IDENTIFYING THE ROLE OF PROJECT INTEGRATION STRATEGIES IN THE ADOPTION OF SYSTEMIC INNOVATIONS

ABSTRACT

The construction industry structure resists the adoption of systemic innovations because they cross professional and trade specializations, break industry standards, and redefine how existing modules are produced or fit together. Prior research has identified that vertical and/or horizontal integration in the supply chain makes it far more likely that systemic innovations will be adopted. This paper identifies how nine *project integration strategies* – i.e., risk-sharing alliance contracts, colocated project teams – are employed within innovative project delivery methods such as Integrated Project Delivery and explores how they facilitate collaboration to increase the adoption of systemic innovation on complex construction projects.

KEYWORDS: SYSTEMIC INNOVATION, RELATIONAL CONTRACTING, PROJECT INTEGRATION STRATEGIES, INTEGRATED PROJECT DELIVERY, PROJECT DELIVERY METHOD

INTRODUCTION

The construction industry has long been described as slow to adopt new innovations. The problem 'is that the rate of innovation lags behind most other sectors, and appears to be falling further and further behind (Winch, 1998). The discourse of construction innovation is lengthy and has been explored by many scholars (Ball, 1999; Dubois & Gadde, 2001; Winch, 1998). However, it appears the innovation story in complex projects is more nuanced than previously thought. Recent scholarship shows that the adoption rate of innovations is in fact dependent on the characteristics of the innovation itself (Sheffer, 2011; Taylor & Levitt, 2004c). Innovations that cut across discipline and supply chain boundaries – termed *systemic innovations* - are especially difficult to implement in a fragmented industry arranged into decentralized projects. Because systemic innovations cross professional and trade specializations, redefine how work is done, and break craft administration standards (Taylor & Levitt, 2004a), they are three times less likely to be adopted in comparison to *modular or incremental innovations* that fit within existing discipline and supply chain boundaries (Sheffer, 2011).

This recent scholarship on construction innovation also finds evidence that the adoption of systemic innovations is dependent on the organization structure of the project. Research finds that projects with higher levels of organizational integration are two and a half times more likely to adopt systemic innovations than projects with low levels of organizational integration (Sheffer, 2011). This need for integrated project organization matches trends across the industry to move to more innovative and collaborative delivery models for infrastructure and complex projects. The creation of new 'Integrated Project Delivery' (IPD) models creates an inter-organizational governance structure to collaboratively manage complex infrastructure projects across organizational boundaries. These project organizational forms use specific mechanisms and constructs to overcome industry fragmentation and encourage collaborative behavior. In theory, the strategies used by innovative project delivery models such as IPD should impact the adoption of systemic innovations. Yet the link between the strategies used by these project teams and their resulting impact on systemic innovation remains unexplored. How do the mechanisms and strategies used by collaborative project teams facilitate greater adoption levels of systemic innovation?

To answer this question, we describe how nine specific mechanisms often found in innovative project delivery methods facilitate the adoption of systemic innovations. In the absence of an appropriate descriptive term for these mechanisms, we term these *project* *integration strategies*. A project integration strategy is defined here as *a single mechanism with the power to organize information, processes, or people for the purpose of collaboration within a construction project.* This paper attempts to make the connection between the project integration strategies and the adoption of systemic innovations. Using a grounded theory methodology, the authors conducted ethnographic observations at four projects and interviewed 63 people across 24 projects. The sample included owner representatives, general contractors, architects, engineers, and trade contractors from healthcare projects in the state of California. The resulting account highlights nine specific project integration strategies that were found to enable the adoption of systemic innovation. For each project integration strategy, the authors describe the specific ways in which they enhance the adoption of systemic innovations. The paper briefly touches on the interaction effect of these project integration strategies on one another. We also organize project integration strategies within existing frameworks that categorize mechanisms for collaborative and integrated project teams, to create a new framework for understanding strategies for collaborative practice. In the end, the description of the nine project integration strategies represents a starting place to understand how to create a strategy for collaborative teams to manage and implement systemic innovations.

POINT OF DEPARTURE

Construction innovation is defined in this paper as a nontrivial change and improvement in a process, product, or system that is novel to the institution developing the change (Slaughter, 1998). Construction innovation—in contrast to invention—does not require a detailed design or physical manifestation. It need not be novel in respect to all potential solutions, but only to the creating institution (Slaughter, 1998).

Categories of Construction Innovation

Innovations can be categorized by their effect on the existing supply chain, the design and construction process, or the participants involved. Extant literature discusses this categorization in terms of autonomous vs. systemic innovations (Taylor & Levitt, 2004b; Teece, 1986, 1996); bounded vs. unbounded innovations (Harty, 2005) and integral vs. modular innovations (Sheffer, 2011). According to Teece (1996), an autonomous innovation can be introduced without modifying any other components of equipment whereas a systemic innovation requires significant readjustment to other parts of the system. Therefore, systemic innovations require more coordination in the development and implementation stages of the innovation. Similarly, Taylor and Levitt (2004a) define systemic innovations as innovations that reinforce the existing product but require multiple firms in a network to change practices in a coordinated way. As a result, systemic innovations will typically create significant increases in overall productivity but may induce switching or start-up costs for some participants and reduce or even eliminate the role of other participants. Harty (2005) adds another layer to this categorization by introducing the concept of boundedness. Bounded innovations can be contained within an organization's control whereas unbounded innovations cannot.

Henderson and Clark (1990) distinguish between innovations that induce changes to components within a product and innovations that change the linkages between components. Using these two categorizations, they classify innovations into four types – incremental, architectural, modular, and radical (see Figure 1). Incremental, modular, and bounded innovations that fit within the existing divisions of work and specialization tend to proliferate because they do not cross traditional discipline boundaries. These modular innovations such as energy-efficient light bulbs and water-efficient toilets fit within the existing supply chain and have standardized interfaces. They do not alter the interface of adjacent construction products or the process of installation within the building. Implementing a modular innovation can be as simple as removing the old component and installing the new one.

[Figure 1 about here]

Systemic and radical innovations reinforce the overall product function but redefine the boundaries between the units of work traditionally provided by each firm in the supply chain. Systemic innovations require multiple firms in the supply chain network to change their design, prefabrication and/or assembly practices in a coordinated way (Taylor, 2006) They alter the interfaces between the modules or the overall system architecture. Systemic innovations can create increased overall product value or delivery productivity but will typically induce switching or start-up costs for some participants while reducing or potentially eliminating the role of other participants. Examples of integral innovations include radiant floor heating and smart building management systems. These innovations may introduce a change in the interfaces or design criteria between two or more modules, a change in the process (e.g. schedule, sequencing, etc.) of the overall system, or both. Because these integral innovations cross professional and trade specializations, redefine how work is done in the industry, and break industry standards, they diffuse up to three times slower than modular innovations that fit within the existing supply chain (Levitt & Sheffer, 2011).

Fragmented Industry Structure and Decentralized Projects

Systemic Innovation in construction cannot be accomplished by a single firm. It is highly influenced by the inter-organizational nature of the industry. Innovations must be negotiated among multiple actors involved in the various projects (Winch, 1998). For this reason, the slow rate of systemic innovation adoption in construction is highly influenced by the industry structure and project organization.

The Architecture, Engineering, and Construction (AEC) industry is characterized by extreme fragmentation (Fergusson, 1993). Horizontal fragmentation occurs in the trade-by-trade competitive bidding environment of traditional project deliveries. Because it is difficult to cross-subsidize changes across trades, globally-optimal innovations cannot compete with traditional solutions that are more cost-effective from the perspective of a particular building element or phase. Vertical fragmentation occurs because each project phase to has a different set of stakeholders, decision-makers, and values. This creates displaced agency – also called 'broken agency' - where involved parties will engage in self-interested behavior and pass costs off to stakeholders in a subsequent phase to the detriment of the long-term user (Henisz et al. 2012). Longitudinal fragmentation occurs in North America when project teams disband at the end of projects. Team members lose tacit knowledge about how to effectively work together and organizations are unable to build upon ideas that cross firm boundaries (Dubois & Gadde, 2001). Taylor and Levitt (2004a) term this knowledge breakdown as an industry "learning disability" that slows innovation diffusion. In addition, the high demand fluctuations within the industry creates a reluctance by firms to invest overhead in innovation development (Sheffer, 2011). The system of tort liability that holds firms responsible for design and construction mistakes encourages technological risk aversion.

The fragmented industry structure leads to the organization of large construction projects as decentralized modular clusters (Sheffer, 2011). The vertical fragmentation of the industry splits the role of the systems integrator role between two very different actors – the principal contractor and the principal architect (Winch, 1998). As a result, 'mediating and championing roles essential to successful innovation are less likely to be carried out effectively' (Winch, 1998). The majority of project work is governed through standardization (Langolis & Robertson, 2009) and 'craft administration' (Stinchcombe, 1959). The institutionalized product architecture and design rules act as the coordination standards to ensure that modules produced by separate firms fit together in the end (Langolis & Robertson, 2009; Sheffer, 2011). The general contractor acts as a weak systems integrator but typical work can be designed, coordinated, and constructed as independent pieces with relatively little system integration required.

However, general contractors in a decentralized modular cluster lack the necessary capacity required to coordinate systemic innovations, which can require major changes in the design interfaces and/or installation processes. As a result, systemic innovations are passed over for localized product innovations that offer less global benefit but fit within the existing divisions of work and specialization (Sheffer, 2011). This decentralized modular cluster arrangement for construction projects reinforces industry participants 'not only [to] resist innovative threats, but actually resist all efforts to understand them, preferring to further entrench their positions in the older products' (Utterback, 1996).

Integrated Project Delivery and Project Integration Strategies

Frustrated by the limitations of the fragmented industry structure and decentralized project organization, complex projects are frequently embracing innovative project delivery methods to improve project governance. One emerging method in North America is known as Integrated Project Delivery (IPD) (Lahdenperä, 2010). IPD is defined as 'a project delivery method that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to reduce waste and optimize efficiency through all phases of design, fabrication and construction' (AIA, 2014). As a method of relational contracting, it encourages collaborative behavior to better handle the uncertainties and risks – including risks of innovating - for large, complex projects, including risks of innovating. It can be viewed as providing 'virtual horizontal and vertical integration' of the supply chain.

The IPD approach is built around specific strategies – also referred to as mechanisms in the literature - that project teams can employ. Because the purpose of these strategies is to re-integrate the supply chain across organizational boundaries, we use the broad term *project integration strategies* to refer to the breadth of potential mechanisms. A project integration strategy is a single mechanism with the power to organize information, processes, or people for the purpose of collaboration within a construction project. Examples of project integration strategies used in the IPD model include multi-party contracts, early involvement of key participants, collaborative decision making and control, shared risks and rewards, liability waivers among key participants, and jointly developed project goals (Ashcraft, 2012; Cheng, Allison, Dossick, & Monson, 2015; Ghassemi & Becerik-Gerber, 2011; Thomsen, Darrington, Dunne, & Lichtig, 2009). Additional project integration strategies such as building information modeling (BIM), lean construction tools, and team colocation are catalysts to foster successful IPD projects and are often required in contracts (Kenig et al., 2010). Scholars have categorized these strategies for IPD in various ways, including: informal v. formal (Bygballe, Dewulf, & Levitt, 2014); workplace v. technical v. contractual (); legal/commercial v. leadership & management v. processes & lean (University of Minnesota, University of Washington, University of British Columbia, & Scan Consulting, 2016); legal and commercial v. management

v. social v. workplace & technological (Cheng, Dale, Aspenson, & Salmela, 2012); and micro- and macro-frameworks (Ashcraft, 2012).

IPD should, in theory, have a significant impact on the adoption rates of integral innovations. In a sense, IPD re-envisions the historical concept of 'Master Builder' as a collaborative building team of specialists, uniting the key stakeholders (architect, contractor, and owner) under a single contract. It reduces horizontal and vertical fragmentation through shared incentives and creation of a 'virtually integrated supply chain.' The framework can mitigate longitudinal fragmentation by offering multi-project commitments, thus addressing the issue of learning disability. IPD focuses on the formation of cross-functional, high-performance teams characterized by high levels of creativity, information sharing, and exceptional work output (Ashcraft, 2012; Chinowsky, Diekmann, & Galotti, 2008; Dougherty, 1992; Van Der Vegt & Bunderson, 2005). The framework for IPD is informed by theory on team creativity, social exchange, and team cohesion (Hackman, 2011; Homans, 1958; Robbins & Judge, 2012). IPD facilitates the formation of strong social networks and knowledge sharing – both necessary for systemic innovations – through team colocation, shared incentives, and multi-project commitments.

In practice, however, IPD projects employ significantly different sets of project integration strategies to achieve these collaborative teams. IPD did not emerge in a vacuum; it has been fashioned from existing structural and symbolic best practices used in other project delivery methods (Scott, 2014) such as alliancing, partnering, and design-build (Lahdenperä, 2010). Accordingly, actors working within the emerging project delivery method use combinations of the different elements they are comfortable with or fit the needs of a given project. For example, in projects with a public owner, a single multi-party contract may be difficult to implement due to state regulations. IPD can still be applied as a philosophy by implementing other project integration strategies to support the integration of the project team. Thus, there are different levels of application of project integration strategies in practice. Additionally, traditional project delivery methods that use contract forms such as design build and design bid build are also experimenting with many of the same project integration strategies. The end result is that no two projects are alike; each project team uses various combinations and degrees of project integration strategies to achieve collaborative teams.

METHODOLOGY

To understand how different project integration strategies impact the adoption of systemic innovation, researchers underwent two phases of data collection. The first phase occurred in 2013. Researchers observed four large-scale IPD construction projects over a period of six months. This included two hospital projects, one medical office building, and one large commercial headquarters. These projects were described as using the IPD model, but as mentioned, employed various combinations of project integration strategies. In total, the researchers observed fifteen meetings and conducted twenty-one interviews with actors on the projects. Interviewees included owner representatives, architects, engineers, general contractors, and trade contractors. See Table 1 for a breakdown of the number of interviews by discipline.

[Table 1 about here]

Using constructivist grounded theory, researchers worked towards ‘a “discovered” reality arising from the interactive process and its temporal, cultural, and structural contexts (Charmaz 2003).’ As opposed to traditional grounded theory, constructivist grounded theory does not assume that theories nor data are discovered, but instead are constructed by the researcher through interactions in the field and with interviewees. Researchers entering the field asked participants to first describe their specific experiences on the project. Researchers then asked participants if they felt the project was adopting any types of new products, processes or technologies as an innovation. If so, the interviewee was asked to describe the innovation or technology in detail, including the circumstances and decision points discussed for the adoption. Researchers did not ask specifically about systemic innovations but stories of innovation were later classified as systemic or incremental/modular. During team meeting observations, the team noted key project issues, collaboration between various project teams, and the overall dynamic of the organizational structure.

Interview transcripts and meeting notes were compiled and coded using the cloud-based Dedoose software. Key phrases or ideas, either explicit or implicit, were recorded as nodes and sub nodes. Both the frequency a concept was noted and the relationship between two concepts act as a foundation for the theories and key findings discussed in this paper.

In 2016, researchers returned to the field for phase two of the data collection. The second round of interviews focused on understanding how the project integration strategies are deployed in practice. Specifically, researchers sought to understand the practical implications of implementing these strategies, and waited to see if interviewees would connect the strategies to adoption of systemic innovation. Interview questions during this phase did not explicitly ask about innovation. Instead, questions focused on the purpose, execution, and benefits of the project integration strategies identified from phase one interviews and a review of the literature.

Researchers interviewed an additional forty-three participants representing twenty additional projects (see Table 1). All of the interviewees represented healthcare construction projects in California, USA. Collaborative and integrated project teams has been particularly attractive for the delivery of healthcare facilities. This is likely because the complexity of building systems is greater in healthcare facilities than in conventional commercial buildings. Healthcare construction requires significant additional effort in planning, permitting, and construction. Stringent seismic requirements and regulations place extra burdens on project teams. The duration and uncertainty of the project requires design decisions to be made years before decisions about the purchase of the latest high-tech (and expensive) medical equipment can be made. Complex healthcare projects have been plagued by frequent changes and rework resulting in cost and schedule overruns (Feng, 2009). Some of these projects used the IPD model but others used ‘IPD-ish,’ ‘progressive design-build’ or ‘design-bid-build’ project delivery methods. Once again, transcripts were compiled and coded with key phrases and ideas coded using existing nodes from phase one, or new nodes that emerged from phase two.

FINDINGS/RESULTS

[Table 2 about here]

During phase one, participants described sixteen examples of systemic innovations (See Table 2). Some of these innovations required a change in the product interface and all of them required a change in the design or construction process. Participants discussed the adoption of systemic innovations in two ways. First, when asked how the team was able to adopt systemic innovations, they explicitly mentioned how one or more project integration strategy helped (see pathway 1 of Figure 2). Second, when asked how the team was able to adopt systemic innovations, they pointed to characteristics of the high-performance project teams. These characteristics included a positive team culture, mutual team trust, idea generation, support for creative thinking, and a collaborative mindset. When asked to describe why the project team demonstrated these characteristics, participants would refer to one or more project integration strategy as an enabler (see pathway 2 of Figure 2). This pathway matches previous construction literature that connects project integration strategies to characteristics of high-performance teams such as trust (Pishdad-Bozorgi & Beliveau, 2016), creativity (Fellows, 2014), and project climate (Sun, Mollaoglu, Miller, & Manata, 2015) and innovation literature that connects high-performance teams to innovation (Bain, Mann, & Pirola-Merlo, 2001; Katzenbach & Smith, 1993; Montes, Ruiz Moreno, & Garcia Morales, 2005).

[Figure 2 about here]

In the following sections, we identify nine project integration strategies and unpack how they contribute to systemic innovations. The majority of the nine strategies are not new concepts in the construction project industry. However, the specific impacts of the project integration strategies on systemic innovations remains unexplored. We situate the project integration strategies within three broader categories – integrated information, integrated organization, and integrated processes - that describe the purpose of the strategy for integrating the project teams. This categorization matches that used by Fischer et al. (2014) in their simple framework for integrating project delivery.

Strategies to Integrate the Project Information

Participants described three project integration strategies - strong owner leadership, building information modeling (BIM), and fiscal transparency - used to integrate the project information.

Strong Owner Leadership

The role of the owner[1] was often identified as a critical component for driving collaboration and creativity for the result of systemic innovation. According to a general contractor, 'collaboration never really works in construction, because it, historically, has not been set up properly by the owner.' Traditionally 'many of those owners, know a lot about healthcare or other industry [but] very little about construction' For systemic innovations 'the leadership from your owners is just as important as the leadership from the construction side of it. That is a key.' The contributions of the owner to the adoption of systemic innovations include setting a vision for innovation and collaboration, avoiding a first-cost mentality when selecting the project team, and acting as an appropriate gatekeeper of information for the rest of the team.

[1] On large complex projects, the owner is not a single individual but instead an organization comprised of its own hierarchies. Here, however, we use the singular term 'owner' to match the language and meaning of most interview participants. The majority of designers and contractors – despite interfacing with different individual owner representatives responsible for managing a particular scope of the project – repeatedly referred to the 'owner' as one singular entity.

An owner's vision and goals for a project has one of the largest influences on team decision-making. Strong owner vision 'sets the stage for the project' and acts as a support system for idea incubation. The project team's pursuit of systemic innovation tends to mirror the owner's enthusiasm and expectations about the potential for innovation adoption. Self-reflective owners describe that 'the owner has a lot of power and … whether it's collaboration or trust, what they hold as sacred, it kind of drives the project' while considering that 'honestly, I believe the owner is the one who sets the culture. If the GC [general contractor] and the architect [and] engineers wanted to create a collaborative trusting environment, they can only do so with whatever limitation, whatever culture the owner wants to set.' For innovation, 'it's something that you have to allow people the space to do. I don't think a lot of projects allow people space to be innovative. You have to fit in this box, go build what's on the plans.'

General and specialty trade contractors agreed with the importance of the owner's vision for innovation in moving systemic innovation ideas forward. A trade contractor describes the role of visionary as an important role for the owner. Once they are 'clear how they want to see their vision or their goal for how it's going to work and relay that to the team… they're big in coaching that we all will follow their lead on that.' A match in vision between the owner and the rest of the project team resulted in increased creativity and idea generation because 'I know the client gets that [vision]. That is why there are better ideas faster.' One general contractor working on a prefabricated conference room innovation describes hypothetical conversations around adoption of the innovation idea:

> *"Tell me if you are interested. Here is what we think. It will ultimately go the way that conference room modules are going. 'We have really cool ideas. Here is our cool idea. What do you guys think in designing? What do you think Mr. Client?' They will either say it is crazy and then we take it off the table, or somebody will say it is cool and they like the idea. Then we will continue to explore it."*

The fundamental tension for innovation between project teams and owners is that 'owners want everything, but they do not necessarily want to pay for everything, which is a problem.' Innovators describe hesitation to deal with 'the old owner [that says] "I win, you lose." They're out there. There's still a lot of predatory owners that just look for a low price and then they get what they pay for and they pay the attorney's [fees] at the end. We try to avoid that path.' Instead, participants expressed the need for competent owners that take an active role in the team selection while avoiding the low-bid, first-cost mentality.

Owners emphasize their own responsibility in selecting the right firms and individuals on the project. One owner explains:

> *"If you've got the old project manager or superintendent here that's got the attitude that, 'Oh fuck, I could have done this anyway.' It gets in the way of it [innovation] quite a lot. Trying to identify team members that will collaborate is important."*

Yet public owners are often held captive by state regulations and institutionalized organizational procedures for competitive bidding. Sometimes they could achieve contractual and organizational 'work arounds' such as using a prequalified bidding process with an emphasis on the quality and experience of the team selected. Yet in the end individual owners with a passion for innovation themselves express the limitations of the low-bid process:

"I've been doing project management for 28 years. It's all I've done in health care. I've only had three projects that I would consider that are following the model that I really want to follow. The rest of the time, I'm in a trailer with some low bid guy who really doesn't care if he works here again and that's a whole different thing."

The owner takes a more active and iterative role as the 'gatekeeper of information' in collaborative projects that adopt systemic innovations. Instead of designated design review stages in traditional projects, owner feedback is solicited in a more continuous and informal manner. The 'owners have to take a very active part in this, because there is a lot of decision making.' As opportunities for innovation emerge, 'the owner is involved in all of these meetings. They are seeing every issue that comes up.' The level of collaboration 'raises the bar for owner involvement. Some owners like that and some owners do not like that.'

In acting as gatekeeper, the owner makes important decisions about what information is passed to the team. Conflicting and unsubstantiated information can hamper the project team's momentum and create confusion about the project direction:

"I feel really strongly and when I say that the owner has such an important role, the owner can control so much information and sometimes as an owner you have to be really selective about what you give a contractor or the consultant. Not because you're keeping it from them, but because sometimes it's not for them to worry about. I feel very strongly that it's sometimes your burden to carry that until you know what direction you're going to give. Often it just becomes this pass through and it's like well it's time for you to deal with that. Then on [the general contractor's] side, they're like what the hell are we supposed to do with this information, it's half baked. And then they stress out about it."

The owner representatives interacting with the project team must be bestowed with the authority to provide immediate feedback on ideas as they emerge. Owner organizations with centralized hierarchies that give little decision-making power to local owner representatives emerge as a bottleneck that impedes the momentum of innovative ideas. Trouble arises when owner directives are not clear and consistent. One project was significantly hampered by the owner's organizational structure and decision making process. The project lacked a central gatekeeper for information, so the project teams could receive conflicting information about innovation direction. In addition, the local representation for the owner had to pass some decisions up to the CEO of the company. The general contractor expressed significant frustration with the decision making:

"Local decision making would make this thing really take off as well. We know that the client's decision making structure is very opaque. I am not trying to step on anybody's toes by saying it that way, but that is the perception. If we knew the decision making was localized and here at the job site level, if [the owner] was here at the job site, then things would go at light speed."

Fiscal Transparency

The cost uncertainty of new technologies discourages project teams from innovation. Actors described the risk of cost uncertainty in different terms from professional liability. Actors spoke clearly of legal risks to innovation, but spoke in more practical language about the risk of cost overruns. Many participants shared past stories of systemic innovations that promised cost savings, only to find later in the project that additional costs were incurred. In general, experienced contractors showed skepticism toward innovation 'optimism bias' at the outset of the project. One mechanical contractor explained:

> *"if you had just a consultant engineer, then you're running around, they drop price, they drop dollar figures and things like that [about the innovation]. But they tried to pull from their past experiences but they really don't know the dollar side of it that well. They have a lot of price per square foot numbers in their head but that's about it."*

Actors working on systemic innovations described fiscal transparency as a way to clearly demonstrate the value of the innovation and overcome ingrained resistance to 'optimism bias.' They specifically mentioned that the use of detailed and accurate cost estimations from the trade contractors during the design stage, so that the design team 'can be talking real numbers not just theoretical savings' that 'help [the rest of the project team] understand why we did this and what the real value was in doing it.' Project teams exploring innovation put significant effort into these early cost estimating exercises. A mechanical trade project manager describes his team taking three months to expand the possible mechanical air systems from three options to 'another ten options and I did full budgets for like all of them. But that was a huge benefit to the [innovation] process.'

Because systemic innovations change standard work processes, the ancillary cost impact of the innovation to other trades can be unclear. Project teams had success by considering cost implications to multiple firms. Teams needed to:

> *"put all of these pie charts and matrices together that say, 'Here are all the trades we think will save money and here is why we think they are going to save money. Here are the percentages, ranges, highs and lows' … at the end of the day, until you do something like this you do not know. [Otherwise] it is a leap of faith."*

Innovators often spoke of fiscal transparency in conjunction with the importance of agile cost shifting and the early involvement of key stakeholders – two additional project integration strategies that will be unpacked later in the paper.

Building Information Modeling

Throughout the research, participants frequently mentioned the use of Building Information Modeling (BIM) as a tool to improve collaboration among stakeholders. The use of BIM has created an additional strategy to integrate the information on the project. An executive for a mechanical trade firm describes it as:

> *"…communication, information, decision making. That's it! It used to be the only common denominator a big project had was the schedule. Everybody did their own thing but at least there was a schedule. As long as that schedule was reasonably realistic, all the rest of the trades could work to that. Well now, there's two. Now you got the model… If they [the models] are done right. It's transformative."*

In considering the adoption of a systemic innovation, BIM allows for firms to visually understand the changed product interfaces in the new system. The visualization of the innovation concept communicates changes much more accurately and quickly and helps impacted firms to understand their changed responsibility in the new system. Researchers observed a live modeling session where an interdisciplinary work team with actors representing the general contractor and the structural, mechanical, electrical and plumbing trades worked collaboratively to coordinate the virtual placement in the BIM of prefabricated multi-trade vertical utility racks. Later in the process, cross-discipline clash-detection sessions resolve coordination conflicts and increase confidence in the constructability of innovations. The general contractor described the process, saying:

> *"…it is really about flushing out all those concerns amongst the team. Who has the issues with this stuff? We do an initial model. We present it to the team. We say, "This is our initial concept. What do you think?" I had a couple of guys work on it with me. Then it is a matter of what their thoughts are."*

For multi-trade prefabrication innovations - systemic innovations that require both a change in the product interface and a change in the process of construction – BIM played an especially important role. A trade contractor describes how BIM 'gave us the technology to be precise enough, and the collaborative environment to bring the other parties in.' One project owner representative explains that 'trades have really embraced it [BIM], and they use all their modeling to do pre-fabrication and to develop a lot of things [innovations]'.

The actors highly engaged in the adoption of prefabrication innovations emphasized the need to balance precision and tolerance. An overreliance on precision from the BIM could hinder systemic innovation adoption. One framing contractor detailed frustration with a systemic prefabrication innovation because 'we are delivering 100% from the model' but in 'real life construction' the presence of imprecisions between the model and the innovation hindered adoption. Project teams on more successful systemic innovations described:

> *"We took away the opportunities for the precise science to kill us. That being said, the connection points between the racks are down to a quarter of an inch. That has got to be exact. The modeling helps us do that."*

Two different mechanical trade contractors describe how helpful model precision can be to drive confidence in prefabrication, saying:

> *"We are very detailed in our BIM modeling because we do download that to a machine that creates our ductwork and we do prefab almost all of our components to within a quarter inch' and 'what we send out of that shop will be exact. It will be perfect. That is ultimately what you want to see in your building, that high level of precision."*

Participants often spoke of the theoretical opportunities for BIM as a strategy to further integrate information and increase adoption of systemic innovations. For example, 4D schedule visualization – which displays the 3D model over a time series - could effectively communicate changes in the construction sequence required by systemic innovations. 4D models are themselves a form of systemic innovation as well as they require multiple firms to coordinate schedule information. However, participants lamented missed opportunities to use BIM to innovate when other project integration strategies were not aligned, expressing issues with interoperability and that 'the problem is our industry does not want to be on one software. So then it doesn't really work.'

Strategies to integrate the Project Organization

Participants described three project integration strategies – colocation, multi-party contracts, and early involvement of key participants - used to integrate the project organization.

Colocation

The use of colocated space drove informal forms of collaboration among the key participants on the project. Many projects designated a large construction trailer or open floor plan office - commonly referred to as the 'Big Room' by participants – that would house as many as 250 to 300 team members representing the project owner and the key design and construction firms.

Colocation encourages iterative and immediate face-to-face communication. The intense social exchange builds shared goals and trust (Homans, 1958) much more quickly than distributed teams. The first few days of an idea for a systemic innovation can be crucial. Informal information exchange over lunch or coffee with a team member from another discipline can vet out potential obstacles and form an interdisciplinary coalition of support for good ideas. Systemic innovations require a change in the design or installation process or in the product module interface and often require more engagement and explanation than possible through email and formal weekly coordination meetings. A mechanical trade contractor explains this 'is the whole premise of us making [colocation] happen that way because if you do not have access to [others], then it is another day before a decision is made.' Another mechanical contractor describes how 'you want to be there [in the colocated space]. You do not want to go back to the old way of take a snap shot, and PDF it, and email it to somebody, and wait for a reply.'

Actors emphasized the importance of continuous local representation by all of the stakeholders. When discussing systemic innovations, actors repeatedly used phrases such as 'if the concrete guy wasn't here for me to talk to about that, [the innovation] would never come together' and 'if we did not have a structural steel partner here, we would just kind of be assuming, guessing' to emphasize their value for the shared space. Physical presence was described as the best way to build interpersonal connections and establish trust that an innovative idea is worth pursuing. One general contractor explains 'you could do it via web link [but] I think that is challenging. There is a certain amount of energy and passion that goes along with this too. You have to convey it in the room.' Innovation champions must express the new idea and answer questions that others have.

Colocation can lose effectiveness when team members have different levels of engagement. For example, team members from two cases expressed frustration that the architectural designers (whose home firm was located in another state) were only colocated two or three days per week. Team members expressed the desire for all members of the team to 'forget about all of the other resources that you have got to deal with in the main office' and join the project team 'full time.'

During implementation of the systemic innovations, colocation encourages dialogue to deal with the 'different nuances' that must be accounted for 'with each issue, especially cross-disciplinary issues.' The setting 'facilitates a more open discussion…. Everyone realizes that this [systemic innovation] is the thing to do. It is the right thing to do. Everybody is all buying-in on that.' Some projects arranged the collocated space into inter-organizational sub-team clusters where participants were organized by their scope of work instead of their firm. Examples of clusters might include Core and Shell, Façade, Interiors, or Services. As one trade contractor in the services sub-team cluster explains, ‘I’ve got a union trade detailer [next to me] and I’ve got the consultant engineer sitting right next to him.’

Projects that adopted systemic innovations used visual posters across the collocated space to project vision and align goals. A trade contractor explains:

> *“this helps a lot because what changes a mindset for people is not just if you tell them once to do it or I read it in my contract, that’s what it says here, but [a] kind of repeated practice. If it becomes repetitive, then that finally changes your mind.”*

The idea of a visual culture intersects with concepts from the project integration strategy of lean construction, and indeed projects that adopted a higher level of lean techniques tended to have higher levels of posters and visuals in the colocated space.

An intersection with the project integration strategy of owner role is that project teams valued owner representatives who were also available in the collocated space. On one project, team members did not appreciate an owner representatives who:

> *“sat in a corner office over here and it looked like you had to pass through the golden gates to get there. I think that was a mistake in setting the wrong kind of culture. You're in the same room but I'm in the corner office, and just the psychology of that. It looks unapproachable.”*

Project owner representatives who were collocated but lacked authority to make decisions and give directives were also source of frustration. They were described as middlemen that slowed down the adoption of innovative ideas. In contrast, some project owners pushed the limits of decentralized leadership. For example, one owner representative described:

> *“I don't have an office here. I sit in the middle of the cubicles out there. People walk by every day or I hear things every day. Somebody will walk by and say, "I know we're tight budget. I got a way to save you $60,000. Are you interested?" I'm the owner. I love that though, that people feel the freedom to say it. This is wasteful. We're putting in stuff we're going to turn out. Do you want to do it? It's this big room, you really can be honest.”*

Incentivized or Multi-Party Contracts with Guaranteed Cost Reimbursement

When adopting systemic innovation, ‘contracts are very important. The reason they are called contractors, because the majority of the time is just doing contracts.’ Most innovators strongly pushed against ‘that same old, "Throw a low price." Bid low price and then fight as to who's entitled to every nickel from that point on.’ The first cost, low-bid mindset was specifically highlighted as a barrier to systemic innovation. Instead, to adopt innovation, ‘it comes down to motivating, and what motivates people in the different [collaborative] structure is maybe contract language.’ One general contractor explains ‘with all this innovation, it keeps going up, but at the core of this stuff [are] things like collaboration, how to motivate people. It has a lot less to do with technology and a lot more with the social experience and the contracts.’

Some actors described the benefit of incentivized contracts with guaranteed cost reimbursement – in contrast to first cost competitive bidding - as having an impact on adoption of systemic innovations. Guaranteed cost reimbursement contracts pay the actual labor and material costs to firms instead of paying the value of a competitive bid. Guaranteed cost reimbursement shields firms from the risk of systemic innovation adoption. Should a failed innovation cause a project to miss targets, the organization still will be reimbursed for project costs instead of taking a loss on the project. A mechanical trade contractor explains 'the risk has been taken out; but our billable hours on every month for what we spend on it, we are guaranteed to make a certain amount, and then we are guaranteed... you know, there's a certain amount of overhead for that. The risk is less, and the rewards could be greater.' Another trade contractor also describes how 'there's a tremendous benefit when … you take that financial piece, not entirely off the table but, you know, stop [it] from being the focus.' Guaranteed cost reimbursement was often coupled with incentivized contracts to drive innovation. One project owner decided that 'instead of continuing to bid, I set targets for each one of these guys. I said, "If you beat your target, I'm going to give you an incentive. I set their fees. If they beat the target, which is good for me, they end up getting a 3% fee adjustment [bonus].'

However, there was a much stronger and more decided voice for the use of shared risk and reward multi-party contracts which were referred to as an Integrated Form of Agreement or Integrated Project Delivery (IPD) contract. These multi-party contracts unite multiple design and construction firms together with the project owners to have 'skin in the game' under a single legal agreement. This contract creates a built-in challenge for the project team. The team will 'set their own target value. Between that time and the finalization of design, the final estimate, the savings there is shared incentives. That is the incentive for the team to keep innovating and find cost savings.' Put another way:

> *"we then challenge ourselves. We have not cracked open the can of innovations yet. We have not thought about different ways to do this yet… Now, if everyone is smart and can bring ideas and we expect those ideas to be on the table for consideration, what do you think we can bring this building in at? … Can we take off five percent? Is it reasonable to think that we can innovate five percent out?' Another general contractor states that 'while their fee is 100% at risk, they know that investing in innovation is likely only going to improve their position on the job."*

During project meetings, 'everyone is challenged to come up with ideas and then as they are put forward on the table, for this idea how much do you think it is going to save or cost?' This motivation led to the consideration of systemic innovation adoption to decrease project cost and increase the team bonus pool (and therefore, their own share of the profit). According to a general contractor, the benefit of this contract structure is that:

> *"It does allow you to evolve without the difficult contractual liabilities or siloes, or even the contractual walls that are formed where everybody is protecting their own interests. That can also get in the way of this type of [systemic innovation] initiative. I think that the great benefit of IPD to this process is the ability to break down those walls and allow our teams to work together in a risk-free environment."*

This theme of reduced and distributed risk was central to many firms participating in multi-party contracts. For trade contractors, 'the risk has been taken out' and 'they can develop a completely different approach for the project. They are not at risk for how they got on the project in the first place.' The cost of innovation is:

> *"split amongst multiple people, right? So it affects almost the whole project team. Everybody has got some little component to it but we're able to pull that all together, analyze it, make our decision, and then everybody go back and carry it on the same page."*

Trade contractors 'are all in because what we are saying is we live or die together. If you [the owner] agree with us then what risk do we have? We are going for it, right?' Thus multi-party contracts provide an innovation safety net for both the individual and the organization. For traditional projects, time spent pursuing an innovative idea will count as billable hours that must be absorbed by an individual's own firm. Furthermore, firms are more likely to consider how their decisions and actions will impact the work of others. Promises of innovation savings are closely vetted among all impacted parties as 'there are a lot of interdependencies. Because if I make a decision, how does it affect my trade partner? Do their costs go up because I made a decision for my costs to go down?'

The impact of contract on systemic innovation was not consistent among all interviewees. Many innovators – notably those not working on projects with multi-party contracts - expressed the importance of the team and project culture over contracts. One owner explained the psychological importance of team members saying 'I like to go to work because my job is fun and we're doing really well. That's important' and another owner explained 'the money part doesn't help you work weekends and nights and bring crews out at your own risk to solve that problem.' Still, one general contractor suggested that while 'on a traditional project without a contract, it is still possible to encourage [innovative] behaviors … without actually having a contract, but it is better to have that behavior in a contract' and another working on a traditional contract project mentioned that 'the interesting thing is we're still kind of stifled by contracts.'

Early Involvement of Key Participants

Early involvement of key participants refers to contractually involving the general contractor and the trade contractors earlier in the design process. In practice, this is done at various stages of the project. Typically, projects using early involvement would arrange contracts with the general contractor during conceptual or schematic design and key trade contractors during the design development or construction document phases of the project. However, this level of engagement of the stakeholders ranged throughout projects, and sometimes involved multiple contractors starting from the conception or very early stages of the project. One owner explains 'we want to get the subs [e.g. trade contractors] on as soon as possible, sometimes even before schematic design. That's the best. That's where they can have a lot of impact on the design.'

Early involvement of key participants provides a decentralized source of innovative ideas. By having 'everyone at the table,' ideas that are not feasible can be discarded early in the process, allowing teams to focus on good ideas. Participants recognized 'the value of bringing your major subs in and helping the design team get it right earlier than they normally would.' The trade contractors 'would work hand-in-hand with the architect' and 'really get into the weeds of the details' when discussing new and innovative ideas. In addition, trade contractors could provide important and immediate feedback on constructability issues. One engineer expressed that 'sometimes, you will come up with ideas and the sub-contractor will say, this is crazy! [Laughing] It does not work.' A general contractor describes the importance of early involvement because 'the person that is installing it will feed information about what they have encountered' on other projects as a way to vet potential innovations. Early involvement intersects with the need for fiscal transparency, as contractually agreeing with trade contractors is the best method for accurate and iterative pricing on new ideas.

Participants expressed conflicting accounts of when to involve trade contractors earlier in the process. For one project, the trade contractors did not have enough work to do for the first few weeks. Another project owner described a project that started wrong because 'they bought the trades earlier on this [project] which ended up being a nightmare. They couldn't manage. They brought them on too early.' Yet a general contractor expressed an alternative perspective, saying that starting the trade partners at the end of schematic design was too late, 'I think the biggest tweak I would make is probably bringing more of the major trades on earlier.'

Strategies to integrate the Project Processes

Participants described three project integration strategies – joint project ownership, lean construction tools, and agile cost shifting - used to integrate the project processes.

Joint Project Ownership

Systemic innovation emerged from a culture that promoted collaborative decision making and team structures that emphasized joint project ownership by the firms. Collaborative decision-making requires parties to jointly agree on important choices. By leveraging experiences from all parties, collaborative decision-making brings forward ideas about innovation implementation while surfacing important coordination concerns. Projects that promote collaborative decision-making is reinforced by both organizational strategy and project culture.

As an organizational strategy, many of these large projects often gathered 'the CEO's or the principles of the primary players [e.g. firms] once a quarter get together in a room and just get it [any problems] out there.' But projects seeking systemic innovation often also created an inter-organizational 'core team [composed of whom] they feel are the most important people.' This is sometimes referred to as the 'PMT' (Project Management Team) or the project 'board of directors.' These teams were composed of 'the general [contractor], the owner, the architect, the engineer, and eventually some of the key subs. Their task was 'not talk about the day to day stuff, but to strategize about where we could make a difference in the project.' These teams often created a project 'mission statement' and set the joint goals agreed upon by many members of the project team.

The purpose of this organizational strategy was to create a sense of joint project ownership among the firms and individuals working on the project. As one project owner explains:

> *"Sometimes people are always focused on their own contract. It's probably the harder thing. Like how do you connect people to a bigger picture? It's something our board worked on a lot. We tried a lot of things that didn't work, a lot. We tried a ton of stuff, but there was a very intentional roll out of a message, but as a group we came up with mission and core values, behaviors, and once we did that then we talked about okay how do we connect to the guys in the field?"*

Project teams that created a sense of joint project ownership saw innovation benefits, especially among the trades. One trade contractor working on a systemic innovation for the floor deck explained 'it's rare that I ever even get asked what kind of deck.' One project owner explicitly linked joint project ownership to creativity and innovation by the trades:

"because the trade was engaged up there. They were thought of as valuable. They were free to give their input. They solved an issue that all of our college degrees couldn't figure out a way to solve and they did it in less than an hour. It was a really cool thing to watch that happen. That doesn't happen if you don't engage them and make them feel valuable. As soon as you say I'm open and someone comes and says, I have a great idea and you don't listen, or you ignore them because they're wearing a tool belt, you'll never hear from those people again. As soon as you engage them and word gets through in the trailer, I had an idea and they listened, it's like wildfire, and you get all sorts of ideas. I wasn't exaggerating about guys stopping by my desk and saying, I can save you $60,000 [USD] if you'll go out in the field and take a look at this clip, these angle clip things. We did that."

The result was decentralized decision making made closer to the job site. These projects avoided decision making 'based on a completely different set of goals' driven by the 'general contractor taking the lead and saying this is how it's going to go down' in a more 'authoritarian way of dealing with it [decisions for innovation].' Instead, collaborative decision making and joint project control create a 'group environment' where 'the core group would be in charge of making that final decision [for systemic innovation] for us. The core group may think about what it's going to cost, and what are our benefits, and how we are going to protect the job. But in the end, we are all going to say this is a decision that's made, this is how we are going.' This collaborative decision making ensures time is spent on the most beneficial ideas so that 'before anybody can spend much more time on [the innovation idea], it has to prove itself.'

Lean Construction Principles

Lean construction is not the source of new ideas; instead it is a set of principles about decentralized, collaborative, value-driven work processes that can facilitate cross-disciplinary implementation of the innovative concepts. In general, 'lean has the tools that could better help everybody understand the sequences and pre-requisites to do the job far more effective than they do today.' Lean construction processes include target value design (TVD), pull scheduling, reliable promises, daily huddles, last planner, and other methods to promote efficiency in the design and construction stages of a project. Lean methods provide additional flexibility to the client, decentralize decision-making, and squeeze out buffers and inefficiencies from the process. Using the last planner system, general contractors noted increased ownership of the schedule by subcontractors. The participation of subcontractors increased conversation and dialogue about coordination problems. By placing a focus on the 'flow' of the project, lean construction methods surface potential cross-discipline coordination problems more quickly. However, lean processes were hampered by the lack of integrated information or lack of involvement by key participants. Lean processes fail when someone says 'I don't have the information' or 'somebody won't make a decision.'

Agile Cost Shifting

Agile Cost Shifting describes the degree to which project teams can engage in the rapid and easy redistribution of project funds across traditional firm boundaries. Systemic innovation often requires switching of labor and material costs between firms to account for the reassignment of work—and hence direct costs—between firms under the new system architecture. Agile Cost Shifting reduces the burden of transaction costs imposed by traditional hierarchical change order management systems. Instead, money is rapidly allocated between firms to the overall benefit of the project. A full discussion of Agile Cost Shifting and its benefit to systemic innovation is discussed in Hall and Lehtinen (2015).

The Story of One Systemic Innovation

One example of a systemic innovation is radiant heating/cooling adopted by one project in phase 1. Radiant heating/cooling is a HVAC solution driven by radiation rather than convection. It requires an underfloor water system integrated with a structural slab. Radiant heating/cooling requires a change in interface (alternative structural and HVAC design decisions) and a change in process (alternative construction schedule sequencing with piping required before structural slab pour) among mechanical, electrical, plumbing, and structural disciplines (Sheffer, 2011). A project manager for the mechanical trade partner describes the challenge of implementing radiant heating/cooling:

> *"radiant tubes never get put in because we never have this kind of cross group coordination. That is a major, major cross-group coordination between the structure on the ground floor."*

On the project, the owner gave high value to indoor air quality and user comfort. In addition, the owner was concerned with life cycle cost and the overall leadership team was concerned with first cost. During conceptual design, a colocated sub team cluster of architects, engineers and trade partners met often to brainstorm possible HVAC systems that would meet these objectives. Once the merits of several potential ideas were considered, the mechanical engineers and trade partners conducted preliminary pricing analyses to narrow the field of choices.

The sub team made the final selection of a radiant system by 'choosing by advantage' to the rest of the project instead of deciding by lowest first cost. The choosing-by-advantage strategy factors life cycle costs and the schedule impact to other trades in order to emphasize selection of a system with the greatest global advantage. Next, team members used lean construction tools such as the last planner system to commit design and construction firms to the process for implementing the innovation, with the expectation that the reliable commitments will be kept during construction. Finally, the team incorporated the radiant floor heating into the building design using multi-trade BIM sessions and into the project budget by entering the cost into the Target Value Design. Money was shifted between the different mechanical, structural and roof deck design and construction firms to accommodate the innovation.

[Figure 3 about here]

The systemic innovation of radiant heating/cooling required each of the nine project integration strategies: strong owner leadership and vision, early involvement of key participants, joint project control, colocation, fiscal transparency, agile cost shifting, lean construction principles, incentivized contracts with guaranteed cost reimbursement, and BIM (see Figure 3). While the sequence was not always the same, many of these same nine project integration strategies emerged from participants when describing the adoption of other systemic innovations.

DISCUSSION

Each of the nine project integration strategies did not exist in isolation. They were often mentioned in the context of other project integration strategies. Remarkably, even though interviews touched on experiences from twenty-five different healthcare projects in California, no single project employed the same sets of project integration strategies to the same degree. Even when owners wanted to build off the success of a previously completed project, they tended to 'tweak' their use of project integration strategies. For example, they would describe decisions to involve the key trade contractors earlier in the project, or to use a less inter-organizational form of colocation, or to experiment with the contractual model. For this reason, it is not especially useful to categorize collaborative projects using a single description such as the 'project delivery method.' Within the category of Design-Bid-Build, Design-Build or Integrated Project Delivery, projects would employ vastly different combinations of project integration strategies. Furthermore, projects with very similar uses of project integration strategies would describe the 'project delivery method' using different terms. It seems that the emergence of collaborative project teams has reframed the project structure and the associated terms for large, complex projects. The project delivery approach must be described using more detailed dimensions to be useful in research exploring the relationship between integration strategies and outcomes.

Project integration strategies address the vertical and horizontal fragmentation of the industry structure. Vertical integration is improved when owners with a strong vision use alliance contracting to align participants' goals across the supply chain and can iterate more frequently with the project team while creating a shared sense of project control for the designers and contractors. This greater sense of agency is reinforced by colocation and early involvement, and facilitates collaboration and idea generation. Horizontal integration is improved through multi-party contracts that reward decisions that benefit the project as a whole, instead of a single party. Shared risk/reward contracts hold the entire team accountable for project success. Innovations that do not fit within the existing supply chain can be cross-subsidized by reimbursing each parties' direct costs, not only at bid time but also throughout the project by enabling agile cost shifting between firms. Longitudinal fragmentation remains a challenge, however, for these projects. The project integration strategies described by participants were designated for a single project. An effective strategy to move project teams together from project to project –facilitating continuous learning and improvement– does not appear to be present at this time.

Project integration strategies transform the project organization to move from a decentralized modular cluster to a collaborative modular cluster (Sheffer, 2011). The core team creates a collaborative and jointly owned structure that can coordinate and centralize some of the decision making. When the project owner acts as an appropriate gatekeeper, information can be provided as necessary to move decision making for systemic innovations forward.

CONCLUSION

Complex construction projects are using new and innovative project delivery methods to create collaborative teams, yet these project delivery methods show a great deal of variation in how they employ combinations of as many as nine project integration strategies. These project integration strategies —defined in this paper as *strategies to integrate information, organization, and processes*— should in theory help to overcome the fragmented industry structure and decentralized project organization, resulting in higher levels of adoption of systemic innovations.

This paper contributes by creating a detailed qualitative understanding of how nine project integration strategies that are employed in practice help to facilitate the adoption of systemic innovations. However, the link between the number and value of systemic innovations *vs*. the use of individual or combined sets of project integration strategies on a given project has not yet been quantified. Because different projects employ different levels and sets of project integration strategies, there is an opportunity to make a comparative analysis with the relative frequency and value of systemic innovations as the outcome variable. Future research should build upon the qualitative constructs presented here to quantify their impact on the number and value of systemic innovations adopted using multiple case studies.

REFERENCES

AIA. (2014). Integrated Project Delivery. Retrieved April 28, 2014, from http://ipd-ca.net/

Ashcraft, H. (2012). The IPD Framework.

Bain, P. G., Mann, L., & Pirola-Merlo, A. (2001). The innovation imperative: The relationships between team climate, innovation, and performance in research and development teams. *Small Group Research*, *32*(1), 55–73.

Ball, M. (1999). Chasing a snail: innovation and housebuilding firms' strategies. *Housing Studies*, *14*(1), 9–22.

Bygballe, L. E., Dewulf, G., & Levitt, R. E. (2014). The interplay between formal and informal contracting in integrated project delivery. *Engineering Project Organization Journal*, (January 2015), 1–14.

Charmaz, K. (2003). Grounded theory. In *Strategies of qualitative inquiry*.

Cheng, R., Allison, M., Dossick, C. S., & Monson, C. (2015). *IPD : Performance, Expectations, and Future Use*.

Cheng, R., Dale, K., Aspenson, A., & Salmela, K. (2012). *IPD Case Studies.*

Chinowsky, P., Diekmann, J., & Galotti, V. (2008). Social network model of construction. *Journal of Construction Engineering and Management*, *134*(10), 804–812.

Dougherty, D. (1992). Interpretive barriers to successful product innovation in large firms. *Organization Science*, *3*(2), 179–202.

Dubois, A., & Gadde, L. (2001). The construction industry as a loosely coupled system–implications for productivity and innovativity. *Paper for the 17th IMP Conference, Oslo.*

Fellows, R. (2014). Towards satisfying the client: optimizing, satisficing or disappointing? *Engineering Project Organization Journal*, *4*(2–3), 89–106.

Feng, P. P.-Y. (2009). *Causes and Effects of Rework on the Delivery of Healthcare Facilities in California*. *Dissertation*. University of California, Berkeley.

Fergusson, K. J. (1993). *Impact of integration on industrial facility quality*. *Dissertation*. Stanford University.

Fischer, M., Reed, D., Khanzode, A., & Ashcraft, H. (2014). A simple framework for integrated project delivery. In *22nd Annual Conference of the International Group for Lean Construction: Understanding and Improving Project Based Production, IGLC 2014* (pp. 1319–1330). Department of Civil and Environmental Engineering and Computer Science, Center for Integrated Facility Engineering (CIFE), Stanford University, Stanford, CA, United States.

Ghassemi, R., & Becerik-Gerber, B. (2011). Transitioning to Integrated Project Delivery: Potential barriers and lessons learned. *Lean Construction Journal*, *2011*, 32–52.

Hackman, J. R. (2011). *Collaborative intelligence: Using teams to solve hard problems*. Berrett-Koehler Publishers.

Hall, D., & Lehtinen, T. (2015). Agile Cost Shifting as a Mechanism for Systemic Innovations. In *Engineering Project Organization Conference 2015 Proceedings* (pp. 1–15). The University of Edinburgh, Scotland, UK.

Harty, C. (2005). Innovation in construction: a sociology of technology approach. *Building Research & Information*, *33*(6), 512–522.

Henderson, R. M., & Clark, K. B. (1990). Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms. *Administrative Science Quarterly*, *35*(1), 9–30.

Henisz, W. J., Levitt, R. E., & Scott, W. R. (2012). Toward a unified theory of project

governance: economic, sociological and psychological supports for relational contracting. *Engineering Project Organization Journal*, *2* (January 2015), 37–55.
Homans, G. C. (1958). Social Behavior as Exchange. *American Journal of Sociology*.
Katzenbach, J. R., & Smith, D. K. (1993). *The wisdom of teams: Creating the high-performance organization*. Harvard Business Press.
Kenig, M., Allison, M., Black, B., Burdi, L., Colella, C., Davis, H., & Williams, M. (2010). *Integrated project delivery for public and private owners*. *National Association of State Facilities Administrators (NASFA), Construction Owners Association of America (COAA), The Association of Higher Education Facilities Officers (APPA), Associated General Contractors of America (AGC) and American Institute of A*. NASFA, COAA, APPA, AGC, AIA.
Lahdenperä, P. (2010). Conceptualizing a two-stage target-cost arrangement for competitive cooperation. *Construction Management and Economics*, *28*(January 2015), 783–796.
Langolis, R. N., & Robertson, P. (2009). Networks and Innovation in a Modular System: Lessons from the Microcomputer and Stereo Component Industries. In R. Garud, A. Kumaraswamy, & R. Langlois (Eds.), *Managing in the modular age: architectures, networks, and organizations*. John Wiley & Sons.
Levitt, R. E., & Sheffer, D. A. (2011). Innovation in modular industries: Implementing energy-efficient innovations in US buildings. In *Proceedings of the Energy, Organizations and Society Conference, U.C. Davis* (pp. 1–29).
Montes, F. J. L., Ruiz Moreno, A., & Garcia Morales, V. (2005). Influence of support leadership and teamwork cohesion on organizational learning, innovation and performance: An empirical examination. *Technovation*, *25*(10), 1159–1172.
Pishdad-Bozorgi, P., & Beliveau, Y. J. (2016). Symbiotic Relationships between Integrated Project Delivery (IPD) and Trust. *International Journal of Construction Education and Research*, *8771*(March), 1–14.
Robbins, S. P., & Judge, T. A. (2012). *Organizational Behavior 15th Edition*. prentice Hall.
Scott, W. R. (2014). *Institutions and organizations: Ideas, interests, and identities*. Sage Publications.
Sheffer, D. A. (2011). *Innovation in modular industries: Implementing energy-efficient innovations in US buildings*. *Dissertation*. Stanford University.
Slaughter, E. S. (1998). Models of construction innovation. *Journal of Construction Engineering and Management*, *124*(3), 226–231.
Stinchcombe. (1959). Bureaucratic and craft administration of production: A comparative study. *Administrative Science Quarterly*, *4*(2), 168–187.
Sun, W. A., Mollaoglu, S., Miller, V., & Manata, B. (2015). Communication Behaviors to Implement Innovations: How Do AEC Teams Communicate in IPD Projects? *Project Management Journal*, *46*(1), 84–96.
Taylor, J. E. (2006). *Three perspectives on innovation in interorganizational networks: Systemic innovation, boundary object change, and the alignment of innovations and networks*. Stanford University.
Taylor, J. E., & Levitt, R. E. (2004a). *A New Model for Systemic Innovation Diffusion in Project-based Industries*. *Center for Integrated Facilities Engineering Working Paper #WP086*.
Taylor, J. E., & Levitt, R. E. (2004b). Bridging the Innovation Gap in Project-based Industries: 2003-2004 CIFE Seed Project Report. *CIFE Technical Report #159*, 2003–2004.
Taylor, J. E., & Levitt, R. E. (2004c). *Understanding and managing systemic innovation in*

project-based industries. *Innovations: Project management research*. Project Management Institute, Newton Square, Pa.
Teece, D. J. (1986). Profiting from technological innovation: Implications for integration, collaboration, licensing and public policy. *Research Policy*, *15*(6), 285–305.
Teece, D. J. (1996). Firm organization, industrial structure, and technological innovation. *Journal of Economic Behavior and Organization*, *31*(2), 193–224.
Thomsen, C., Darrington, J., Dunne, D., & Lichtig, W. (2009). Managing Integrated Project Delivery, 105.
University of Minnesota, University of Washington, University of British Columbia, & Scan Consulting. (2016). *MOTIVATION AND MEANS: How and Why IPD and Lean Lead to Success*.
Utterback, J. M. (1996). *Mastering the dynamics of innovation*. Harvard Business Press.
Van Der Vegt, G. S., & Bunderson, J. S. (2005). Learning and performance in multidisciplinary teams: The importance of collective team identification. *Academy of Management Journal*, *48*(3), 532–547.
Winch, G. (1998). Zephyrs of creative destruction: understanding the management of innovation in construction. *Building Research & Information*, *26*, 268–279.

FIGURES

		Core concept	
		Reinforced	**Overturned**
Linkage between core concepts & components	**Unchanged**	**Incremental innovation** *Example: Lumber wall truss frame replacing conventional stick-built lumber wall frame*	**Modular innovation** *Example: Extruded metal truss frame replacing conventional stick-built lumber wall frame*
	Changed	**Architectural (Systemic) innovation** *Example: Prefabricated wall frame with HVAC, plumbing & electrical components replacing conventional stick-built lumber wall frame*	**Radical innovation** *Example: Geodesic dome frame replacing conventional stick-built lumber wall frame*

Figure 1 - Innovation Framework (Henderson & Clark, 1990; adapted by Taylor & Levitt, 2004a);

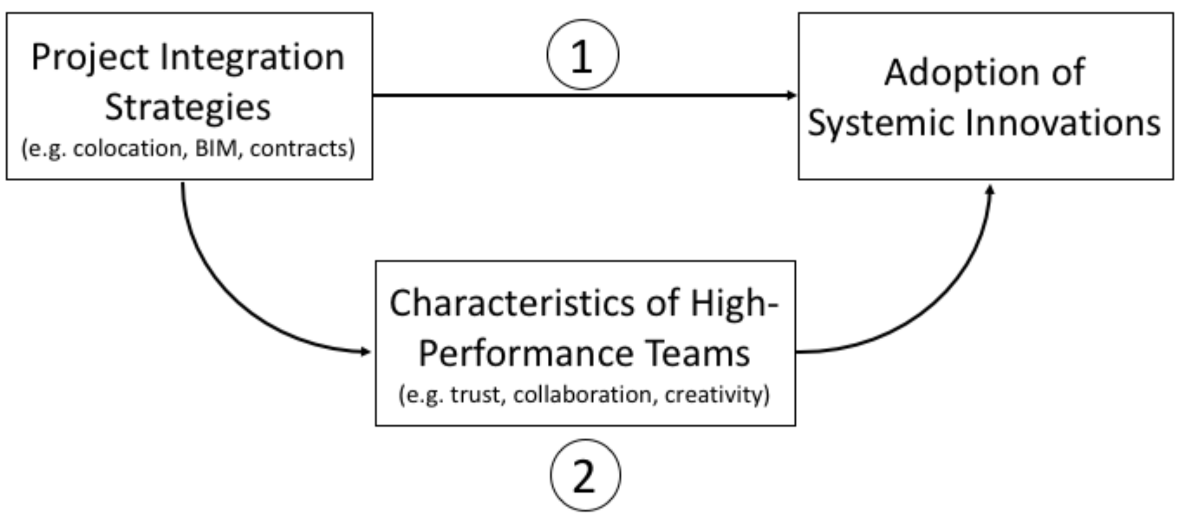

Figure 2 – The two pathways that participants discussed systemic innovation adoption.

Figure 3 - The Adoption for a Radiant Heating/Cooling Systemic Innovation

Table 1 - Number of Interviews and Meeting Observations

	Phase One (2013)	Phase Two (2016)
# of Projects	4	20
# of Meeting Observations	22	2
Interviews		
General Contractors	5	21
Owner	3	6
Trade Contractors	10	8
Architects	1	5
Other (Engineers, Lawyers, etc.)	2	3
Total Number of Interviews	21	43

Table 2 - Systemic Innovations identified in Phase 1

Innovation	Alternative	Changed Interfaces*	Changed Process**
Resequence parking structure	Erect Parking Structure, then Erect MOB		x
Auger Pile Foundation System	Traditional CIDH pile Foundation	x	x
Prefabricated X-wall system	Traditional Façade	x	x
Celcrete Foam Concrete Filling	Traditional Soil Filling		x
Prefabricated med-gas pipe systems	Individually Build Pipes On-site		x
Universal wall design for flexibility (doors)	Wall Design based on Predefined Door Locations		x
Alternative duct routes for flexibility (equipment)	Predefined Duct Routes		x
ConXtech Structural Steel	Traditional Steel Frame	x	x
Horizontal & Vertical MEP racks	Route Each Service Individually		x
Prefab. Restroom Modules	Stick-build Restrooms		x
Radiant Heating/Cooling	Forced Air HVAC	x	x
Slotted Architectural/ Structural Deck	Structural Deck w/ Acoustical Ceilings	x	x