting project expectations (not committed to BP or has false focus).	B					
20	Client has unreasonable expectations of budget and BP	I	T	T			
21	Client is looking for short term BP benefits	I	I				
22	Client doesn't engage or care about decisions	I	I	I	I		
23	Clients are slow to make decisions, limiting BP considerations		I	B	B	T	
24	Client makes decisions based on personal preferences, not what is appropriate for project	I	I	I	I		
	PROJECT BUDGET						
25	Budget restricts BP considerations / does not align with realistic BP goals	B	B	B	B		
26	Budget does not allow for BP consultants to be hired	I	B	B	I		
27	Budget restricts time available for BP evaluation and exploration	I	I	I	I		
28	Rework due to value engineering restricts time available for BP			T	T	T	
	PROJECT SCHEDULE						
29	Schedule limits collaboration or ability to interact with stakeholders	I	I	I	I		
30	Schedule limits the time available to refine or consider BP	I	B	B	I		
31	Client has personal restrictions that limit the schedule and BP considerations	T	T	T	T	T	
32	Lead times for systems and material limit BP considerations					T	
	EXTERIOR INFLUENCE						
33	Outside influence can hinder BP decisions or capability	I	I	I	I	I	I

I = Integrated workflow, T = Traditional workflow, B = Both workflows

Findings

Overall, Case 1, the traditional process firm, identified fewer challenges in addressing building performance, with most of their challenges relating to Infrastructure and External factors. However, the firm frequently discussed the challenges that they did encounter as too debilitating to consider building performance consistently. Comparatively, the ID cases identified a more comprehensive range of challenges across all three primary themes and more

challenges overall. However, the ID cases typically discussed their challenges as having a low impact on their design process and not discouraging them from incorporating BP in their design process. The three themes—Infrastructure, Process, and External Factors—and their associated challenges are further explored below.

Theme 1: Infrastructure

Infrastructure challenges are associated with the firm's resources and employees. While all three firms identified Infrastructure challenges, these challenges were often experienced and handled differently across the two different workflows. Case 1, using the traditional workflow, experienced a significant challenge with employee knowledge and the inability to hire experienced architects to conduct building performance analysis due to cost. On the other hand, Cases 2 and 3, using the ID workflows, faced challenges managing the availability of individuals with specialties, software, and employee knowledge and ensuring their employees' time remained billable to projects instead of being associated with training or research.

Case 1 frequently discussed Infrastructure challenges as limiting their ability to further consider building performance. The traditional process firm shared that it cannot expand beyond its current method of viewing building performance due to a lack of employee knowledge and time. The firm employs young professionals with diverse abilities due to the firm's size and variety of project types. The firm needs "somebody who can jump in the model shop and build physical models, we need somebody who can jump on Rhino, and render, and that same person…can look at [building] code." With this perspective, the firm prefers diversity of knowledge over specialization and acknowledges that this results in their employees having limited knowledge regarding building performance assessment. Building performance is not prioritized in the spectrum of diverse employee abilities sought by the firm.

Furthermore, Case 1 states that its range of project types exposes them to various performance considerations, hampering the ability for employees to really focus in on any specific types of evaluation. For example, in their commercial projects, there is more emphasis from clients on building use and operational efficiency. In contrast, single-family residential projects demand reductions in environmental impact and energy use. This traditional process firm feels that this range of performance considerations across their project types makes it difficult for the firm to concentrate on one area of performance or hire experienced staff to cover all the concerns. As such, Case 1 believes that they cannot fully handle the consideration of building performance internally due to a lack of employee knowledge, availability, and overhead.

To counter these challenges associated with limited employee knowledge and availability, Case 1 identified two solutions: hiring employees with significant building performance knowledge or hiring consultants with that type of knowledge. The firm, however, currently feels unable to compensate an experienced, in-house architect or specialist adequately. The firm's workload and budgetary restrictions make less experienced architects more appealing to hire, as one participant states:

> For us to have a junior architect, who has maybe three to five years experience is much more useful to us than to have, say, someone who's got 15 years experience… We don't have that luxury of being able to basically pay your higher salaries for those people that have that long-term experience.

Valuing flexibility, Case 1 believes they would be unable to employ a specialist solely to analyze building performance given other more pressing daily needs and the wide variety of performance considerations across their building types. Instead, Case 1 relies on consultants when the project budget allows.

Case 2 and Case 3, using ID workflows, discussed Infrastructure challenges differently than Case 1. The firms acknowledged challenges with employee knowledge but identified steps taken to address the issue. Case 2, having a similar size and office structure as Case 1, recognized the need for flexible employees as they "do have to be generalists to some degree" but felt that adjustments to their workflows and structure could reduce the challenges associated with employee knowledge. Case 2 has taken steps to educate or hire employees with specific expertise regarding building performance, prioritizing diversity, and building performance in their flexibility requirements for hiring. Capitalizing on individual interest, one participant shares that "If there is an area that someone has a passion for or an interest for, they bear that flag, and they take on that additional research and additional certifications." These individuals become the firm's "champions," specializing in an interest area that often relates to building performance, such as restaurant operation, patterns of use, and material life cycles. The firm feels that using "champions" allows the firm to benefit from the employee's increased knowledge, reducing its reliance on consultants and improving in-house design performance.

On the other hand, Case 3's justifies hiring an in-house energy specialist because of their internal focus and prioritization of energy performance across projects. Acknowledging that energy analysis software can be expensive, and employees must have knowledge of the applications, the firm has opted to have the on-staff energy specialist support the firm's entire design process instead of actively performing simulations. In this role, the energy specialist manages the analysis and review of the design to ensure it complies with their energy performance intent. However, outside consultants are used to perform the energy simulations due to the heightened specialized knowledge required to perform in-depth analyses. This approach creates a hybrid operation, where the energy specialist provides in-house expertise and support

while still relying on outside analysis. In this manner, the in-house energy specialist of Case 3 performs a similar role to the champions of Case 2. The energy specialist can perform a variety of roles, from design to construction administration, and the firm benefits from the in-house knowledge of the energy specialist, while more complex modeling and considerations still require the use of an external consultant.

Case 2 and Case 3, however, do acknowledge other Infrastructure challenges when employing in-house specialists. These ID firms believe that they must balance the diversity of roles needed in a small firm with the specialized knowledge of these individuals. As Case 2 shares, firm employees are "constantly putting on many different hats…[you] don't have the luxury of just handing it off to somebody, [you are] usually working right beside the project manager, who's also the job captain, who's also, [etc.]". These shifting conditions require the firms' employees to manage multiple job duties, impacting their availability to assist with their specialty. As explained by Case 3, if the firm does not allocate the in-house specialist's time correctly, "the employee ends up feeling stretched and stressed and just gets upset with management about it." There are also times when the firm's in-house specialists cannot handle the breadth or demands of assessing building performance. As Case 2 explains, they do not "fake it till we make … that's not being responsible." If these firms feel like they cannot make a good decision after conducting initial in-house research, they will hire a consultant at their own cost to receive "some guidance and make the decision." In this situation, the firms find using consultants more cost-effective than struggling in-house with the decisions and possibly making a wrong decision. As a result, Case 2 and Case 3 feel that using their in-house specialist reduces issues associated with employee knowledge. Still, the in-house specialist can experience additional stress, or their knowledge may not be sufficient for all situations.

Overall, all three firms discussed Infrastructure challenges. The challenges in this primary theme focused on employee knowledge and allocation and firm overhead. This research traced the challenges identified in this theme to how the firms viewed and addressed challenges with employee knowledge. Case 1 viewed the challenges with employee knowledge as very debilitating, focusing them on a limited number of challenges in this theme. On the other hand, the ID firms addressed the challenges with employee knowledge through in-house specialists. The use of the in-house specialist led the ID firms to acknowledge other challenges relating to their use. In this manner, Infrastructure challenges can be viewed as restrictive but have been shown to be manageable.

Theme 2: Process

Process challenges are most associated with communication, technology, and the overall complexity of building performance. Of these challenges, communication was more prominently discussed by all three firms; they all face challenges with managing communication between stakeholders and properly relaying the design intent. Overall, however, *Process* challenges were mainly reported by the ID firms. Case 2 and Case 3 noted difficulties with their use of technology, its limits, and the industry's understanding of building performance.

In discussing *Process* challenges, Case 1 focused on their traditional workflows and issues that arose later in the design, typically during DD and CD. The firm discussed process issues either as a result of design delays due to the many iterations needed in early design or as a result of improper design coordination between stakeholders. At times these types of issues – iterations and improper coordination - were interrelated. For example, in one instance, Case 1 failed to properly coordinate the design with the structural engineer, impacting the project's thermal efficiency. The firm passed design files electronically to the engineer with limited

context, not communicating the need for continuous insulation. Due to the limited communication and improper coordination, they could not incorporate continuous insulation into the design. This issue,

> had more to do with taking too long in the SD/DD phases when we should have been looking at some things that weren't seen until CD, like the wall sections …so we had to rush to cram a lot of CD stuff in all at once. And then that communication breakdown [resulted in] the structural engineer [not] really knowing what we were doing until weeks before the deadline for CD.

The ID firms discussed *Process* challenges differently from the traditional process firm. Case 2 and Case 3 identified a larger number of challenges, as shown in Figure 3. Some of these challenges relate to improper communication, the number of consultants required to evaluate building performance, flaws within the software and simulation process, and the need to actively consider building performance in all design stages. However, the ID firms discussed these challenges from a cautionary perspective rather than routinely occurring challenges. For example, both firms discussed challenges relating to communication, but the firms acknowledged that these challenges were manageable through their workflows. The firms viewed communication as an intentional and critical component of their design workflows. As Case 3 explains, proper communication requires intentional time and involvement of the project stakeholders. It is essential to "allow for more time for discussions between everybody on the project and work to solve [performance-related] problems." Both firms expressed that proper communication helps support building performance; building performance is complicated and requires the repeated interaction of multiple stakeholders to ensure that all design decisions are appropriately assessed. Case 2 states,

> ... if you can't communicate properly, performance becomes an accident rather than something that's very intentional. We always want it to be something that's incredibly intentional. So you've got to make sure everyone is communicating in the same language.

Both ID cases have taken steps to ensure that they use frequent and intentional communication in recognition of the impact miscommunication can have on a project. Both firms engage stakeholders early and require project team members to use BIM and coordinate files through cloud storage, limiting project design and documentation oversights or communication and omission errors. Both firms reinforce the transfer of information through BIM by intentionally and frequently communicating with all stakeholders. Communication varies by project phase and stakeholder involvement but ranges from bi-weekly meetings during heavy involvement to monthly updates when the pace is slower. Case 2 and Case 3 feel these steps help mitigate *Process* challenges associated with communication.

When compared to the ID firms, Case 1's methods for communication are less intentional. The firm primarily communicates electronically one-way, passing files back and forth with limited supplemental information. Termed "over the wall" by Elvin (2007), neither participant fully sees nor understands what the other is doing at any given time in this process. The firm uses BIM but only for modeling, not for routinely coordinating design files. Furthermore, the firm typically involves outside consultants later in the design process than Cases 2 and 3, limiting the time for changes. As a result of this late-stage coordination and limited communication, the firm feels that conflicts are sometimes not identified until the information is reviewed later in the project.

Case 2 and Case 3 also discussed *Process* challenges relating to technology. Both cases acknowledged that technology presents challenges, but they could take intentional steps to reduce its negative impact. As Case 2 explains, "technology is a tool, it's all how you use it… I think technology has helped …I [also] think it has become a little bit of an impediment". The two firms recognize that technology aids in considering building performance but can also

increase the complexity of the design process. For example, both cases recognize the benefits of BIM but acknowledge that it has challenges. Case 3 explains that BIM software is a powerful tool, but it does not allow designers to make quick changes. BIM also requires more detailed information to be entered into the program earlier in the design process, which may be difficult as the design is still developing. Case 2 also pointed out that there can be issues when coordinating BIM software and the modeling process between stakeholders. These issues can be due to inconsistencies in BIM software between versions, such as architectural and mechanical engineering versions, and firms not being at the same level of integration or using the same standards.

Performance simulations are another example of how technology can introduce challenges when considering building performance. Simulation software is crucial to Case 3's design process but presents challenges with potentially flawed output. As Case 3 explains, "in [the] energy modeling world, the models are perfect. …But the models are only as good as the information you put in". For example, while modeling the energy use of a building, one external energy consultant for Case 3 did not correctly account for the opaque structure of the windows, resulting in a 30% difference between the targeted and actual energy consumption of the building. This oversight is a process issue as the energy consultant was either not told or didn't fully understand the conditions associated with the structure.

The ID cases have taken steps to mitigate these technological challenges. Case 3 recognizes the benefits of BIM and has modified its design process to engage stakeholders sooner and investigate systems more thoroughly in early design phases to reduce the need to redesign later. Case 2, on the other hand, holds a retreat every two years with critical stakeholders and repeated team members to discuss their use of BIM across projects and

coordinate the standard processes to reduce errors and coordination issues. Finally, to help minimize simulation errors, Case 3 stresses the accuracy of simulation input through proper communication of the design details; information is provided through BIM and supplemented by increased contact with the energy consultant. As a result of these steps, the ID cases state that they have reduced their *Process* challenges relating to technology, even though they still recognize them as a consistent threat.

The final set of *Process* challenges were only acknowledged by Case 3 and deal with building performance's overall complexity. Specifically, these challenges address the need to consider building performance at all design stages, the inability to quantify some performance considerations, and variations between stakeholder definitions. Case 3 explained that these challenges impact the ability to set expectations and deliver on the project goals. They also noted that intentionally considering building performance further complicated their design process because they must actively consider building performance during all phases or feel less likely to achieve their goals. Furthermore, depending on which performance measures are being addressed, the firm states that different design strategies may be difficult to quantify, making them less desirable for clients. Finally, the firm acknowledges that the definition of building performance varies between stakeholders, sometimes making a client's building performance expectations hard to understand and achieve. Case 3 often works with the same consultants and communicates the project objectives early in design to create a level of understanding between stakeholders to mitigate some of the issues surrounding this set of challenges. The firm believes this involvement helps in the design stages, prioritizing performance across an understood process, and during operations. This understanding sets the standards for building evaluation after occupancy.

The *ID* cases primarily identified the *Process* challenges. Of the 11 challenges identified in this category, only two were identified by Case 1. However, the magnitude of the challenges for Case 2 and 3 were less, even with a higher quantity expressed. The communication challenges were the most predominantly discussed. The ID firms used frequent and intentional communication to address these challenges but still experience issues resulting from their technology use. The ID firms relied on BIM to aid in communication, and Case 3's focus on energy efficiency led them to use simulation modeling. These challenges are specific to the systems used by the firms and do not relate to the ID workflows. BIM and simulation modeling are not required for ID workflows to function. However, these firms rely heavily on the systems to facilitate their workflows and building performance focus, therefore experiencing issues related to building performance.

Theme 3: External

The previous challenges primarily originate from internal factors of the firms, while those in the External theme primarily arise from outside the firms. *External* themed challenges relate to the client's expectations, project budget and schedule, and the influence of other entities like code officials, vendors, or business associations. The firms universally identified *External* challenges relating to (1) restrictions placed on the project by the client's expectations of building performance; (2) lack of client engagement or slow decision making; and (3) a client having unrealistic goals, schedule, or budget. These *External* challenges can vary between projects and cannot be fully managed by the firms through changes to their internal processes or knowledge. However, like other identified challenges, the three firms take steps to mitigate their impact.

The participating firms frequently discussed *External* challenges as originating from the client and often being interrelated. For example, the client may have an unreasonable expectation for performance based on their current budget. Case 2 discussed situations where clients may "want [a] building to last for five to 10 years [between redesigns or significant maintenance] …[for] $50 per square foot… [however] for a five-to-10-year building, we need to look at $150 a square foot". This disjoint between the client's expected performance and their budget requires the firm and client to reassess their expectations for both the building and their budget. However, without identifying these challenges relating to the client's budget and expectations early in the process, Case 2 believes that additional challenges can be created, requiring the firm to alleviate disparities between what is expected by the client and what can be reasonably achieved, often sacrificing performance. As Case 1 pointed out, projects may "start with [building performance] and then as the cost starts to build, and people start to have to make decisions and decide if they want it … even the ones that are adamant about [performance]. A lot of that stuff gets [value engineered]".

All firms discussed *External* challenges as indirectly impacting building performance. For example, Case 1 explained that in selecting the "correct" material or system, a client might delay decisions late into the design, inhibiting the firm's ability to incorporate building performance tied to material selection or building systems, like HVAC. Case 1 tied this challenge of delayed choices to a client's personal connection to the project. While found across all their projects, commercial and residential, this is particularly evidenced within their single-family residential design. In these cases, the firm is,

> in a constant struggle to kind of keep these things on schedule as much as possible, but also be sensitive to the fact that this is such a personal process, and people are so worried about getting it wrong, and it's very time-consuming. [This is] something that's so personal to people. [For example] even just knowing that we wanted [sustainable materials], I felt like we had a pretty good handle on what they were interested in, and what was going to be more sustainable, but drywall is going up, and they still haven't decided on the floors, they've been back and forth, there's so many little things that happen [that impact performance].

Significant delays in client decisions make it difficult for the traditional process firm to adjust the design or account for long lead times for systems or materials, making it challenging to accommodate performance aspects such as high-performance HVAC systems or energy generation.

As Case 3 explains, the *External* challenges often "come down to re-designing, re-evaluating". When making design decisions, "if there's a lot of client back and forth, where you're not quite sure what the client exactly wants, you don't want to bring [consultants] in when you haven't made the fundamental decisions". Advancing a project as required by schedule without the needed information can result in future scheduling delays, increased cost, and compromising building performance due to incorrect information or assumptions. As Case 2 describes:

> The other issue that we run into a lot is just clients changing their minds. So it may be that we have looked at how certain aspects of the project come together and have come up with a solution. And then down the road, past the time when the client would hopefully be making changes, they introduced something new that then kind of throws us into a tailspin. And we have to kind of reevaluate a number of elements that again, that domino effect comes into play where this one change that the client thinks will take, you know, 20 minutes because it's just a simple thing turns into a two-hour process is trying to figure out exactly what else has been affected because of that change.

Clients making changes or delaying decisions cause hardships on the firms that impact building performance. Both ID firms explained that significant changes or delays impact performance by pulling employees away from the project development to make the changes;

sometimes conditions surrounding the project change, affecting the building structure, workflows, materials, or other aspects of performance. For example, Case 3 explains that they make design decisions based on the systems selected during SD. These systems included envelope, renewable energy, and HVAC systems. These systems are interrelated, and changes to one system can directly impact another. If a client changes the size of the windows or number of windows later in the project, these systems will be impacted. The envelope will become less efficient, the HVAC system may have to be enlarged, and the renewable energy system may now be undersized to achieve net-zero output. The firm must now choose to reduce the performance of the building or spend time adjusting for the impact. A client changing or delaying a decision late in the project can have significant consequences as firms struggle to adjust or sacrifice building performance.

In recognition of the source of the challenges (the client) and the root of the problems (redesign), the ID firms create formalized project objectives at the beginning to minimize *External* challenges. The firms feel that these objectives help manage client expectations and assist in building performance evaluation by providing a baseline expectation. Creating the goals during PD guides the firms' intentional focus on building performance and early understanding of the client's needs. The objectives are formed in conjunction with the client and input from other stakeholders (Case 2) or by the design principal after consulting with the client (Case 3). If the firms identify an issue while creating project objectives, they work with the client to rectify it and clarify expectations. These goals help guide the remainder of the project and keep both the design and client on task and clear on expectations. Each firm stated that this focus aids the firms in reducing the impact of challenges around client expectations.

Case 2 and Case 3 recognize that the use of project objectives may not reduce all *External* challenges. The client may not be committed to building performance or only be interested in short-term benefits, despite the value placed on building performance by the firms internally. Case 3 views this limited interest as having a 'false focus' on performance. The client is only focused on design, such as aesthetics, and does not fully embrace the importance of building performance. Case 3 described an example.

> Recently we teamed up on a project that was supposed to be a net positive building, and they just wanted a more grandiose building …, they were more the design driver on this one, just wouldn't make the decisions, in my opinion, that needed to be made to make it a better performing building, but also make it a better building, for the occupants, but they wanted a very classical, big grand space. It's going to be a beautiful building, but they were more interested in terms of how the building looked.

As in this case, when a client is only superficially committed to building performance or is not willing to compromise in favor of building performance when conflicts arise, the firm finds it difficult to achieve the desired outcomes. Even with creating the objectives, both ID cases acknowledge that it can be hard to manage a client that is not focused on building performance.

The client is not the only exterior influence that can cause challenges. Cases 2 and 3 identified that other stakeholders, like vendors or occupants, building code, and business associations, can impact building performance. These groups can have vested interest in the project themselves, such as vendors recommending kitchen equipment, or neighborhood associations that influence the project through mandates, like restrictive covenants. In both cases, the ID firms acknowledged the challenges but understood the firm had little control over the influence. At most, they stated that the firm could advise the client in situations where other stakeholders were making recommendations, and other forces like code or covenants require policy changes, providing the firms with little control at the project level.

The *External* theme contained the most challenges at 15. The three firms discussed these challenges more uniformly between the ID and traditional firms than the other two themes, as they acknowledged that they could not control the exterior influences of project budget, schedule, and client expectations. As with the other themes, the ID offered ways to manage these challenges early in the design process but recognized that their solutions were limited in their effect. Overall, these challenges were viewed across all three firms as difficult to overcome.

Findings Summary

In total, this research identified 33 challenges across three themes: Infrastructure, Process, and External. Case 1 discussed these challenges differently from the ID firms, identifying fewer overall. Case 1 frequently discussed the challenges as more debilitating, finding the most difficulty with the *Infrastructure* challenges. The firm values general knowledge over building performance knowledge and therefore feels limited in their ability to perform in-house assessments due to limits on their employees' building performance knowledge. The ID firms offered solutions to this challenge through the use of in-house specialists that are skilled in general design. However, in doing so, the firms acknowledged that they face additional challenges such as properly utilizing the employee's skills while also keeping them from becoming overwhelmed.

The disparity between the firms' discussion of challenges was most evident in the *Process* challenges. The ID firms acknowledge significantly more P*rocess* challenges than Case 1. Case 1 only identified two *Process* challenges: improper communication between stakeholders and their design process limiting the time available for building performance. On the other hand, the ID firms identified 11 P*rocess* challenges. These challenges reflect the firms' use of technology in the design processes. The ID firms use BIM to assist in their workflows and

overcome challenges with communication. However, using BIM creates additional challenges that they must overcome.

Finally, all three firms acknowledged the significance of the *External* challenges. The most populated theme with 15 challenges, this theme relates to outside factors, such as client expectations, project budget and schedule, and exterior influences. The firms feel as though these challenges are difficult to manage. All three firms held this perspective as the ID firms broke from their normal pattern of acknowledging the challenge in conjunction with a practiced solution. All three firms acknowledged that these challenges were outside of their full control, with the ID firms acknowledging they could only manage the impact of the challenge, not eliminate it.

Discussion

Intentionally incorporating building performance into a design adds another layer of complexity into an already complex process, as shown in the findings of this study. As the firms discussed their methods and challenges for incorporating building performance, it was apparent that they cared about its inclusion. However, all three firms acknowledged that, at times, the challenges prevented them from extensively including building performance in their designs. This impediment was most noticeable in the discussions with Case 1, which uses a traditional design workflow.

The challenges discussed by the three participating firms ranged in severity and were addressed differently by the cases. The ID cases typically discussed the challenges as more minor than those in Case 1 and as manageable issues that need to be acknowledged and addressed individually. The ID firms discussed the challenges from a perspective of caution with practiced solutions. On the other hand, Case 1, the traditional process firm, identified fewer

challenges but discussed them as debilitating, limiting their further consideration of building performance in their projects. According to Case 1, their perspective stemmed from challenges with employee knowledge and the project budget, resulting in a situation they perceived as hard to overcome. The experience of this research is that challenges associated with *Infrastructure* and *External* themes were the most significant barriers to the further consideration of building performance within the firms.

The *Infrastructure* challenges are seen to be related to employee knowledge and the ability to conduct building performance tasks. The tools and processes required to assess building performance can be cumbersome and overwhelming if employees do not have the appropriate knowledge (Denzer & Hedges, 2011; Fernandez-Antolin et al., 2020; Hedge, 2000; Paryudi, 2015), as acknowledged by all three Cases. Brause (Brause, 2017)notes that small firms do not always have the resources available to hire skilled or knowledgeable employees, a condition shared by all the cases. Each case expressed that they frequently need design generalists as small firms, given that their employees may perform various duties. Requiring this flexibility in employee skill reduces the firm's ability to utilize a specialist in a distinct role. Case 1 and Case 2 particularly noted this condition, having a similar size and organizational structure. For Case 1, however, these conditions are especially debilitating as they do not have anyone with significant experience in building performance evaluations. According to Case 1, when coupled with the project budget, not having this experience in-house is a holistic obstacle to considering building performance.

This perspective contrasted with the two ID cases, which took intentional steps to include employees with specialized knowledge. As discussed by the ID firms, employees with focus contribute to their ability to address building performance during design and reduce their reliance

on consultants. While all cases acknowledged challenges surrounding employee knowledge and project budget, as noted above, the ID cases actively sought solutions that they felt support the incorporation of building performance. The ID cases consider the use of in-house specialists crucial to overcoming challenges with employee knowledge and allowing the firms to extend their building performance abilities in-house. However, supporting these employees required the firms to invest time and money into individual professional development. Case 3 simply hired a specialist. Focusing on low- to zero-energy buildings aided this decision, but the firm was required to make an upfront investment in hiring them. On the other hand, Case 2 fostered the in-house specialist through an investment in their training. This development process was not as quick and required patience to foster the individuals. These examples demonstrate that overcoming these challenges is not fast or straightforward. As noted by each of the cases, the *Infrastructure* challenges presented critical obstacles to a firms' ability to incorporate building performance.

The *External* challenges were also difficult for the firms to overcome. All three cases stated that the project budget could restrict their consideration of building performance by limiting their ability to hire consultants or incorporate performance measures into the design. For Case 1, the traditional process firm, the external project budget challenge limited their ability to overcome the *Infrastructure* challenges through consultants. However, all three cases acknowledged *External* challenges in various ways, dealing with schedule, budget, and focus. The difficulties with these challenges stem from the inability of all three firms to control various outside factors. In the other two primary themes of *Infrastructure* and Process, the ID firms typically discussed the challenges as manageable or possible to overcome. With the *External* challenges, however, even the ID cases found these challenges as more restrictive. Unlike the

obstacles with *Infrastructure* and *Process*, the firms did not typically discuss any particular solution, aside from the use of project objectives by the ID firms. These methods could only help manage the challenges; the firms all acknowledged that the difficulties with external influences and the client's commitment were difficult to overcome. For the firms in this study, the *External* challenges were constantly present and could become very restrictive when coupled with challenges from other themes.

Of the three primary themes, *Process* challenges were the least discussed by Case 1. In the experience of this research, the differences in the firms' discussion of these challenges stems from differences in their use of software and overall recognition of the importance of building performance in their processes. Case 1 felt limited by the *Infrastructure* and *External* challenges and did not pursue the incorporation of building performance beyond their limited evaluations. The firm also limited its use of technology (BIM) for 3D modeling. However, Case 2 and Case 3 embraced building performance and relied heavily on BIM to aid in their workflows. This technology was noted to both help the ID firms and cause challenges within their workflows. For this reason, it is important to note that while BIM is frequently discussed with ID (Aksamija, 2016; Deutsch, 2011; Elvin, 2007; Fischer et al., 2017), they are not requirements of each other. ID can function without BIM as the workflow is based on early and frequent collaboration. However, in recent years BIM has been introduced as a method to help facilitate communication and aid in building performance evaluation. In incorporating BIM into their workflows, the ID firms introduced solutions as well as additional problems. While the firms demonstrated methods of overcoming these additional challenges, BIM is not without its faults. The conditions surrounding the *Process* challenges demonstrate that there was a cost-benefit within the ID firms related to the modification of their workflows and the introduction of technology.

Because contexts and projects vary, differences in the firms' workflows likely influence how or what challenges the firms experience at any given time. However, the findings of this study suggest that the workflows and the challenges may well be related. Throughout the study, the ID firms discussed their challenges in conjunction with solutions based in their workflows. However, Case 1 frequently cited their workflow as a reason for restricting their abilities to consider building performance. Aksamija (2012) and Turrin et al. (2011) provide light on this perspective, explaining that traditional design workflows are nonsequential and iterative, reducing the ability of firms to accommodate the processes and consultants required to assess building performance. Case 1 mirrors this issue, expressing that they are frequently too occupied with general design duties, especially during the early phases, to incorporate building performance further. The firm generates many iterations during the early stages, making it feel like they are pulled between building performance and evaluating all possible design strategies. Case 1 shares that this process commonly strains the employee focus and limits the time available for building performance. On the other hand, the two ID firms purposefully consider building performance as early as PD, prioritizing the consideration in their workflows. The ID firms feel that in-house specialists, workflow changes, and communication strategies aid the internal assessment and management of building performance, which are all steps identified by Aksamija (2012), Olanipekun et al. (2018), and Elvin (2007). The difference in the firms' perspectives towards their workflows was evident in their discussion of the challenges. While Case 1 discussed the workflow as restrictive, the ID cases used their workflows to support their ability to overcome the difficulties.

The role that building type may play in identifying challenges cannot be overlooked. While overlaps between building types do occur, focusing on a particular program can help

minimize the breadth of knowledge required when considering building performance (Fischer et al., 2017; Hedge, 2000; Mostavi et al., 2018; Zuo & Zhao, 2014). Case 2 and Case 3 focus on a specific building type; Case 2 primarily designs restaurants, while Case 3 focuses on high-performance K-12 schools. Both firms acknowledge that their size still requires them to employ generalists, but they have hired individuals with more specialized knowledge pertaining to their focus building type. Case 1, however, designs a variety of building types, exposing them to a range of performance considerations not consistent between projects. Unlike Case 2 and Case 3, Case 1 must adjust expectations and performance scopes between projects, modifying considerations for each design. Case 1 explained that considering an extensive range of performance considerations makes it difficult to generate and sustain internal knowledge around building performance. These findings support further exploration into the role of a project's focus in building performance challenges.

Study Limitations

This study identified 33 general challenges across the three participating firms. These findings are subjectively based on the researcher's perspectives and experiences in the field, the interviewees' perspectives, and the properties of the cases. As a constructivist, exploratory study, objectivity and generalizability of the findings are not possible, nor are they the goal. Exploring the challenges of small firms in incorporating performance is essential. This study was able to gain a deep insight into practice that is difficult to achieve through other methods. However, these challenges are not universal across all firms nor limited only to small firms. Some factors may lead to commonalities between firms, such as workflows; however, as firms differ by size, project types, and internal structure, firms may experience the challenges differently or not at all.

It is, therefore, essential to continue considering how challenges with building performance may present themselves across architectural firms of different sizes, workflows, and project types.

This study was also limited by conditions surrounding COVID-19. Interviews were required to be conducted remotely, and all three firms had experienced hardships with operations and employment due to the COVID-19 conditions. Two of the three firms were still operating remotely when the interviews occurred, and one firm had only recently returned to the office. These conditions had placed undue stress on the employees and limited their availability.

Conclusion

The significant presence of small architecture firms across the United States makes it essential to understand their specific challenges in addressing building performance and how their workflows may influence those challenges. The challenges identified by this research are not guaranteed to be universal, and the methods used by the firms to address the challenges may not result in similar outcomes. It may be possible for large firms to experience these challenges as well. Recognition of these challenges, their conditions, and how they are discussed help to pinpoint areas where additional research can be conducted and possible pitfalls within the design community, ultimately helping to improve incorporating building performance within the design process.

This study confirmed concepts discussed in existing literature surrounding building performance challenges. The study also identified and highlighted three primary themes for small firms' challenges: *Infrastructure, Process*, and *External*. This research demonstrated that even though the three small participating firms ranged in size, firms with similar workflows and design focus may face similar challenges with building performance. The findings also suggest that there might be certain key obstacles that make firms feel as though they are less able to

incorporate building performance smoothly and uniformly into their designs. Future studies should expand upon this exploration to evaluate how the identified themes and challenges compare across firms of all sizes and explore solutions to address these challenges.

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CHAPTER 4: Article 3

Building Performance in Practice: Engaging Integrated Design Workflows in Small Architectural Firms

Abstract

Society is increasingly becoming more focused on a building's environmental, social, and economic impact, resulting in growing pressure on architects to actively include building performance in their designs. Small firms, making up the majority of architectural practices nationally, face greater challenges as compared to large firms when facing these increased responsibilities due to fewer financial resources and flexibility. Integrated design (ID) workflows have been identified as a tool to aid small firms in overcoming these challenges and to allow for increased focus on building performance in their design processes. This research conducted case studies of three small architectural firms in North Carolina to explore how ID workflows help these firms to overcome challenges with building performance considerations. The study selected the firms based on their design workflows and consideration of building performance. One firm using a traditional design workflow and two firms using integrated design workflows were investigated using replication logic. Individuals within the firms were interviewed to gain insight into their design process. Results suggest eight themes that aid the ID workflow firms in actively and meaningfully supporting building performance in their designs.

Introduction

More emphasis is placed on a building's environmental, social, and economic conditions (Bilan, 2013; Göçer et al., 2015) than in past decades. Often referenced as sustainable, high-performance, or green, these buildings provide efficient, healthy, and productive environments (Zuo & Zhao, 2014). However, these buildings require project stakeholders (e.g., design team, contractor, owner, users, etc.) to manage and consolidate a large amount of information across the building's design and construction, leading to an associated increase in project complexity (Hien et al., 2000; Olanipekun et al., 2018). This increase in complexity results in architects experiencing more significant challenges in their design process than in past decades as the Architecture, Construction, and Engineering (AEC) community seeks to embrace this more performance-conscious approach (Rezaee et al., 2019). As a result of this shift and increasing complexity in design, a documented gap has been recognized between buildings' expected and operational performance (Augenbroe & Park, 2005; Maslesa et al., 2018; Tweed & Zapata-Lancaster, 2018).

In an attempt to address this gap, multiple strategies for improving building performance evaluation during design have been studied, ranging from predictive parametric optimization of design features (Gadelhak, 2013; Gonzalez & Fiorito, 2015; Zani et al., 2017a) to stakeholder collaboration (Ku, 2009; Mesa et al., 2016; Rohracher & Ornetzeder, 2002). However, these studies do not always consider the complexity of the design process or conditions that impact a firm's ability to adopt the strategies. The challenge of adopting these strategies and the usefulness of the strategies in different practices will vary based on firm size, composition, resources, and project focus. Of the strategies discussed within literature, integrated design (ID) workflows have the most significant ability to address building performance during design and

provide practical applicability. ID's focus on collaboration, process, and technology (Hjelseth, 2017) supports design teams with the flexibility to 1) address various performance considerations simultaneously (Liu et al., 2017); 2) integrate advancements in technology and design (Aksamija, 2016); and 3) compensate for operational factors that may influence the workflow's feasibility, such as firm size, financial status, team compositions, project cost, timelines, and employee knowledge (Brause, 2017). These helpful characteristics of ID can assist all firms in addressing building performance during design, but they can especially aid small firms facing significant challenges due to operational factors.

Small firms, under 50 employees, make up the majority of architectural practices in the United States. Still, they typically have fewer resources than larger firms, such as less flexibility with expenses, and may face difficulties uniquely related to their firm size (Brause, 2017). Compared with large firms, small firms have less personnel and financial resources available to target building performance. Small firms must often choose between considering building performance or meeting other fundamental design requirements such as structure, program, and life safety. Therefore, it is essential to understand how small firms can successfully use helpful components of design workflows to better address building performance in their design process. To contribute to this understanding, this research conducted case studies of three small architecture firms in North Carolina to explore how the firms use components of ID workflows to consider building performance and how these components relate to the social and technical subsystems of ID.

Background

ID is subject to individual interpretations and therefore has "a multiplicity of definitions, none of which is entirely right or entirely wrong" (AIA-AGCA, 2011, p. 1). This study's

perspective is that ID is a sociotechnical workflow that relies on collaboration, data integration, and the uninterrupted transfer of information between project stakeholders to allow for a better understanding of the project, building system analysis, and construction of the building (Hjelseth, 2017; Lu et al., 2017; Negendahl, 2015; Pauwels et al., 2011; Succar, 2009). ID workflows differ from traditional design workflows on many levels (Table 4.1), providing ID workflows the ability to incorporate building performance better than the traditional design processes (Aksamija, 2016). ID workflows are composed of two interdependent subsystems, technical and social, that influence each other (Bostrom et al., 2009). The components of ID workflows, such as software applications, design process, people and their roles, and communication methods, can be grouped into these subsystems based on their properties. The technical subsystem consists of technology-related components and workflow processes, while the social subsystem relates to people and communication, collaboration, and coordination (Bostrom et al., 2009; Tropmann-Frick & Thalheim, 2015). ID workflows leverage the interaction between these two subsystems to assist in concurrent design development and increased collaboration between stakeholders (Shi & Yang, 2013). Through the interaction of the two subsystems, ID workflows help streamline the design process, allowing for in-depth analysis, resulting in robust designs and improved building performance (Aksamija, 2012; Shi & Yang, 2013; Turrin et al., 2011).

Table 4.1
Differences Between Traditional and Integrated Workflows (Modified from Aksamija (2016), p. 180).

	TRADITIONAL DESIGN	INTEGRATED DESIGN WORKFLOW
TEAMS	Fragmented and hierarchical	Integrated, involving all stakeholders from the start
PROCESS	Linear and segregated	Concurrent and collaborative
CONTRACTS	Based on unilateral efforts, allocate and transfer risk	Multilateral, promote collaboration and risk-sharing
COMMUNICATION AND TECHNOLOGY	Analog, 2D	Digital, virtual, BIM
RISK	Individually managed, transferred	Collectively managed and shared
COMPENSATION AND REWARDS	Individual, first-cost based	Value-based, tied to project services

However, all ID workflows are not the same, especially when used to better building performance. ID is flexible and can adjust to varying operating conditions within firms and project requirements (Elvin, 2007; Fischer et al., 2017). This flexibility means that the components making up individual workflows and their application can differ. Therefore, it is important to understand that some of the components found within practiced workflows may not be necessary for ID to function. For example, BIM and performance simulation software are frequently discussed as a means to measure performance outcomes within ID workflows (Aksamija, 2012; Deutsch, 2011), but not all ID workflows use these components. Technical components such as these assist ID and improve certain workflow features, such as collaboration or communication between stakeholders; however, their elimination does not prevent ID from functioning or achieving similar results through different methods. Literature often obscures this condition as the literature frequently discusses BIM in conjunction with ID (Aksamija, 2016; Deutsch, 2011; Elvin, 2007; Fischer et al., 2017), but the use of BIM is not a requirement of ID. With this understanding, workflow components commonly associated with ID and building performance assessment can be broken down into ID's technical and social subsystems to understand how the components support ID and building performance assessment.

ID's technical subsystem includes processes and technology. Processes are a collection of activities or events that depend on context and influencing parameters for their execution (Tropmann-Frick & Thalheim, 2015), while technology, for this discussion, relates solely to software. When discussing building performance assessment, the technical subsystem is more frequently associated with software within the literature (e.g., Gadelhak (2013), Zani et al. (2017b), Gonzalez and Fiorito (2015), S. Lin and Gerber (2014), Glassman (Glassman, 2015), Samuelson et al. (2016), Shi and Yang (2013)). This relationship between digital technology and performance is due to simulation software's ability to quickly and accurately assess building performance metrics (Attia et al., 2013; Clarke & Hensen, 2015), like energy use and daylighting. The structure of ID allows for performance simulation to be conducted early and often through its emphasis on information transfer and early engagement of stakeholders (Aksamija, 2016a). However, designs are conceptual in the early design phases, lacking the detail required to conduct precise performance simulation (Liu et al., 2017). Furthermore, the software cannot routinely address qualitative concerns, like the occupant's perception of the space or thermal comfort (Peters & Peters, 2018). Accurate and meaningful consideration of qualitative concerns requires the engagement of the social subsystem to gather information through stakeholder interaction.

The social subsystem of ID includes the knowledge of individuals and interactions between stakeholders. ID emphasizes direct and routine interactions between project stakeholders that are not generally found in traditional workflows (Elvin, 2007). Elvin (2007) explains that traditional workflows frequently rely on 'over the wall' communication which separates individuals, passes information with limited context, and leaves stakeholders with little information about other stakeholder needs or progress. ID emphasis on collaboration and regular

exchange is counter to this communication pattern and can reduce project timelines, improve user satisfaction, and improve occupant-oriented performance considerations (Andreadis et al., 2015; Fischer et al., 2017; Liu et al., 2017; Rohracher & Ornetzeder, 2002). Collaboration is essential to ID as it supports the technical subsystem functions by increasing stakeholder understanding of project goals and conditions and allowing stakeholders to manage complex design processes (Cross & Clayburn Cross, 1995), overcome resource deficiencies (Brause, 2017), and expand knowledge through communication with other stakeholders (Du et al., 2012). Through collaboration, stakeholders can easily share information to reduce errors by making more informed and accurate design decisions when evaluating building performance.

Even though the two subsystems and their components can be discussed separately, the two subsystems of ID are not isolated. Components within the two subsystems rely on each other, which is an important consideration when exploring ID workflows. Processes within the technical subsystem may rely on collaboration to obtain insight or information regarding the design, and collaboration may rely on technology to support stakeholder understanding and communication. BIM is one example of this interdependent nature.

Software, such as BIM, supports ID's emphasis on collaboration even though it resides within the technical subsystem. BIM and other 3D modeling software assist stakeholders in understanding the design and communication during performance evaluation at all stages (Aksamija, 2016; Deutsch, 2011; Kraatz et al., 2014; Ku, 2009). However, BIM is unique in this consideration. It can serve as both a software (technology) and a process within the technical subsystem as it promotes collaboration within the design workflow (Habibi, 2017; Sacks et al., 2018; Sharma & Fisher, 2013; Succar, 2009). BIM's dual nature is dependent on its use within the workflows (Deutsch, 2011; Succar et al., 2012). In its most simple use, BIM is a software

used for object-based modeling; however, when used to its full capacity, BIM becomes an overlapping process that allows for the production, communication, and analysis of building models through a synchronous interchange of information between stakeholders (Deutsch, 2011; Sacks et al., 2018; Succar, 2009). When used at its full capacity, BIM supports the seamless analysis of a design's performance (Aksamija, 2016; Ghaffarianhoseini et al., 2017), makes stakeholder communication more efficient (Oh et al., 2015), and removes unnecessary waste in the process (Liu et al., 2017). However, like many components of ID workflows, BIM is not a requirement for ID to function properly.

Even with its benefits, ID is not without difficulties. Collaboration in any design workflow involves diverse professionals with varying perspectives; conflicts may occur around group interaction, reasoning, and the sharing of tacit knowledge (Negendahl, 2015; Oh et al., 2015; Stompff et al., 2016). Failure to properly coordinate stakeholders and clarify their perspectives can also lead to misunderstandings and uncoordinated actions (Valkenburg & Dorst, 1998), possibly causing project inefficiencies such as unnecessary iterations, reduced quality, and slow progress (Cross & Clayburn Cross, 1995; Du et al., 2012; Negendahl, 2015). Furthermore, the limited or improper use of software can result in reduced benefits or inappropriate output that hinders design decisions. While many components found within ID workflows can be important for the consideration of building performance, they are not necessarily a requirement of ID workflows to function, such as performance simulation software or BIM. These components can be found outside of ID and inherently bring certain requirements to any workflow. It is important to understand how these components support ID, the challenges or requirements for their implementation, their benefits, and their interaction with other components. Failure to understand all aspects of ID workflows, their components, and how they

vary based on firm structure, project type, and building performance considerations can still result in ID workflows being ineffective or hindered in their application. This study, therefore, used the understanding of ID and its subsystems to explore small firms and their use of ID workflow components to address building performance.

Methods

This paper outlines an exploratory case study that evaluated the workflows within three small architecture firms that intentionally consider building performance in their design processes to identify workflow components used to overcome building performance challenges. This research was part of a more extensive study that focused on how a firm's design workflow influences the challenges encountered around building performance considerations and their solutions. This research chose a case study methodology based on the emphasis of real-life context (Yin, 2018). This paper utilized a literature synthesis to understand the primary concepts of integrated design workflows and cross-referenced these established design concepts with case study interviews, group discussions, and firm process diagrams that highlight workflow properties, components, and contexts. Complex processes, such as design workflows, can result in multiple challenges which may not always be recognized or consistent across situations (Rekola et al., 2010). This research sought to explore design workflows that the firms used across their entire project portfolio.

Selecting Cases

Small firms were purposefully chosen for this research as they comprise a majority of the firms in the US and have fewer resources available than larger firms and may face difficulties uniquely related to their size. The American Institute of Architects (AIA) defines small firms as those that employ fewer than 50 people (American Institute of Architects, 2018). Due to limited

resources, these small firms cannot freely invest in infrastructure, access technology, and hire specialized expertise to produce complex projects (Brause, 2017). The large number of small architecture firms makes it essential to understand how different workflows may help address these organizational challenges while also addressing building performance.

A survey solicited 765 North Carolina architectural firms through email for their views on building performance. Fourteen of the survey participants indicated a willingness to participate in a more in-depth case study. Eight firms were eliminated based on firm size, with either over 49 employees or being single practitioners. The research further evaluated the six remaining firms based on public information and short interviews about the firm's design workflows, availability, and their consideration of building performance as a design criteria. This research purposefully sought firms that use ID workflows with a firm that uses traditional design workflow for comparison. To be considered for the investigation, the firms needed to be available, willing to discuss their workflow processes, and demonstrate that they actively considered building performance. Three firms were selected for the study, two using ID workflows and one using a traditional workflow.

Interviews and Focus Groups

Interviews and focus groups with each firm collected insightful, context-based data regarding organizational structure and workflows. Suggested by each firm's principals, individuals with in-depth knowledge of the firm's workflow were approached for participation. The researcher interviewed eleven people across the three firms: four in Case 1, three in Case 2, and four in Case 3. Eight were registered architects, seven of those were acting as design principals/project architects, and one acting as an energy manager. The three others were design professionals: two junior designers and one interior director. Due to COVID-19, the interviews

were conducted remotely using conferencing software and lasted approximately 60 minutes. The interviews were semi-structured and performed using a casual tone with open-ended questions. Participants were encouraged to discuss their roles within their firm's workflows, critical elements within the projects and workflows, challenges experienced with building performance, and how they felt their workflows addressed these challenges.

After the individual interviews were completed and analyzed, the study held a focus group with each of the three firms to review initial findings. These focus groups were open to individual interviewees and any additional firm employees who wanted to discuss the firm's workflows and building performance. Participants were presented with the collective results from their firm and encouraged to provide further insight or corrections to the initial synthesis. After focus groups were completed, all data from the three firms were analyzed within the individual cases, after which findings were compared across the cases.

Analysis

Data from the interviews and focus groups were analysed to better understand how the ID firms addressed building performance. In this analysis, this study considered the properties of the cases, their discussion of challenges, their workflows, and the properties of ID workflows identified through the literature.

Case Profiles

Case 1's office uses a matrix structure (Hayes, 2014), employing six full-time and two part-time designers (Table 4.2). Using a traditional workflow, the firm works on various commercial and residential projects, not specializing in any building type. The firm considers a limited range of building performance considerations, such as social programming and operational workflows, while emphasizing aesthetics. At a client's request, the firm does

consider other performance considerations such as life-cycle analysis and energy-efficiency or sustainable systems. Limited evaluation of these performance considerations is conducted internally, with outside consultants engaged for more in-depth or complicated assessments. Performance evaluations can begin as early as schematic design when requested. Still, this evaluation typically occurs in later design stages, such as during late-stage design development or construction documents.

Case 2 specializes in restaurants, employing 11 designers and one support staff (Table 4.2), using an ID workflow and an office matrix structure. Performance considerations for their designs focus on use and operational concerns, such as occupant processes, wayfinding, and maintenance. The firm employs designers with specialty areas but also relies on consultants as needed. Building performance is considered both internally and externally through all phases. The firm involves multiple stakeholders to address building performance as early as pre-design. The firm establishes performance objectives and emphasizes performance consideration throughout the design to aid in their focus on building performance.

Case 3 employs 20 full-time employees, including support staff, and is structured into two studios (Table 4.2). The firm concentrates on the design of institutional buildings, specializing in K-12 schools. Energy and maintenance efficiency are their primary performance considerations, designing low- to zero-energy buildings, with some secondary safety and operational efficiency considerations. Case 3 employs an energy specialist in-house but works heavily with outside consultants to verify energy performance considerations. Building performance is considered early in the design process, including discussions with consultants, the formation of design objectives, and early-stage analysis during pre-design.

Table 4.2
Case Characteristics.

	Case 1	Case 2	Case 3
Workflow	Traditional	Integrated	Integrated
# of Employees (Total)	8	12	20
Structure	Matrix	Matrix	Studio
Project Types	Commercial and Residential	Resturant	Institutional (K-12)
Primary Performance Considerations	Social Programming and Operational Workflows	Operational Workflows, Wayfinding, Maintenance	Energy and Maintenance
Specialist	None	Multiple	Energy and K-12 Workflows/Safey
Consultants	Yes (As needed)	Yes (As needed)	Yes
Stage of Performance Consideration	Design Development or Later	Pre-Design	Pre-Design

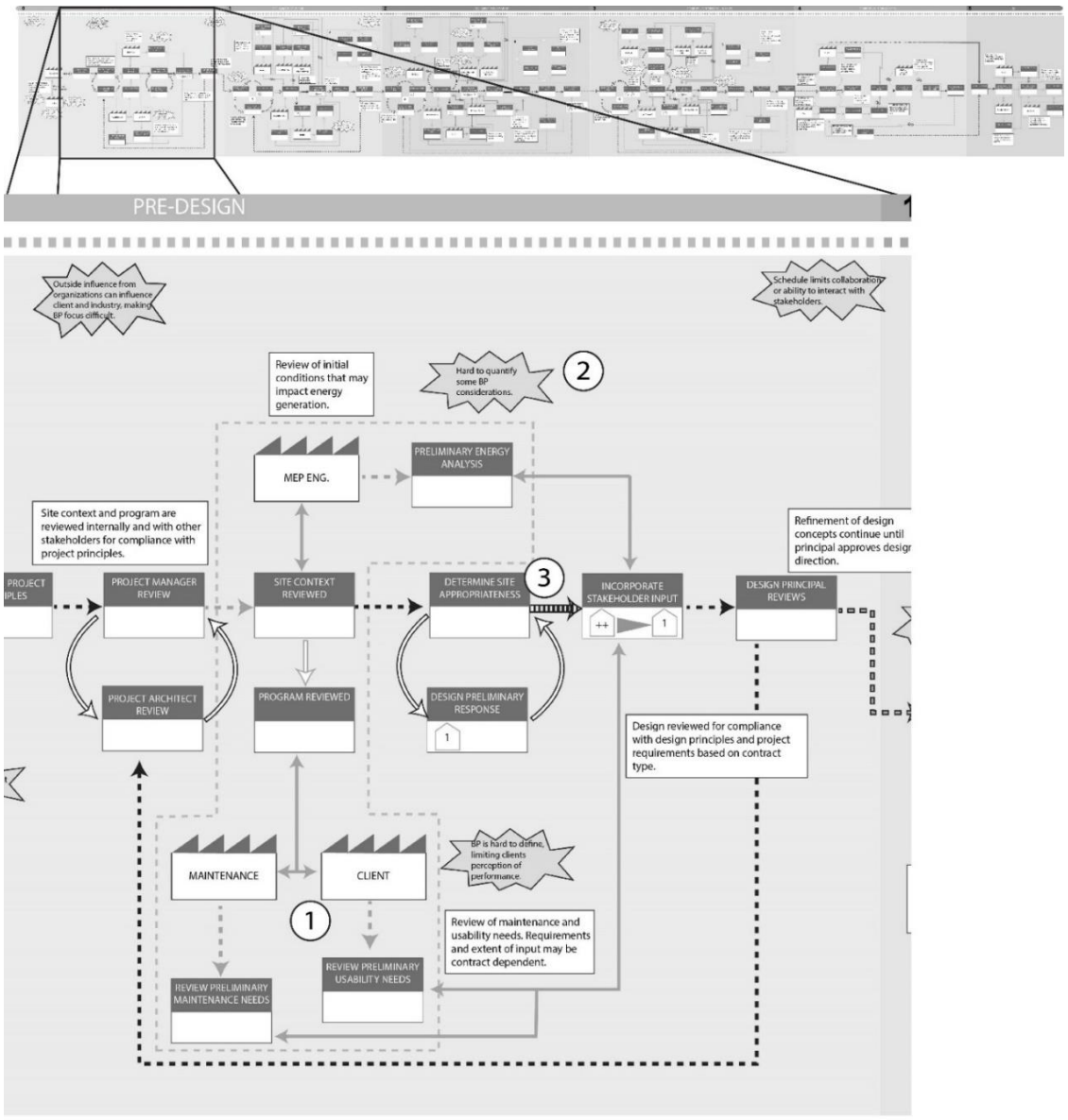
Evaluating Workflows

After completing the interviews for each case, the data was evaluated and coded for elements such as tasks, roles, performance considerations, communication methods, challenges with building performance, and critical stakeholders. The codes used in this process were drawn from the literature and allowed to emerge from the interviews. After coding each interview, the data was consolidated and compared across individual interviews within the same firm for confirmation. This data was used to construct process maps and diagrams for each firm that reflected critical components of their workflows. The researcher provided synthesis documents for each firm to review, and these synthesis documents were used during the focus groups to help communicate the emergent understanding of each firm's workflows. After each focus group, the researcher evaluated the discussions and updated documents accordingly.

Process maps (Figure 4.1) were created using value stream mapping notation and using the AIA design phases: pre-design (PD), schematic design (SD), design development (DD), construction documents (CD), construction administration (CA), and operations/use. Value stream mapping is a method to see and understand the actions and flow of information within a

process through visual representation (Rother & Shook, 1999). This method of exploring and representing the workflows better highlighted stakeholder interactions, sequencing of events, challenges, and critical tasks relating to building performance.

Figure 4.1
Enlarged Portion of Case 3's Process Map.



Map illustrates a value stream mapping notation. Interaction between stakeholders (1), challenges associated with building performance (2), and design task (3) are noted for each phase of design.

The study used the building performance challenges identified as part of the larger research project to help evaluate the workflows across cases and address the research questions. The researcher compared process maps, interviews, and diagrams between firms, noting how each firm addressed these challenges as well as how workflows differed between the cases. Critical processes, interactions, and challenges were documented and compared. The research noted 1) similarities and differences in how and when the firms addressed building performance; 2) how the firms interacted with stakeholders around building performance; 3) the technology used in the evaluation of building performance; 4) how firms discussed challenges with building performance; and 5) the roles of individuals within each firm.

Similarities between the ID firms were noted and compared to the traditional workflow firm to identify common themes in how the ID firms addressed building performance in their workflows and overcome identified challenges. When similarities were identified, this research looked for commonality in the roles of the individuals involved, the design stage in which the process occurred, and perception of benefits. These similarities were then compared to Case 1, the traditional workflow case, to identify the absence or lesser use of the workflow component within Case 1's workflow, the discussion of the component as unachievable or unusable in their current workflow, and the impact of the challenge associated with the workflow component on Case 1's perception of building performance assessment. For example, it was noted that the ID firms used in-house specialist to address building performance while the traditional workflow firm felt as though they were unable hire specialist. The ID firms used these specialists to allow for easy access to knowledge and internal assessment of building performance. However, in the absence of in-house specialist, Case 1 felt restricted in their ability to internally address building

performance and linked this to their ability to only conduct simplified performance assessments. The exploration of this pattern resulted in the emergence of the *Foster Champions* theme.

Eight themes that were perceived as necessary to the ID firms' consideration of building performance emerged from this process: *Foster Champions, Establish Objectives, Involvement of Stakeholders, Internally Value Building Performance, Direct Communication, Integrate BIM, Involve General Contractor, and Late-Stage Involvement* (Table 4.3). These eight themes were further evaluated for their relationship to the technical or social subsystems of ID, with particular care taken as to their relationship to *process* or *technology* within the technical subsystem. Themes identified as *process* related to workflows or timing of an event, themes identified with *technology* related solely to software use, and themes identified with the social subsystem related to collaboration or employee knowledge.

Table 4.3
Eight Themes and Their Relationship to the Technical and Social Subsystems.

	Technical Subsystem		*Social Subsystem*
	Process	Technology	People
Foster Champions			○
Establish Objectives	○		
Involvement of Stakeholders			○
Internally Value Building Performance	○		
Direct Communciation			○
Integrate BIM	○	○	○
Involve General Contractor			○
Late Stage Involvement	○		

Findings

The eight themes aligned almost evenly between the two subsystems with the social subsystem slightly more dominant as it is associated with five of the eight themes. The *Integrate BIM* theme was associated with process, technology and the social subsystem in the ID firms since it functions as both a type of software and a process that supports collaboration within their

workflows (Habibi, 2017; Sharma & Fisher, 2013). Further analysis of the *Integrate BIM* theme within the ID firms also revealed that it was related to the social subsystem as the ID firms' use of BIM impacted their collaborative abilities and employee knowledge requirements.

Technical Subsystem: Differences Between ID and Traditional Workflows

In the technical subsystem, this research identified three themes perceived as necessary to the ID process: *Establish Objectives*, *Internally Value Building Performance*, and *Late-Stage Involvement.* The three themes relate to the ID firms' methods for clearly understanding design objectives, their intentional emphasis on building performance, and performance assessment during commissioning and post-occupancy. The implementation of these themes differs between the ID firms and the traditional workflow firm; ID firms identified these components as helpful in overcoming challenges associated with late-stage design changes and misunderstandings between stakeholders.

The *Internally Value Building Performance* theme emerged as a result of the value that the ID firms placed on building performance. This research identified critical differences in how the ID firms, Cases 2 and 3, discussed the value of building performance to architecture design, compared to Case 1. Case 1 stated that they base many of their design decisions on the project's aesthetics. Performance considerations are incorporated when possible but are not as valued as the aesthetics of the building. For Case 1, the client's objectives and personal opinions drive the consideration of performance rather than the architect. On the other hand, Cases 2 and 3 intentionally establish building performance as a core value, referencing it early and frequently and using it to provide structure for their designs. As Case 3 states, "you need to have a plan, every building has a different plan, and we try to put the energy plan right up there with how many chairs do you need in the classroom; it's that important to us." Case 2 believes that without

valuing building performance and communicating its importance throughout the design process, "performance becomes an accident, rather than something very intentional. We always want it to be incredibly intentional." Cases 2 and 3, *Internally Value Building Performance,* making building performance the foundation for their designs and workflow structure decisions. Building performance remains a crucial consideration for these ID firms in all designs, even when the client does not stress it.

The *Establish Objectives* theme emerged from the process of Cases 2 and 3 establishing project objectives at the beginning of PD to help manage building performance expectations and project outcomes. Their establishing of objectives serves as an overarching narrative for the project, aiding in managing expectations and controlling design decisions. Early client discussions help to generate these objectives before the start of the design. The objectives include performance-related goals, such as metrics relating to energy use, building life expectancy, occupant workflow efficiency, and other design criteria such as material properties or aesthetics. Case 2 generates the objectives collaboratively with key team members within the firm, while Case 3's design principal generates the goals after meeting with the client. These objectives are shared with stakeholders to focus the ID design process by providing a road map of building performance objectives to inform design decisions.

Case 1 does not formalize an established list of objectives, permitting the detailed scope of work between parties to be interpreted or changed over the design process. Case 1 stated that their clients frequently change a project's focus, eliminating or reducing the opportunity for them to consider building performance. The lack of priority and late-stage changes can hinder the firm's considerations of building performance criteria or delete them from the project altogether. Case 1 often finds itself in "a constant struggle to kind of keep [the projects] on schedule as

much as possible." Experiencing delays related to lack of clarity of owner decisions make it difficult for Case 1 to manage decisions relating to building performance.

On the other hand, Cases 2 and 3 believe that establishing objectives helps their firms minimize project delays and negative impacts on building performance. For example, Case 2 uses agreed-upon goals to refocus a client on objective decisions and not personal preferences. The firm strives "to get everyone signed off on [the objectives] in the beginning so that when these hurdles come up down the road, we can hopefully point back and say, you know, [is that decision] the best method for achieving the objectives that we set forth in the beginning." In this manner, the firm states that the objectives focus the client on making quick and educated decisions that support building performance, reducing costly delays or reworks that may impact the time available for performance evaluations. The *Establish Objectives* theme illustrates the difference in how traditional and integrated design firms address project objectives to clarify and focus on building performance decisions.

The *Late-Stage Involvement* theme emerged from the two ID firms extending their involvement with a project, past construction completion, to help ensure the operational performance of their design. Case 1 traditionally ends its project involvement at the end of CD or CA, while Case 2 and Case 3 often work with the clients after CA. Case 3 continues its post-occupancy project involvement by helping with HVAC and renewable energy systems and training maintenance staff on system upkeep. Being on-site for these purposes allows the design team to observe unintentional outcomes like occupants using makeshift window coverings or modifying those present to prevent glare or heat gain. These observations contribute to information incorporated into future projects as the project team members "learn from [their] mistakes." Following a similar approach, Case 2, when involved with a prototype restaurant

project, evaluates operations through discussions with the client and users after occupancy. The firm uses this feedback to adjust subsequent designs and modify similar elements through different projects, like wall assemblies. The ID firms feel that *Late-Stage Involvement* helps provide them with data gathered during occupancy and real-world contexts that improve performance decisions in future designs.

Social Subsystem: Differences Between ID and Traditional Workflows

Four emergent themes under the Social Subsystem spoke to employee ability, interaction with other stakeholders, and methods of communication: *Foster Champions, Involvement of Stakeholders, Direct Communication,* and *Involve General Contractor*. These themes relate to the firms' internal assessment of building performance, their methods and frequency of communication, the stages at which they interact with stakeholders, and how they involve the general contractor. The ID firms identified the strategies within these themes as helping to increase their ability to consider building performance and reduce design errors.

The *Fostering Champions* theme emerged from how the ID cases discussed their ability to evaluate building performance internally, particularly in comparison to Case 1. Case 1, unlike the two ID cases, relies on young professionals who can perform various tasks because Case 1 believes their firm needs generalists to support multiple design activities instead of having easy access to specialists. Case 1 recognizes that hiring generalists limits its ability to support and emphasize building performance, thus resulting in a limited number of building performance considerations in its design process. Instead, Case 1 relies heavily on consultants, such as energy or sustainability specialists, to conduct in-depth performance evaluations, which is often restricted by the project budget.

Cases 2 and 3 value access to specialized in-house knowledge, reducing their need for outside consultants. Case 2, still acknowledging the need for generalists, relies on champions in their ID workflows, while Case 3 explicitly hires a specialist to support energy efficiency in-house. For Case 2, their champions are designers with an extended understanding of a particular subject, such as building assemblies, material life-cycles, occupant workflows, and accessibility standards. The role of champion allows Case 2 team members to act as specialists when needed but still retain the role of a general designer. Acknowledging that "certain people have certain passions," Case 2 encourages their employees to become knowledgeable in a specific subject, fostering their internal champions. Similarly, Case 3 employs some designers with specialized knowledge in school workflows and safety, which act in a similar capacity as Case 2's champions. Case 3 also employs a dedicated energy manager to support the firm's focus on energy efficiency. The energy manager does not perform design duties and instead engages with outside energy consultants, supports energy analysis, and assists the design team during all project phases to ensure a proper design and installation of energy-critical systems. Through the use of champions or in-house specialists, the ID firms feel that they gain greater insight into building performance while still retaining the general capabilities of the designers. For the ID firms, *Fostering Champions* provides the flexibility of generalized support often needed in their small firm while enabling increased in-house knowledge on specific subjects.

The *Involvement of Stakeholders* theme emerged from the timing and frequency of stakeholder engagement. Cases 2 and 3 involve a greater breadth of stakeholders during the early design phases than Case 1 and frequently and intentionally communicate with these stakeholders throughout the design process. During PD, the ID firms initiate communication with core team members to introduce the project, establish expectations, and perform initial performance

evaluations. The ID firms also involve users or facility staff early to gain additional insight into the needs of the building's occupants. Case 2 describes their early meetings as very important so that they "… know all the pieces that will be involved". As the project progresses, Cases 2 and 3 communicate as frequently as daily with other stakeholders, depending on their role and project needs. Cases 2 and 3 also involve the client weekly and schedule communications with non-actively involved stakeholders monthly to update them on project progress. As Case 3 explains, this involvement of the stakeholders is deliberate to help prevent mistakes or oversight within the projects, "[the firm has] a weekly meeting with [design team members] at a set time every single week, to go through [the project] to make sure we coordinate issues. And part of that, even if we don't have specific issues to tweak, it is just keeping [the project] in the front of their mind".

Comparatively, Case 1 brings on outside stakeholders, such as structural and mechanical engineers, later in the design process than Case 2 and 3 and may not significantly engage these stakeholders until the DD or CD phases. Case 1 also communicates with the consultants less frequently than the ID firms and often only at milestones in the design timeline. Case 1 shared that this late and infrequent involvement of the stakeholders sometimes impedes the firm's ability to adjust to project conditions and address problems that might affect building performance. In these late stages, consultants may identify conditions counter to building performance, such as structural issues that impact HVAC or the building envelope. Since these conditions occur in the late design stages, Case 1 feels that they have to choose between delaying the project or sacrificing building performance. Frequently, due to budget concerns or conditions relating to the client's schedule, performance is sacrificed. As discussed, this pattern is counter to the conditions in the ID firms. The ID firms feel that involving stakeholders early and frequently increases the stakeholders' understanding of the project, helps reduce oversights, and allows

them to adjust to conditions that might impact building performance. For the ID firms, the *Involvement of Stakeholders* theme is important to their coordination of the project, the early identification of issues, and ensuring that building performance is maintained throughout the design process.

The *Direct Communication* theme emerged from the ID firms' direct and frequent communications. Cases 2 and 3 communicate with core stakeholders like mechanical engineers, energy consultants, clients, maintenance personnel, and key users through in-person meetings or phone conversations. A centrally shared BIM file, located in the cloud and directly edited by stakeholders, supports this communication. Case 1, however, communicates with its stakeholders indirectly through email or the passing of a static CAD or BIM file. Case 1 explained that this communication style, coupled with previously mentioned factors like the late involvement of critical stakeholders, result in under addressing building performance considerations. For example, a structural engineer did not design one of their projects with continuous insulation in mind due to a miscommunication. This issue:

> …had more to do with maybe taking too long in the SD/DD phases when we should have been looking at some things that weren't seen until CD, like the wall sections …so we had to rush to cram a lot of CD stuff in all at once. And then that the communication breakdown [resulted in] the structural engineer [not] really knowing what we were doing until weeks before the deadline for CD.

Cases 2 and 3 believe that direct communication helps prevent performance and coordination issues by eliminating opportunities where communication can fail. For the ID firms, *Direct Communication* is a critical component of their entire design process. It provides support for other functions and the overall understanding of the project.

Lastly, the *Involve the General Contractor* theme emerged from the ID firms' early involvement of the general contractor (GC) during the design process to specifically consider

building performance. All three firms frequently incorporate a GC in their workflows. However, only Cases 2 and 3 ask the GC to consider building performance. Cases 2 and 3 begin engagement with the GC during SD to understand the construction cost. As ID firms move into DD, they repeatedly engage the GC to evaluate quality-control concerns and building performance-friendly solutions. Case 1, on the other hand, uses the GC to assess their design solely from a budget standpoint, engaging the GC at the end of the DD phase to provide a construction estimate. Based on this estimate, the firm edits its design late in DD or during early CD. The firm shares that this late adjustment can result in value engineering that adversely impacts building performance. However, the ID firms feel that their early and repeated communication with the GC for items beyond budgetary concerns aids in avoiding such late-stage decisions that may adversely impact building performance.

BIM: Differences Between ID and Traditional Workflows

Of the eight themes, this research identified *Integrate BIM* as unique because it straddles the technical and social subsystems. Both Cases 2 and 3 use BIM fully as a process and software, and they emphasized its importance within their workflows. Case 1, using the traditional workflow, has a low BIM capability, only performing object-based modeling within the software to produce construction documents (Succar et al., 2012). The firm does not synchronize design files with other team members or require them to use BIM, preventing Case 1 from using BIM as a process. Comparatively, Cases 2 and 3 use BIM to its total capacity, achieving network-based integration and using it to improve collaboration between stakeholders (Succar et al., 2012). Case 2 states that BIM is so important to the firm that "a prerequisite for working with [us] is that everything is done in [a BIM capable program] and we require [consultants] to have [BIM server] licenses, and everything is coordinated, as close to real-time as possible." These

conditions require specialized knowledge of BIM as a 3D modeling software and process within the ID firms and stakeholders. The ID firms believe that integrating BIM in this manner is important, even if it results in some additional challenges that must be overcome, such as finding employees and consultants with the ability to use BIM to this level. The firms feel that the use of BIM as both a software and process results in more robust communication with other stakeholders, enabling better decisions and earlier identification of conflicts. This study recognizes that ID does not require BIM, and the use of BIM does not necessarily mean the firm is using an ID workflow. However, the ID firms specifically identify BIM as a crucial software and process within their design workflows, with its ability to quickly and seamlessly coordinate between stakeholders. As a result of this shared perspective, the *Integrate BIM* theme emerged.

Discussion

ID is a complex system that relies on the interaction between technical and social subsystems to support the design process. By acknowledging these subsystems and recognizing their interdependence, the complexity of ID workflows can be simplified into individual components that help overcome challenges with considering building performance during design. The ID cases shared experiences allowing for this research to identify components within their workflows that they felt aided them in overcoming challenges around incorporating building performance. The two firms practicing ID strongly felt that using these procedures permitted more freedom in their workflows while helping to mediate challenges associated with building performance. On the other hand, Case 1 frequently discussed challenges around building performance as debilitating and only offered limited theorized solutions. Recognizing the differences between the studied workflows in partnership with the eight overarching themes

helped this research establish a basic understanding of how some small firms intentionally use ID to address building performance.

The findings of this study differ from some patterns found in literature. The small firms in this study relied more heavily on *people* and *process* strategies, limiting their reliance on *technology*. Existing literature frequently discusses the use of technology for evaluating building performance (e.g., Peters and Peters (2018), Nguyen et al. (2014), Gunay et al. (2019), and Hollberg and Ruth (Hollberg & Ruth, 2016)). However, the use of technology for the explicit purpose of evaluating building performance is felt to be less significant for participating small firms using ID. For these specific firms, the identified themes that best support building performance emerged almost equally between the technical and social subsystems, the themes depended mainly on the processes and people, not technology. Besides using BIM comprehensively, the firms in this study using ID did not directly use any software to assess building performance. This absence of technology and heavy reliance on social strategies is counter to trends within research that indicate favoring technology in evaluating building performance, focusing on quantitative performance considerations and performance simulation (de Wilde, 2019; Nguyen et al., 2014).

The de-emphasis of technology within the participating firms does not indicate that firms lack the need for performance simulation or do not evaluate performance quantitatively. Instead, these firms concentrate on other solutions based on their dedication to building performance, in-house abilities, and risk assessment. Case 2 acknowledges that performance simulation is expensive and requires specialized knowledge. When simulation, such as energy or daylighting analysis, is needed, they use outside consultants. Conversely, Case 3 is actively engaged in energy analysis and has an energy specialist on staff. However, the firm still collaborates with

another stakeholder to conduct detailed simulations. Case 3 recognizes that simulation software is susceptible to improper inputs, resulting in calculation errors, a trend supported through literature (Deutsch, 2011; Kim & Park, 2011). Acknowledging the error risk associated with in-house simulation, Case 3 feels that they benefit most from using a specialized consultant to perform the simulations instead of their staff. Based on their firms' focus on building performance, employee knowledge and availability, and the risk associated with performing complicated simulations in-house, participating ID firms believe there are more significant benefits in using outside consultants to evaluate performance considerations using technology.

The ID cases perceived more benefit in the use of people and process strategies. The firms support building performance through (1) recognizing its importance, (2) early-stage clarification of project goals, (3) direct communication, (4) stakeholder involvement, and (5) late-stage verification of outcomes. Literature supports these strategies (e.g., Fischer et al. (2017), Preiser and Vischer (Preiser & Vischer, 2005), Brause (2017), Leaman and Bordass (2001), Elvin (2007)) as key components in ID. The data shows that these strategies are readily used by the participating ID firms, delineating them from the traditional process case.

As Fischer et al. (Fischer et al., 2017) discuss, the eight identified themes help move the participating ID firms from exclusively focusing on "lowest first cost," as the traditional process firm does, to a focus on larger performance results. While Case 1 acknowledges the importance of a quality product, Case 1 has difficulty balancing aesthetics with incorporating building performance in design. For example, the firm felt compelled to generate upwards of 30 design iterations during early design phases even when they acknowledged that it limited their ability to evaluate building performance. On the other hand, the ID firms recognize the importance of building performance beyond what the client requests. Holding to these internal values, the ID

firms sought solutions to the challenges they experienced and shared examples of practiced solutions within their workflows. The ID firms' overall recognition of the importance of building performance supports their design processes and investment in people. The ID firms believe that intentionally managing people and processes help to improve their understanding of building performance, increase project efficiency, and reduce misunderstandings, all benefits noted in literature around ID (Aksamija, 2016; Deutsch, 2011; Elvin, 2007; Fischer et al., 2017).

These exploratory findings show that it is crucial to recognize the balance between the technical and social subsystems within ID firm processes, as ID firms rely equally on both subsystems to support building performance. This dependence on both subsystems within the ID cases reflects Hughes et al. (Hughes et al., 2017) discussion on ID, noting that ID can only be fully understood when the technical and social subsystems are treated as interdependent systems. Viewing the ID workflows of the participating firms through this sociotechnical perspective helped to generate a real-world understanding of the processes that support and result in an increase in building performance considerations in small firms. This holistic view helped this study explore the interactions between systems, revealing both support and potential conflicts. Investigating ID through this lens supports the better exploration of a workflow, its components, and its relationship to building performance evaluation.

It is also important to recognize that the eight themes revealed in this study are not exclusive to ID. While ID and its concepts can support the implementation of such strategies, they are not dependent on it. Each strategy, or a combination of strategies, can be used without necessarily adhering to the ID process, and the ID process can happen without these listed strategies. The implementation of ID and the components that comprise the workflow can vary between all firms. Additionally, the strategies associated with these themes also have challenges.

One example is the theme *Integrate BIM*. As a process or software, BIM is not necessary for ID, even as literature frequently discusses the two in conjunction (Aksamija, 2016; Barlish & Sullivan, 2012; Deutsch, 2011; Fischer et al., 2017; Sacks et al., 2018). The participating ID firms felt that BIM in all capacities is beneficial and supports a deeper and more fluid consideration of building performance, a perspective also supported through literature (Aksamija, 2012; Deutsch, 2011; Habibi, 2017). However, the ID firms did share challenges in using BIM. Case 2 felt that coordinating varying software versions and ensuring that the stakeholders could use BIM was complex. Case 3 also felt that BIM was overly complicated in the early design stages, forcing them to modify their workflows to allow for the increased detail associated with the program. However, for these firms, the benefits of BIM were perceived as more significant than the disadvantage. The data supports the popular notion that ID is fluid and will vary in its implementation. At its core, ID is a process that involves stakeholders to a greater extent than the traditional design workflows, requiring proper communication and structure as support. As such, the themes emerging from this study may not be exclusive to ID.

Limitations

The emergent themes are subjectively based on the researcher's perspective and experience in the research area, as well as the interviewees' perspectives. The findings are rooted in a small, purposeful sample, restricting the objectivity and generalizability of the study. This study purposefully chose small firms due to their significant presence in the AIA community and the acknowledgment that they face conditions unique to their size. However, while literature often discusses small firms as homogeneous, this is not always the case. The themes identified by this research are not necessarily universal and may not be exclusive to small firms. Firms of all sizes can implement ID, and the needs of the firms will vary based on their project focus,

delivery type, and organizational structure. As a result, all small firms are not guaranteed to experience the same challenges identified within this research or find benefit from the eight emergent themes; the themes may not apply to all situations. Since many of these themes support the discussions of ID in literature, it may also be possible for large firms to utilize and benefit from these themes. However, larger firms were not the focus of this study.

This study was also limited by conditions surrounding COVID-19. Interviews were required to be conducted remotely, and all three firms had experienced hardships with operations and employment due to the COVID-19 conditions. Two of the three firms were still operating remotely when the interviews occurred, and one firm had only recently returned to the office. These conditions had placed undue stress on the employees and limited their availability.

Despite these conditions, this research provides in-depth, context-based insight into small practice that is very hard to achieve. While the identified themes may not be applicable to all firms, it is essential to further explore how they can support small firms and their relationship to the subsystems of ID. This increased understanding can continue to grow discussions around building performance and its support in design workflows.

Conclusion

This research highlights areas for small firms that may emerge as trends within the industry as it seeks to increase building performance. Findings show that the participating small firms do not embrace technology as frequently as social components within the ID workflows. This absence of technology is counter to popular assumptions based on the significant research into technology, particularly software, that supports building performance evaluation. While software technology can assess building performance accurately and quickly, these small firms do not have the resources to readily adopt these technologies into their processes. Instead, the

firms rely on other stakeholders to incorporate the technology, resulting in an imbalance in the use of technology within the studied firms. The firms have instead chosen to establish new processes that strengthen their understanding of building performance. The participating ID firms view their processes as a means to incorporate building performance into their workflows better while reducing their risk. As these firms modify their processes to evaluate and define building performance, they rely on their people to support their performance objectives through interaction with stakeholders. The recognition of this relationship between process and people within the firms suggests future research around the technical and social subsystem of ID within small firms is important.

This study's exploration of the ID workflows of small firms provides some understanding of their specific needs and their ability to incorporate building performance into their projects. Future studies should explore the identified eight themes in the context of both small and large firms and continue to document their use in practice. Expanding this research by identifying benefits and challenges around these themes can allow small firms to modify their workflows to better incorporate building performance in their design processes. Understanding these relationships will help build scaffolding to support future workflows that can engage building performance as standard.

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Chapter 5: Conclusion

The purpose of this research was to enhance the understanding of building performance in architectural practice. Small firms make up the majority of practices in the United States. Therefore, it is crucial to understand their specific challenges when addressing an industry shift towards higher performance. The inability of any firm to properly consider building performance during design can contribute to a gap between the expected and operational performance of the project (Augenbroe & Park, 2005; Maslesa et al., 2018; Tweed & Zapata-Lancaster, 2018). However, without a unified understanding of building performance, this research first established a sense of the term in practice. With this understanding, this dissertation continued its exploration into small firms to create a shared understanding of common workflows and challenges. Through these explorations, this study demonstrates how firms define building performance, the challenges that small firms may face when addressing building performance, and how the firms in this study modified their design workflows to overcome these noted challenges.

The first article of this dissertation, found in Chapter 2, evaluated design practitioners' definitions of building performance in practice to contribute to the industry's understanding of building performance evaluation and expectation. This research 1) supported the organization of building performance perspectives into focus areas of building-centered, occupant-centered, and blended while adding a fourth integrated approach, 2) confirmed the lack of clarity surrounding building performance definitions, and 3) suggested possible variations between what may be expressed by practitioners in their definition and what they operationally consider elements of building performance. The emergence of a fourth perspective indicates that there may be additional approaches to building performance not yet recognized by literature. The

discrepancies between the building performance definitions and selected design elements also suggest that practitioners should be more aware of communicating building performance goals and strategies.

The second article, found in Chapter 3, explored three small firms' challenges when considering building performance. The study confirmed concepts found in existing literature surrounding building performance challenges. The study also identified and highlighted three primary categories for small firms' challenges: *Infrastructure, Process,* and *External*. Data showed that even though the three small participating firms ranged in size, the firms with similar workflows and design focus areas recognized similar challenges. The study also discovered that there might be certain key obstacles that make firms feel as though they are less able to incorporate building performance smoothly and uniformly into their designs.

In Chapter 4, the third article explored the workflows of the three small firms and identified commonalities within ID workflows that helped the firms overcome challenges with building performance in design. The article highlights areas that, when studied more in-depth, may emerge as trends within the industry. Findings indicate that the small firms did not embrace technology as frequently as other components found within ID workflows, contrary to the focus of literature. This absence of technology was counter to what may be assumed based on the significant research into technology, particularly software, that supports building performance evaluation. The firms have instead chosen to establish new *processes* that strengthen their perspective and understanding of building performance. As the ID firms modify their *processes* to evaluate and define building performance, they rely on the *people* to provide the tools to execute their performance objectives through their interaction with stakeholders.

Research Implications

This research contributes to an important knowledge base by providing a framework for discussing building performance definitions, insight into the challenges firms face, and reviewing methods firms use to overcome the difficulties. The purpose of this dissertation was to explore how architectural firms perceive building performance and how small firms can meaningfully incorporate building performance into the design process. This work supports the discussions surrounding building performance perspectives, challenges, and workflows while highlighting practice trends. Future studies can use the framework established here to discuss building performance further, working towards a unified definition. Future research can also expand upon the knowledge generated to evaluate further how the identified challenges and their themes compare across firms of all sizes; solutions to address these challenges should continue to be explored. Finally, recognizing the relationship within the firms' use of the technical and social subsystems in the ID workflow supports future research into firms' methods to address building performance during design.

Design Implications

This dissertation was based in practice to bridge the gap between academic discussions and practical application. This study's exploration into building performance definitions and ID workflows provides some understanding of the perception of building performance in practice as well as the particular needs of small firms. Understanding the variation between building performance definitions can drive practitioners to identify areas where miscommunications may happen within their workflows. Designers can then modify their design processes to communicate building performance goals and strategies more thoroughly, potentially reducing miscommunication. Using the framework of *Infrastructure, Process,* and *External*, identified in

the second article, firms can explore their workflow to identify critical obstacles that make it less smooth and uniform to incorporate building performance into their designs. The identified eight themes can be explored within the ID workflows to understand how modifying workflows may help overcome challenges. By understanding the differences in building performance interpretation, the challenges that a firm faces, and the methods identified within this study, firms can create a scaffolding to support future workflows that engage building performance.

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