SHIFTING LOGICS OF CONSTRUCTABILITY AND DESIGN: A STUDY OF EMERGING AEC INTEGRATED PRACTICES FOR ENERGY PERFORMANCE

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Abstract: In this paper, we analyze the practices of translation and synthesis for energy performance in building design. We use grounded theory method to collect and analyze qualitative interview and observation data to examine the difficulties of knowledge sharing and problem solving between builders and architectural and engineering designers. Extending the theory of disciplinary specific “institutional logics,” we show that designers and builders integrate their work in three ways: 1) by addressing gaps in their own knowledge that require information from a knowledge domain different from their own, 2) by synthesizing design and construction issues holistically, and 3) through integrating construction and design work practices. These insights offer evidence of shifts in the institutional logics that structure the construction and design disciplines.

1 INTRODUCTION

In the traditional model of architecture, engineering, and construction (AEC) practice, architects and engineers prepare documents for builders to construct buildings in a temporally linear relationship. The “hand-off” between disciplines at the time of bidding establishes professional boundaries with significant cultural differences between the disciplines of design and construction, and transferring knowledge across these disciplinary boundaries is difficult and resistant to easy technological fixes (Neff et al., 2010). Like all industries, AEC industries follow what sociologists have called institutional logics, “the socially constructed, historical pattern of material practices, assumptions, values, beliefs, and rules” which act as “a set of assumptions and values, usually implicit, about how to interpret organizational reality, what constitutes appropriate behaviour, and how to succeed” (Thornton, 2004:69-70). For AEC industries, this means the different cultures of architecture, engineering, and construction are shaped in large part by a set of social logics that are larger than any one company or individual. For example, people on projects have conflicting obligations to company, scope or profession, and to the building project (Dossick & Neff, 2010). These emerge out of different sets of institutional logics at work within the AEC industries.

In this paper we examine work practices of translation and synthesis of energy performance design to examine the difficulties of knowledge sharing and problem solving in integrated AEC teams. We use the notion of institutional logics to help explain the challenges that designers and builders have in collaborating and communicating across the gaps in their professional knowledge. Our findings suggest that designers and builders integrate their work in three ways: 1) knowledge gaps that require accessing builder or designer domain knowledge, 2) holistic thinking that requires synthesizing design and builder
knowledge, and 3) integrated construction and design work practices that occur within and between designer and builder firms. Together, our insights offer evidence of incremental shifts in the institutional logics that structure the construction and design disciplines as they develop new work practices.

The worldview and decision-making processes of designers and builders are shaped by institutional logics such as *professionalism* and *market* that overlap, intersect, and sometimes contradict one another. Builders and designers often employ or evoke certain logics depending upon the type of activity taking place and the social, cultural, and organizational context of the actors engaged in these tasks. For example, builders are often expected to evoke the logics of market and cost; they analyze building elements, turn design documents into cost estimates, view their work processes through quantification and linearity, and consider themselves business people engaged in the capitalist market. Comparatively, designers are often expected to evoke logics of professionalism; they synthesize across building elements, turn ideas into form and documentation, view their work processes through qualification and ambiguity, and consider themselves as professionals mandated to serve the public.

Closer collaboration between builders, engineers, and architects has benefits both for project efficiency and for improving the quality of building outcomes (Kent & Becerik-Gerber, 2010), particularly for high performance buildings (Reed, 2009). However, builders and designers have very different ways of talking and thinking about their work which often frustrates good collaboration (Carrillo & Chinowsky, 2006). One of the substantive challenges to contemporary integrated AEC work practices is the translation and interpretation necessary for interdisciplinary teams to communicate and share domain knowledge. To realize the benefits of integrated work practices, collaborative teams need to bridge across their disciplinary differences in two parallel directions; builders need to engage the logic of design and designers need to engage the logic of constructability.

### 2 LITERATURE REVIEW

Institutional logics include such things as the demands of the market, needs of a company or practice, and commitment to a profession. These conflicting obligations can be described using the theory of *institutional logics* (Thornton, 2004; Thornton et al., 2013). On all building projects, "conflicting obligations push people away from as well as towards good collaboration" (Dossick & Neff, 2010:463). These obligations include legal, professional, and ethical responsibilities for the scope of work and sense of professionalism to a specific role on the project (e.g., structural engineer, lead architect), a “tentative temporary alliance to the project,” and “a more permanent obligation to their company” (Dossick & Neff, 2010:466). AEC team members must routinely bridge the knowledge boundaries among the different design and building disciplines. In these settings, different institutional logics can be used as justifications for actions or cause conflicts among different members of the team. For example, new skills can offer value, efficiencies, and increased authority but change the way that people collaborate and rely on institutional logics to guide or justify their behavior (Smets et al., 2012). Because communication practices are central to how institutional logics are constructed and changed (Green et al., 2008), how people talk within integrated teams—whether through coordinating, translating, sense making or theorizing—has the power to make and reshape these institutional logics (Ocasio et al., 2015).

Integrated AEC projects ask collaborating team members to manage gaps in their own knowledge with information gained from other disciplines. This process requires that connections be continually made and unmade between an individual’s domain of expertise and the expertise of other team members. Integrated project practices encourage AEC professionals to acknowledge, interpret, accommodate, and adopt the approaches of people from other AEC disciplines. Theories of “conflicting obligations” and “institutional logics” seem to suggest that these connections are where we might expect to see incremental shifts of institutional logics and predict why some integrated projects are more successful than others.

To test this we conducted a qualitative study to see how people on integrated AEC projects talk about different institutional logics on these projects to suggest ways these shifts are occurring with the rise of integrated practice.
3 METHODS

3.1 Data

The data used in this study derived from three interviews (one engineer and two contractors) and twenty-one hours of field observations of participant meetings and work sessions between energy consultants, architects, engineers, and builders across four months and 12,978 words in written field notes. Our interview questions focused on collaboration, communication, translation, and synthesis of energy modeling data, including respondents' collaboration strategies and best practices for increasing team integration. Our observation data consist of conversations about new construction projects, renovation projects, and the submission of design-build proposals where energy performance was a key issue. This select dataset emerged from a larger dataset focused on issues of knowledge and translation and synthesis for energy performance in building design (10 interviews across the U.S., 19 projects, 195 hours of field observations, 141,000 words of written field notes). From a grounded theory analysis of this large data set, we found patterns in our smaller set of interview and observation data that opened up questions of shifting logics of constructability and design.

3.2 Qualitative Open Coding of Themes

Our data analysis relies on coding the team interactions that took place in our observations and in the detailed stories told during interviews. These interactions and stories reflect a stated desire for disciplinary knowledge that research participants imagined other professionals have or that they wish that they could access in the moment. We used a modified grounded-theory approach for open coding (Strauss & Corbin, 1990) for themes where designers and builders engaged in logics of “professionalism” and “market” evidenced in these interactions. For example, we coded for moments when someone expressed the desire for builder knowledge, raised questions about the constructability of a design, or acknowledged or engaged in discussion of specific construction methods or constructability costs.

We clustered themes found in our qualitative data around three key concepts showing the shifting institutional logics brought about by integrated practice: 1) designers using ideas about constructability, 2) builders using ideas from design, and 3) the evolution of builders’ thinking.

4 FINDINGS

4.1 Designers engaging the logic of construction

Our data suggests that designers engage in the logic of construction when they encounter gaps in their knowledge connecting design to construction, where they see holistic thinking that synthesizes design and construction issues, and where domain knowledge acts to link design and construction. In some cases, designers may request or suggest receiving a contractor or builder’s input to come to a shared resolution on a constructability issue. In other cases, designers appear to engage in the logic of construction during interactions where they demonstrate their ability to cross into the knowledge domain of construction and incorporate concerns of constructability into their design.

4.1.1 Gaps in knowledge connecting design to construction

At times, designers realized that input from a builder would assist in problem definition and would provide details that could help make decisions among design options. These moments frequently occurred when the contractor was not yet working with the design team, but the team anticipated gaps in their knowledge or expertise that the contractor could fill.

While working on design development, designers will direct their staff to detail elements to engage constructability issues. For example, an engineer working on a design-build contract for a renovation project pointed out to a new employee how to use a ductulator to transcribe duct measurements onto floor plans in Revit. The engineer advised the staff member that he shouldn’t use “weird dimensions. Six inches is the limit, anything else confuses contractors.” He then advised the staff member to “try to think
like a sheet metal guy. Ask, is it easy to make?” (Field Note 140808). The engineer told his staff member to anticipate questions, expectations, and concerns in the design work.

In one example, a design team was having a conversation about an ongoing HVAC assessment in an older building. This assessment would culminate in a final report advising what would need to be replaced or fixed on each floor along with cost estimates. They realized that changing out the dampers would be difficult. During this conversation, one of the participants realized that the entire design solution rested on a consideration of the repair and installation process by the contractor—an activity not fully understood by the design team—and suggested getting feedback from a contractor:

*Engineering Consultant:* I have a feeling this is a lot more challenging to change out than the [dampers] downstairs.

*Client Representative:* I agree. They're not easy to get to.

*Consultant:* How do we handle the pricing on this?... We need a mechanical contractor's input. It would be a real Rube Goldberg to fix these and to get these from the inside. We need feedback. It's not clear what the approach is. (Field Note 141107)

Here designers tried to imagine conditions of constructability in the absence of builder input. Designers frequently arrived at these boundaries of domain knowledge as a consequence of their design efforts. However, these moments were also highly unpredictable, and questions of constructability appear to arise out of many different types of design conversations. In these design process contexts where constructability questions impact the definition of the design problem and its potential solution, having immediate access to construction domain knowledge—as in the case of integrated project practice—can be of significant importance in terms of knowledge exchange.

### 4.1.2 Holistic thinking synthesizing design and construction

Designers and builders are trained to think differently about problem solution processes. Where the knowledge management strategies of builders could be characterized by processes of *quantification*, designers have more general knowledge management strategies that could be characterized by *qualification*. The design methodology of qualification can be seen where designers focus on performance metrics and outcomes that could be answered by any number of potential solutions. Sometimes, conflicts between quantification and qualification can lead to poor building performance where building elements that the design team intended to work together are compromised by builder choices and value engineering.

One architectural group and its energy consultants coined “bundles” to get around this problem by joining building elements as a performance package. The bundle protected building elements designed to work together from being cut individually from the final design. This was an effort by the design team to protect interconnected system choices for operational efficiencies and energy savings. This strategy required builder logics to move from building element quantification to building system qualification. This represents an institutional logic shift by builders from quantification to qualification. Another way of defining this shift is a move to synthesize design and construction issues through more holistic thinking.

Designers are not always convinced that this type of holistic team thinking is possible or available from builders. The design team was split on the idea that they needed the contractor to provide an initial review and cost for the first proposed bundle on a large hospital project. The architect suggested that the design team present the energy bundle options to the client as well as an economic analysis of each bundle. The energy modeler responded that it could be difficult to do an economic analysis for the client before having internal discussions with other team members, including the contractor. The architect suggested that the energy modeler has the knowledge expertise to “put numbers on things.” The energy modeler disagreed: “I would want to discuss that in a larger meeting with a contractor. I would want them to at least look the numbers over and put their blessing on it or note what they don’t like about them” (Field Note 141219). The fear the architect had was that the contractor would be unable to think qualitatively and would start picking apart the constituent elements in the proposed design bundle using cost as a weapon. In turn, the energy modeler was accepting the challenge of holistic team thinking and anticipating that the
contractor’s cost estimates could act as a “blessing” for the entire bundle of strategies, a potential resolution.

Later in the same meeting, one of the energy modeler consultants noted that certain systems that they might use to increase building performance also cost less, and that there is a need to “rethink how comfort systems work and move things from one [budget] pot, like mechanical, to another. So [the owner] would not pay more to save more, but pay less to save more” (Field Note 141219). An engineer challenged this assertion, suggesting that a contractor’s domain of expertise and normative institutional logics are stuck in categories of budgeting that make it difficult to design holistically: “The challenging aspect is getting the right baseline and accurate pricing. The contractor won’t be billing to go beyond the cost per square foot.”

4.1.3 Domain knowledge linking design and construction

Our data showing benefits to builders in domain knowledge links between design and construction are slightly more robust than the benefits seen to designers. For builders, construction knowledge is now included in design activities early in integrated projects and thus builders participate more closely with design work. Compared to this general phenomenon for builders, we saw fewer new design-construction knowledge links for designers. One mechanical engineer explained how valuable it was for his own design knowledge base to take a job in a collaborative environment focused on construction: “My career didn’t take off... or, I didn’t understand things until I became a design-build engineer. [Until I] became a . . . I actually started working as a mechanical contractor.” (Field Note 141114). We have found some initial evidence that this kind of cross-disciplinary hiring—designers hired by contractors or builders hired by designers—is associated with firms invested in integrated project delivery.

4.2 Builders engaging the logic of design

We have found in our initial data that builders engage in the logic of design in ways that are parallel to how designers engage in the logic of construction. For builders, this occurs when they encounter gaps in their knowledge connecting construction to design, where they are asked to think holistically and synthetically between construction and design issues, and where domain knowledge between construction and design link the two disciplines.

4.2.1 Gaps in knowledge connecting construction to design

We saw examples in the data where builders often want to know more about the design performance requirements of building elements than is typically provided in traditional design-bid-build. This includes new problems like the lack of design intent in specification documentation which reduces the efficiency of constructability reviews. One builder noted:

What we often get is specs... where it’s “we’re using this light fixture.” And we don’t know if that light fixture is chosen because the owner likes the way it looks, or if it provides the right lumen output, if... you know, it’s the only one that’s available, or they think that’s available in the time that we have in order to procure. So, we get a product package that’s kind of ambiguous. And, so, if we’re going to go back to the team with seven recommendations, we’re going to pull some information from that product spec that may or may not be right. (Field Note 141111)

Here we see that traditional methods of contract document production through specifications by the design team are creating a knowledge gap for the construction team when faced with collaborative activities like iterative cost comparisons. This suggests a need for greater knowledge exchange between builders and the design team.

Another long-time construction director called these design intentions created by the design team the “whys” of a building project. He noted how understanding design intentions would allow his construction team to be “self-adjusting.” He said,
We don't know the “whys” enough . . . “Whys” are great. “Whys” would be helpful for everybody. And a lot of people don’t even know what the “whys” are. But that would be good too, right? To know where you are so you could self-adjust . . .” (Field Note 141107)

Later, he pointed out in concrete terms how design performance knowledge helps builders be leaders on integrated project teams with architects. He said that knowing “why the data is the way it is”—what the design intentions were—“that’s really super important if you’re going to lead . . . be a leader amongst that [integrated] team.” (Field Note 141107)

Builders see the usefulness of design intentions as a tool for bettering their own efforts, and that they have a desire for greater knowledge exchange with designers on integrated teams. Given that design intentions are often qualifications rather than quantifications, it suggests that builders may need to integrate more ambiguous information into their problem solution processes than traditional construction work practices may have required.

### 4.2.2 Holistic thinking synthesizing construction and design

Through the evolution of construction delivery processes, new modes of working have created challenges to the traditional domain boundaries between design and construction. As building information modeling (BIM) has become more widespread among construction teams as a tool for management, we find some instances where BIM has encouraged builders to find ways to have input early in schematic design to reduce subsequent problems during construction.

One large construction firm realized that it was very inefficient to wait for MEP details to be complete before they could do clash detection, and that a better proposition was to reserve spatial volumes through the building for systems development, a strategy they called “internal space planning.” This idea leveraged the 3D capacities of the BIM model produced by the design team but was actually modeled by the construction team. This effort on the part of builders is wholly dependent on their understanding of the full arc of the design effort and their capacity to integrate design activities within construction domain knowledge.

A particularly powerful aspect of holistic thinking on the part of builders is seen in design activities that are dependent upon cost information. This is an important contribution in situations where designers are less focused on cost. An engineer who had moved to a position as a mechanical systems specialist for a large contractor had a particularly clear viewpoint: “Engineers inherently are going to design the best system possible. Period. Without regards to cost. That’s just the way that they’re wired” (Field Note 141114).

Another builder explained the improved benefits between “rules of thumb” costs by designers and actual cost estimates and scheduling information from their collaborating builders:

> We find the engineer of record is kind of using more rules of thumb, like “oh that’s, we’ve typically see that would be ten percent more, and the lead time is generally six weeks.” Well, if we change that one little piece, a condenser, it can go to ten weeks. . . . You know, so when we’re involved in a more integrated process we can. . . we can talk a little bit more intelligently about that. (Field Note 141111)

By being able to offer highly accurate costs, this builder sees the benefits of integrating design and construction knowledge and a holistic engagement with the problem solving processes of both.

This same builder told us how his firm was able to offer more value to design processes by leveraging design information through a constructability lens. When asked to provide add-alternatives to a project, he explained how his firm puts this deliverable into the language of qualifiers and performance metrics aligned with the project’s design intentions found in the project program, its sustainability goals, or its lifecycle assessments. This builder uses services like life-cycle and energy calculations and operations and maintenance information—typically considered to be the responsibility of the design team—to contribute value to these iterative project development activities.
4.2.3 Domain knowledge linking construction and design

In certain construction markets, the increasing demand for preconstruction services and integrated project design early in projects makes having construction staff with design capabilities a necessity. This is a function of how building projects are contracted and how collaboration is advanced in the particular market. One mechanical engineer working as this kind of design specialist for a large contractor said of his market: “Here, if you don’t have, like, thirty people on your staff designing, you’re not even going to be in business” (Field Note 141114). This suggests that the change toward integrated design and construction practice is being taken seriously within the field.

A sustainability director for a large contractor was blunt about how builders can integrate the domain knowledge between design and construction:

So the people you’re seeing doing integrated design well from the construction perspective are the people who saw the benefits of it before there was a title. And, so they’re the frontrunners. I think you’re going to see everybody... they’re going to try to follow... And they’re going to have to learn it. Or, they’re going to hire somebody who already knows it. (Field Note 141111)

In many ways, this shows us how builders who saw the market changes coming to AEC practice found ways to complement their construction skills with those of design—suggesting how they deal with the shifts of institutional logics. The implication is that they are able to contribute more fully and operate with more authority and value in contemporary integrated project environments. Looking more closely at these evolving institutional logics may illuminate how it is accomplished and what new work practices it entails.

4.3 Evolving institutional logic of builders

We have interviewed a number of AEC practitioners who have exhibited integrated practice logic that is emerging as characteristics of a new kind of builder: the *synthesizer*. This kind of builder sees the role of a builder as a synthesizer of building elements and systems, acting as a translator between the design issues of form/systems and constructability. Synthesizers advocate for building performance with cross-disciplinary domain knowledge and an interdisciplinary knowledge management style. Among our study participants, one builder in particular stands out as an exemplification of this logic. His responses to our interview offer some substantive issues that could be thought of as potential foundations for the evolving institutional logic of contemporary builders in integrated project practice. Our synthesizer-builder used this kind of holistic thinking to explain, in his experience, that co-location works because it is

... a back and forth conversation. That smooths the process out a ton, because we don't need a lot of specifications because everyone involved understands the design intent. And the design intent is developed collaboratively. The subcontractors said “Well, what about this? Does this meet your budget?” Eh, it doesn't quite meet our efficiency. What about this?” It's like, “well, yeah, it's close to your budget, but it doesn't meet your schedule” right?. . . It’s like, it’s almost a real-time conversation . . . that’s really developed early on. (Field Note 141111)

Our synthesizer-builder was encouraged by his leadership team to offer environmental design services more typically provided by design professionals such as sustainable design, storm water and habitat restoration. His firm saw this as a good business practice in their market: “[My firm] wanted my expertise to be on the table, whether that was related to schedule or cost or constructability or not...we want to get that information in front of the client” (Field Note 141111).

At some point, integrated design practices may push more construction firms to accommodate other holistic thinking that synthesizes construction and design domain knowledge. Ultimately, this evolution of the institutional logic of this particular construction firm recognized the strong value proposition in being a company with a proven integrated project track record and a demonstrated capability to realize sustainable building performance: “Of course we can meet the budget, of course we can meet the schedule, of course we can get this thing built for you. But, you know, the way in which we’re going to do that is slightly different; we’re going to participate in the conversation rather than do what you otherwise normally would...” (Field Note 141111).
All of these challenges to the existing institutional logics of construction as they move more toward design were wrapped up in our synthesizer-builder’s imagined future for integrated AEC teams:

If I could walk into a room in an integrated design project meeting and not know anybody, I shouldn’t be able to tell the difference between the contractor and the architect. . . . And, that is okay, or it needs to be okay in an integrated design process in order for that process to work smoothly. (Field Note 141111)

5 DISCUSSION AND CONCLUSION

There are parallels in how architects, engineers, and builders in integrated AEC projects attempt to incorporate their disciplinary realms and work toward problem solutions. This occurs when designers and builders encounter gaps in their knowledge that require different domain knowledge, synthesize design and construction issues holistically, and link construction and design work practices. We see incremental shifts of institutional logics when people connect their domain of expertise with that of other team members. This occurs when collaborative communication processes bridge different disciplinary expertise.

We saw this in case of the synthesizer-builder where cross-disciplinary knowledge allowed him to translate between design and constructability issues. The synthesizer-builder allowed shifts from construction to design logics whenever it seemed to be efficient, effective, or brought capabilities necessary to solve the problem at hand. He could engage in a productive and authoritative interdisciplinary knowledge management style that took advantage of the ability to synthesize qualitative and quantitative forms of domain knowledge. When our synthesizer-builder reported how his firm’s management encouraged him to offer design strategies to clients “whether that was related to schedule or cost or constructability or not,” we see a change to the firm’s construction logics by an inclusion of new domain knowledge and ambiguous design problem solving—a direct move toward an incorporation of some of the institutional logics of design.

Our study shows how these design and construction logics can impact builder and designer roles, knowledge management, and domain knowledge. Institutional logics shape the context of professional norms and values in which builders and designers act, and they guide how people perceive project problems and solutions through the lens of their disciplinary domains. However, integrated AEC work practices are creating new professional and social contexts where institutional logics can be challenged, shifted, and adapted. In these contexts, communication processes centered in collaboration are the means by which domain knowledge and expertise are shared. These changes might suggest that builders working in integrated AEC projects pay attention to and test the institutional logics of designers while at the same time become aware of the constructs pushing builders to adopt new institutional logics of design. Conversely, designers in integrated projects might be encouraged to engage in more of the institutional logics of construction through more rigorous attention to constructability and cost issues in the earliest phases of project design.

This study uses a small interview sample of builders and designers from the Pacific Northwest, a region where there is an increasing market in integrated design. To draw more generalizable conclusions, we will need to conduct more interviews with AEC professionals working in other parts of the U.S. and North America. This study also draws from observation data within firms that regularly use integrated design and construction project delivery. Future research could involve observations in firms that are less involved in integrated project delivery allowing for greater comparison between the institutional logic shifts of builders and designers. Still, there is much to be learned from studying leading-edge work practices in a rapidly changing industry. In larger scale studies, we expect to see evidence that evolving dimensions of AEC domain knowledge between builders and designers will be associated with attention to and the testing of institutional logics.
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