



**CIFE** CENTER FOR INTEGRATED FACILITY ENGINEERING

**Bridging the Innovation Gap in  
Project-based Industries:  
2003-2004 CIFE Seed Project Report**

By

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# **Bridging the Innovation Gap in Project-based Industries**

## **2003-2004 CIFE Seed Project Report**

**Prof. Raymond E. Levitt & John E. Taylor**  
**September 30, 2004**

### **EXECUTIVE SUMMARY OF RESEARCH WORK COMPLETED**

The AEC (architecture, engineering and construction) industry is the largest industry in the world and is often described as a laggard industry in adopting new products and processes. Research on this topic has almost exclusively focused on the behavior of firms. This project report presents the CIFE Seed Grant research completed to date on the structural mechanisms that might contribute to an explanation of this phenomenon. Our research focused primarily on product and process innovations of a systemic nature (i.e., those that require multiple specialist firms to change their process in a coordinated fashion) though we also investigated localized innovations (i.e., those that imply change only within a specific specialty type). Systemic innovations researched include integrated supply chain management, the prefabrication of building systems, and the evolution to virtual design and construction. By gaining insight into the mechanisms that impact adoption of systemic innovations in the AEC industry, we can hope to bridge the innovation gap. In doing so we can begin to capture the productivity gains that manufacturing industries earned in adopting systemic innovations.

*During the course of the first year of this seed project, we have:*

- Completed a comprehensive study of the AEC innovation literature which includes approximately 60 journal papers over the past 20 years which debate the innovativeness of the industry. We also completed an expanded literature survey on innovation in project-based industries more generally and reviewed papers on the project-based motion picture, pharmaceutical, healthcare, and biotechnology industries.
- Collected case histories of innovations from an international sample of contractors, architects, engineers, facility owners, and companies promoting innovations. When possible quantitative data was collected to support assertions that systemic innovations diffused more slowly than comparable localized innovations.
- Established a point of departure framework and conceptual model for understanding the innovation gap phenomenon.
- Began an international, intercollegiate dialogue on the ideas contained in the research with Professor Ikujiro Nonaka (Hitotsubashi Business School), Professor Peter Morris (University College London), Professor Antti Lioma (Helsinki School of Economics), and Professor Karlos Arto (Helsinki University of Technology).
- Published (or have been accepted to publish) our findings at the ASCE Specialty Conference on Leadership and Management, the Project Management Institute Research Conference, the NordNet International Conference on Project Management, and the Hawaii International Conference on Systems Science. The findings are also to be included as a chapter in a book on advanced project management to be published by the Project Management Institute in 2005.
- Submitted proposals for funding which were accepted by CIFE member Tekes, by the CIFE Seed Grant program (2<sup>nd</sup> year award), and the Stanford Lieberman Graduate Research Fellowship.
- Enlarged the scope of the research to investigate how market structures in different institutional contexts impact the diffusion process for localized and systemic innovations. Research on this topic has yielded interesting insights into strategies for diffusing product and process innovations.

## **1. INTRODUCTION TO RESEARCH PROJECT**

Project-based industries are among the largest industries in the global economy and the construction industry is the largest among these. Innovation research to date, however, has largely focused on traditional, hierarchical industries. When project-based industries are included in innovation studies, the analyses rarely explore the implications of organizational and industry structure on diffusion. A review of the literature on innovation in the project-based construction, motion picture, pharmaceutical, biotechnology, and healthcare industries suggests that organizing around projects creates difficulties for innovation. The extra effort required to diffuse some innovations leads to an innovation gap for project-based industries. A closer examination of the scope of an innovation and the inter-organizational flow of knowledge holds the key to understanding this innovation gap.

In the innovation literature there has been a call for theories to better understand project-based forms of organizations. Daft and Lewin [1] suggest that project-based forms of organization “emphasize interdependence rather than independence” and that interdependence “may emerge as a distinguishing characteristic of new organizational paradigms.” They suggest that grounded fieldwork be undertaken to better understand inter-organizational collaborations between project-based organizations. This research addresses this call by pursuing case-based research to explain how inter-organizational knowledge flows and innovation scope impact the diffusion of innovations in the project-based industries. We explore these issues through cases of component prefabrication, supply chain integration, and the evolution to virtual design and construction. In this project update we will focus on the case of wall system innovations in the United States residential building industry.

Residential building is the largest market segment of the construction industry in the United States with 2003 revenues exceeding half of the \$882 billion spent on construction [2]. Residential building, along with the construction industry in general, is often described as a laggard in adopting new products and processes. The construction industry innovation literature contains a 20-year debate on whether or not the industry is innovative. Research to date fails to consider how the structural mechanisms inherent in project-based forms of organization might contribute to resolving this debate. However, upon closer examination, research describing “localized” product or process innovations (i.e., those that imply change in practice for a single project specialist type) typically find the industry to be on par with manufacturing industries, whereas research on product and process innovations that require multiple firms to change their processes (“systemic” innovations) find the industry to be a laggard adopter.

Systemic innovations requiring multiple companies to change in a coordinated fashion include recent advances in supply chain management, increasing use of enterprise resource planning, and the prefabrication of component systems. Traditional, hierarchically organized manufacturing industries have adopted these innovations efficiently and captured significant gains in productivity. When similar innovations were promoted in the building industry, they failed to diffuse rapidly or widely.

In this project update we begin by describing the background academic work that provides a point of departure for this research. We then present the findings of our case study analysis of wall system innovations in the United States. Based on constructs identified in the case, we examine the inter-organizational knowledge flows in order to understand the impact on innovation diffusion. The paper ends with a discussion of the implications of this research on industry and organizational strategy.

## **2. BACKGROUND ON RELEVANT INNOVATION LITERATURE**

In this section we discuss the academic literature that provides key points of departure for this research. We first describe literature pertaining to innovation in project-based industries. Then we focus more specifically on innovation in the project-based building industry. We then discuss innovation scope to elaborate the

concepts of localized vs. systemic innovation. Finally, we discuss the relevant literature on knowledge creation and flow.

### **2.1. Innovation in Project-based Industries**

A number of academic papers identify issues related to innovation as industries move toward project-based forms of organization. In this section we will review relevant papers from the motion picture, pharmaceutical, biotechnology, healthcare and building industries.

Lampel et al. [3] published a study of how capabilities evolved in the motion picture industry following the move from hierarchical forms of organization to project forms of organization. Their research revealed that “when activities are grouped under single corporate governance they are more likely to be valued according to their contribution to the firm as a whole... the transition from hierarchies to markets [disturbed] this relationship making it more likely that some capabilities will gain at the expense of others.” The research concludes that this move created “an evolutionary stagnation in the craft of making movies.”

Faulkner et al. [4] contribute to the debate stating that, after the movement to project-based forms of organization in Hollywood, “people who belong to different organizations do not have the incentive to share knowledge.” We extrapolate from the Lampel and Faulkner research that the move from hierarchical organization to project organization made “systemic” innovations more difficult due to new difficulties in coordinating inter-organizational work activities.

Powell [5] studied the pharmaceutical industry’s evolution toward project-based forms of organization. He identifies difficulties for systemic innovation and learning suggesting that “a critical task for participants enmeshed in a web of many relationships is to take the problems learned from one project and make them systematic, that is portable across multiple relationships.” In other words, the differing groups of participants from one project collaboration to another make systemic learning or change difficult. Other work on the pharmaceutical industry by Zeller [6] demonstrates that Swiss pharmaceutical firms that evolved to project-based forms of organization have observed a “slow down in innovation” in situations of “inter-firm cooperation using project teams.”

In the biotechnology industry, Barley et al. [7] identified that the use of project-based, or network, forms of organization has been growing in comparison to hierarchical, free-standing firms. Zucker et al. [8] found that after the move to project-based forms of organization in biotechnology, “organizational boundaries work[ed] effectively to restrict intellectual diffusion.”

In the healthcare industry, Luke et al. [9] investigated the move from hierarchical forms of organization to project-based forms of organization. Their research found that the “inter-organizational forms emerging in the healthcare industry resemble those commonly found in other industries” of which they include residential building. They argue that “existing models of organizational structures inadequately capture the essence of inter-organizational arrangements emerging in healthcare and other industries” and ask that more research be undertaken to “evaluate the performance of quasi-firms” (by which they meant project-based organizations). Luke’s research calls for a better understanding of inter-organizational coordination and performance in project-based forms of organization.

Almost none of these project-based industry studies seek to distinguish among different kinds of innovations, nor do they identify or model the underlying structural mechanisms that contribute to a reduction in innovativeness. Only the Lampel paper explicitly finds that systemic innovation is the predominant form of innovation impacted in the move from hierarchical to project-based forms of organization. This is not surprising since the pharmaceutical, biotechnology and healthcare industries only recently made the transition from hierarchical to project-based forms of organization. The impact on innovation is only beginning to be felt in these industries. In the building and motion picture industries, projects have been the basis for organizing work for over half of a century.

It is interesting to note that some of the seminal work on organizations in the building industry suggests that project-based forms of organization are superior to hierarchical organizational forms without exception. In a seminal paper, Eccles [10] extends Williamson's [11] treaty of markets and hierarchies to include the "quasi-firm." Eccles explores the residential building industry to identify and elaborate the quasi-firm concept. He describes the quasi-firm as a project-based form of organization existing between hierarchical forms of organization and pure market-based transaction arrangements. In the same paper Eccles argues that "there are no advantages of integration over subcontracting."

Stinchcombe [12] in his classic paper on bureaucratic and craft administration of production finds that the building industry should not integrate activities into a bureaucracy. Stinchcombe finds that "the bureaucratic alternative was too expensive and inefficient in construction" due to the "variability in the work flow of construction administrations." Stinchcombe describes this variability as variations in work volume and product mix in the course of a business cycle, seasonal fluctuations in volume, geographic limitations, and the site-based nature of construction. This variability acts to deter systemic innovations that require high fixed capital costs.

According to Stinchcombe's and Eccles' arguments, in the building industry there is a clear need to organize on a project-basis. However, neither Stinchcombe nor Eccles contemplated the "dark side" (to borrow from Lampel's work on the motion picture industry) of project-based forms of organization. At the time Stinchcombe and Eccles completed their research, firms were in the early stages of evolving toward project-based forms of organization. The trade contractors at the time would still be populated with craftspeople who had worked under hierarchical forms of organization earlier in their career. Lampel describes an "evolutionary stagnation in the craft of making movies" that resulted when the older craftspeople with knowledge of working together with other craftspeople within a hierarchy retired from the industry. This may explain why the pharmaceutical, biotechnology and healthcare industries that began organizing around projects in the last two decades are only now beginning to experience an impact on their ability to promote systemic change.

## **2.2. Innovation in the Project-based Building Industry**

Innovation research generally conforms to either "adopter"-oriented studies or "macro"-oriented studies [13]. Adopter research focuses on the willingness of an individual or firm to adopt an innovation. This literature concerns itself with understanding the innovativeness of individuals and organizations by studying the decision-making processes and innovativeness of the adopter. The decision-making process is broken down into a number of phases: knowledge, persuasion, decision, implementation, and confirmation [14]. Adopters themselves are categorized based on their adopter behavior as innovators, early adopters, early majority, late majority, or laggards [14]. In the building industry, most of the literature investigates adoption behavior at the firm level.

Unlike research oriented towards firm behavior, "macro"-oriented research focuses at the market level on a population of firms' ability to adopt. This research tends to focus more on the structural characteristics of the adopting population. Research on market-level mechanisms in the building industry can be broadly classified as relating to the impact of regulation on diffusion of innovations, the impact of the decentralized industry structure on innovation, and examinations of innovations diffusing through the industry. We discuss each of these research trusts below:

**2.2.1. Impact of Regulation on Diffusion of Innovations.** Oster and Quigley [15] and Gann et al. [16] investigated the impact of industry regulations on the homebuilding industries in the U. S. and the U.K., respectively. In testing for a number of variables across four innovations, the Oster research found that diffusion rates are significantly impacted by the education level of the chief building official, the extent of unionization in the population of firms being studied, and the size of the adopting firm. Their analysis points to the fact that building codes and regulation can slow the diffusion rate for an innovation. Gann et al. in a study of the diffusion of energy efficiency in

homebuilding, found that regulations in the U.K. neither inhibit nor stimulate the diffusion of energy efficiency.

**2.2.2. Impact of Decentralized Industry Structure on Innovation.** Citing the work of Karl Weick [17] on loose coupling in educational organizations, a number of studies seek to understand the impact of the decentralized structure of the industry on innovation. DuBois and Gadde [18] claim that the construction industry meets the criteria of a loosely-coupled organization and therefore “localized adaptations can be expected, but the spread of advantageous mutations are forestalled.” Other work by Gann and Salter [19] and Winch [20] makes a related point that the decentralized industry structure facilitates innovation at the project level while, at the same time, making it difficult to diffuse across the industry.

**2.2.3. Examination of Innovations Diffusing in the Industry.** Surprisingly few papers investigate how specific kinds of innovations diffuse in the building industry. Our search identified three papers that explore innovations in the industry to understand the market-level structural mechanisms at work. Ardit and Tangkar [21] explored innovations in construction equipment over a thirty-year period to understand the rate and types of innovations that diffuse in the construction industry. They found that innovations in heavy equipment were all localized in nature but that the rate of introduction of new models, a proxy for innovation rate, had increased. Blackley and Shepard [22] looked at innovations diffusing in a population of 417 homebuilders. The results of their analysis did not support the hypothesis that the fragmented industry structure reduces the diffusion rate for innovations. However, it should be noted that the Blackley study exclusively investigated localized innovations.

Finally, Lutzenhiser and Biggart [23] completed an exhaustive analysis of innovation in the commercial building industry in order to understand how the market structure impacts diffusion of energy efficiency. They found that all innovations in the building industry were “incremental” in nature and argued that the structure of the industry inhibited innovation. Their findings agreed with our own findings on the lack of research on market-level mechanisms, stating that “aside from a bit of work on tax and regulatory policy, relatively little attention has been given to market-level processes.” In the final analysis, the Lutzenhiser research describes the industry actors as each having a “separate social world with its own logic, language, actors, interests and regulatory demands.”

**2.2.4. Summary.** The literature on market-level innovation mechanisms provide a point of departure for the work described in this paper. A gap exists in the innovation literature both in the amount and scope of research on market-level issues. The regulatory and normative barriers that separate the trade contractors in the building industry provide a key mechanism for understanding the diffusion of systemic innovations. The work to date on the impact of regulation on the diffusion of innovations in project-based industries does not explore what specific mechanisms related to regulation meaningfully impact diffusion.

The work on the decentralized structure of the industry seeks to understand why some innovations diffuse more readily than others. This paper extends this work to consider the impact of the scope of the innovation (localized vs. systemic) on the rate of diffusion. Finally, the work on cases of diffusion in the construction industry explicitly or implicitly implies that systemic innovation is not possible in the fragmented building industry. We take the regulatory, decentralization, and fragmentation arguments as a starting point to explore how knowledge flows can impact the rate of diffusion for systemic innovations in project-based industries.

### **2.3. Innovation Scope**

Most research on innovation in the building industry focuses on localized innovations. Localized innovations are those that reinforce the existing product or process and provide a measurable impact on

productivity (e.g., transitioning from “stick-built construction” to the use of prefabricated “wall trusses” in homebuilding). In the case of localized innovations, productivity for individual components can increase while overall productivity may increase, decline, or remain unchanged. Systemic innovations, on the other hand, refer to innovations that reinforce the existing product but necessitate a change in the process that requires multiple firms to change their practice. Systemic innovations typically enable significant increases in overall productivity over the long term. But they may create switching or start-up costs for some participants, and reduce or eliminate the role of others. Examples of systemic innovations include virtual design and construction, supply chain integration, and prefabricated subcomponent wall systems in homebuilding.

#### **2.4. Knowledge Creation and Flow**

According to Nonaka [24], organizational level knowledge is created through a continuous dialog between tacit and explicit knowledge. Various researchers have reviewed [25] and debated [26] [27] the concepts of tacit and explicit knowledge. Recent work by Nissen [28] has focused on extending Nonaka’s knowledge flow framework. In this paper we will use the Nonaka framework to represent knowledge flows in the building industry.

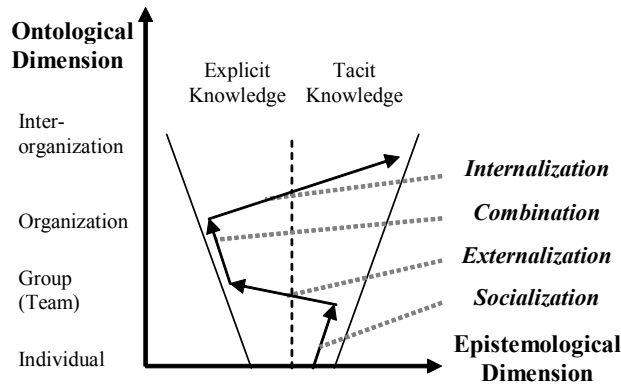
In Nonaka’s framework, it is assumed that new knowledge is created through conversion between tacit and explicit knowledge. Explicit knowledge is defined as knowledge that can be transmitted in formal, systematic language, whereas tacit knowledge refers to knowledge that has a personal quality and is therefore difficult to formalize and communicate [29]. Nonaka discusses four modes of knowledge conversion between tacit and explicit; socialization (tacit to tacit), internalization (explicit to tacit), externalization (tacit to explicit), and combination (explicit to explicit).

Socialization of knowledge takes place through shared experience. Apprentices learn from mentors through a process of observation and repetition. In the building industry as new products or processes are implemented, a team will develop new work practice routines to integrate and make sense of the new product or process. Combination of knowledge is a process by which explicit knowledge held by individuals is shared. In the process of sorting, adding, re-categorizing and re-contextualizing, explicit knowledge can lead to new knowledge. In interacting around a new product or process, a project team would combine knowledge about how best to integrate the product or process during formal or informal meetings. The combined knowledge would lead to new knowledge of better ways to incorporate the product or process.

Internalization of knowledge is analogous to the traditional concept of learning. However, because in this case explicit knowledge is converted to tacit, it is the process or action that enables the conversion. In the case of a new technology tool, the act of using the tool enables the internalization of knowledge. In the opposite case, externalization of knowledge refers to the conversion of tacit knowledge to explicit knowledge. Because tacit knowledge is not definable directly in language, metaphors are often used to explain the knowledge concept. With a new product or process, the externalization refers to an individual describing to the team how he or she uses the innovation.

In the knowledge conversion process, realizing the benefits of created knowledge rests on externalization and “amplification through dynamic interactions between all four modes of knowledge conversion.” Nonaka graphed this dynamic interaction process as an upward spiraling process (see Figure 1 below for an interpretation of Nonaka’s spiral) that starts at the individual level and moves up the hierarchy to the inter-organizational level as a result of knowledge conversion and flows.





*Figure 1. Knowledge creation and flow*

### 3. DETAILS OF WALL SYSTEM INNOVATION CASE STUDY

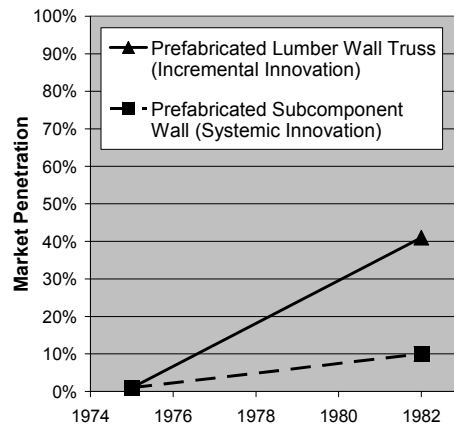
We conducted a case study combining qualitative and quantitative data on wall system innovations in residential building. Our goal was to identify the finer-grained structural mechanisms related to regulation, decentralization, and fragmentation that bear on inter-organizational knowledge flows and impact the diffusion of systemic innovations in project-based industries. We use theoretic replication logic and focused on two cases that we believed would provide contrasting results.

Cases were selected based on their ability to support analytical generalization, as opposed to statistical generalization. The case research involved collecting relevant documentation, investigating third party documentation about the innovations (e.g., from trade magazines), conducting focused interviews, and making direct observations. Since we triangulated the evidence gathered from multiple data sources, we controlled our construct validity and internal validity.

Roof trusses, wall trusses, and floor trusses are commonly used in single-family residential homebuilding in the United States. However, the use of prefabricated wall systems is rare. Prefabricated wall systems include prefabrication of subcomponent systems that include mechanical, electrical, and plumbing in addition to structural lumber. In other instances, they can include the insulation, drywall, windows, and interior/exterior finishes.

#### 3.1. Quantitative Case Discussion

In order to compare localized and systemic innovations, we sought data on building industry wall system innovations. A U.S. Congress Office of Technology Assessment special report [30] revealed some striking trends in systemic versus localized innovations in the U.S. residential building industry. They reported that a wall truss localized innovation in the lumber trade diffused rapidly through the U.S. construction industry over a seven-year period. However, they describe a prefabricated subcomponent wall containing lumber, plumbing, electrical and mechanical components – hence a systemic innovation – diffusing at about one quarter the rate over the same period. This diffusion data is illustrated in Figure 2.



*Figure 2. Diffusion of prefabricated lumber wall trusses and prefabricated subcomponent walls*

To understand why the wall truss systemic innovation diffused at such a slower rate, we investigated a specific case of implementation of a prefabricated subcomponent wall innovation. In completing the qualitative case, we hoped to reveal the organizational interactions that would explain the disparity in adoption rates for localized and systemic system innovations. We now present the case of a United States residential builder.

### **3.2. Qualitative Case Discussion**

Wall System Builders, Inc. was a regional builder who elected to incorporate prefabricated wall systems into their already existing homebuilding business. In attempting to incorporate pre-fabrication into their building practice, Wall System Builders ran into some unexpected difficulties in getting the trade contractors to coordinate their work. They found that the best way to build a prefabricated wall system was to have the lumber, plumbing, electrical, and mechanical teams fabricate their systems in their warehouse. This was a significant departure in the building process for the trades involved. In the end, Wall System Builders made the decision to vertically integrate this process, and hired workers as in-house employees to build their prefabricated wall system. In doing so, they were able to achieve significant increases in overall productivity and profitability, while at the same time reducing the employee turnover that plagues the U.S. residential building industry.

Recently, a larger national homebuilder acquired Wall System Builders. The national builder was impressed by the productivity and profitability achieved by Wall System Builders, and hoped to copy the prefabricated wall system process and diffuse it across their national operation. However, the larger builder was unwilling to integrate the different trade groups into their organization on a national scale. This meant that, from project to project, the constituency of the lumber, plumbing, mechanical, and electrical trade subcontractor teams changed. This variety in constituency of subcontractors from project to project made it difficult for the systemic innovation to diffuse. In the end, the larger builder was unwilling to integrate the trade groups, and the Wall System Builders innovation failed to diffuse across the larger organization. However, the Wall System Builders division, which continues to use integrated trade labor, remains the most profitable in the company.

### **3.3. Research Constructs Identified**

Based on outcome data on localized and systemic innovations from third-party sources and the process data emerging from the Wall System Builders, Inc. case, a number of constructs relating to the structure of the building industry emerges. The building industry operates primarily along a project-based production paradigm. As a result of the project organization, the fragmentation of the market, and the contracts and regulations inherent in the industry (e.g., union agreements and building codes), we identified several research constructs. Below, we identify those that relate to inter-organizational

knowledge flows, begin to dimensionalize them, and offer propositions on how we anticipate they will impact the diffusion of innovations.

**3.3.1. Organizational Variety.** This first construct refers to the change in population of contractors from project to project. The Wall System Builders case identified issues for diffusion related to this phenomenon. Stinchcombe [31] described a related phenomenon as the “rate of social reconstruction.” Rate of social reconstruction refers to the rate at which groups are required to form and reform into a cohesive unit from time to time. If the group’s constituents change from one project to the next, the rate of social reconstruction is considered high. In our research, we are less concerned with the “rate” than the actual “variety” of constituents from project to project. Therefore, we use the term “organizational variety” to describe this construct.

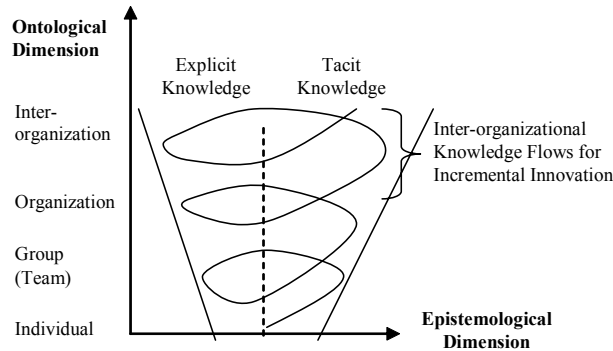
We consider organizational variety to be “high” if there is a tendency to use a different set of subcontractors for each trade classification from project to project. A long-term relationship with a particular set of subcontractors across projects would constitute “low” organizational variety. Wall System Builders reduced the organizational variety by integrating the trade subcontractors impacted by the innovation. We propose that an increase in the variety of project participants from project to project will decrease the ability for inter-organizational knowledge to flow through the industry. As a result, the rate of diffusion for innovations in situations of “high” organizational variety would diffuse more slowly than in situations of “low” organizational variety.

**3.3.2. Span.** A systemic innovation, by its very nature, will span at least one boundary between trade classifications. The number of boundaries between trades that are spanned by a given systemic innovation provides a second construct. In the case of Wall System Builders, four trade labor groups are involved. This means that six interfaces between contractors need to be spanned in order for the innovation to diffuse. The span is reduced to zero by integrating the trade labor groups into the innovating organization. However, in the case of the large builder that acquired Wall System Builders, the span is not reduced and the innovation failed to diffuse.

**3.3.3. Innovation Scope.** We propose that the organizational variety and span constructs described above begin to impact innovations when the scope of the innovation moves from localized to systemic. When an localized innovation is considered for adoption, the structural constructs will not influence diffusion. Adoption in this case can be made purely as a function of production and transaction costs for the affected firm [11] and cultural orientation toward innovation [32]. However, in the case of systemic innovations, the above-defined constructs require that the set of firms involved in a given project spend extra time and cost on mutual adjustment. The magnitude of this extra coordination is a function of organizational variety and span and relates to the ability for inter-organizational knowledge to flow and, more importantly, accumulate.

#### **4. IMPLICATIONS FOR INTER-ORGANIZATIONAL KNOWLEDGE FLOW**

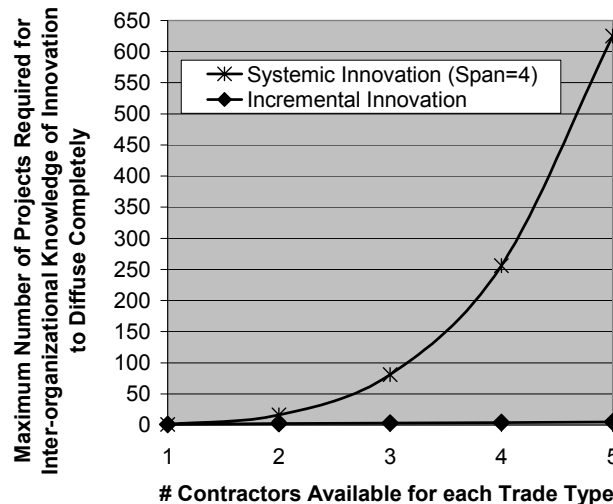
We return to Nonaka’s framework for knowledge creation and flow to interpret the cases discussed. In the case analysis we observed that for a systemic innovations, inter-organizational knowledge flows about how to implement the new product or process have difficulty flowing. In the case of an localized innovation, inter-organizational knowledge flows can amplify knowledge and facilitate the diffusion of the new product or process across the industry. This knowledge spiral is illustrated in Figure 3.



*Figure 3. Inter-organizational knowledge flow for localized innovations in project-based industries*

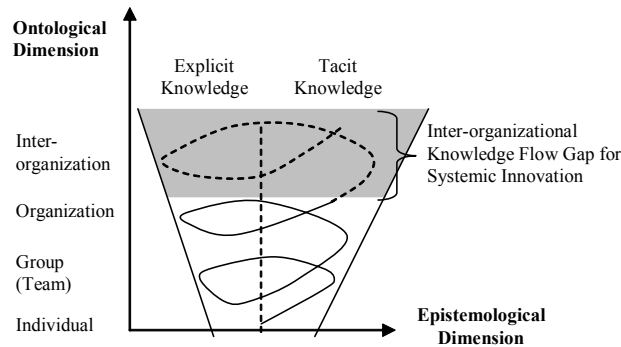
The reason an localized innovation can effectively flow at the inter-organizational level is due to the fact that a limited number of lumber contractors need to evolve their business practices as a result of the prefabricated wall truss innovation. If, for example, there were five different contractors in a geographic area, it would take a maximum of five projects (one for each available contractor) for the knowledge of the business practice evolution required to implement wall trusses to diffuse completely.

In the case of the prefabricated subcomponent wall systemic innovation, inter-organizational knowledge does not necessarily flow effectively. The lumber contractor, the plumbing contractor, the electrical contractor, and the mechanical contractor need to change their inter-organizational business practice, i.e. how they work together to install the prefabricated subcomponent wall, for the knowledge of how to implement the innovation to diffuse. If there are five possible subcontractors for each of these trade types, the total number of possible combinations required for all possible contractor combinations then becomes the number of possible contractors to the power of the number of contract types. This results in a maximum of 625 project combinations before inter-organizational knowledge diffuses completely or 125 times more potential effort required for this systemic innovation to diffuse. The progression illustrating the maximum number of projects required for inter-organizational knowledge of work practice changes to diffuse completely is contained in Figure 4.



*Figure 4. Combinations required for inter-organizational knowledge to flow completely for the localized wall truss and systemic prefabricated subcomponent wall innovations*

Because of the mutual adjustment required for inter-organizational knowledge to flow for systemic innovations in project-based industries we identify a knowledge flow gap. This gap is illustrated in Figure 5. Though it is possible for inter-organizational knowledge of work practices to flow, it is highly inefficient.



*Figure 5. Inter-organizational knowledge flow for systemic innovations in project-based industries*

The number of subcontractors with which contractors contract gives dimension to the organizational variety construct we identified in our case. Since Wall System Builders, Inc. ultimately integrated the prefabricated subcomponent wall subcontractors into their organization they reduced the number of contractors available for each trade type (organizational variety) to one. Then with the completion of only one project the inter-organizational knowledge of how to work together around the innovation diffused. In all subsequent projects the inter-organizational learning of how to better implement the prefabricated subcomponent wall system would improve productivity and, in Nonaka's terms, amplify the knowledge surrounding the innovation.

In the case of the larger residential builder that acquired Wall System Builders, a refusal to integrate the subcontractors meant that from project to project they would most likely be dealing with different sets of subcontractors. Given the 625 maximum number of projects for inter-organizational knowledge to flow completely, it is unlikely that they would even be able to develop a baseline of knowledge for how to implement the prefabricated subcomponent wall systemic innovation. And because they could neither take advantage of the inter-team learning that Wall System Builders, Inc. gained, nor even reach a baseline of inter-organizational knowledge flows, the acquiring firm was not successful at diffusing this systemic innovation.

## **5. GENERALIZING THE RESEARCH**

In addition to the wall system case, the following case research is underway (analysis stage) to confirm the generality of the findings:

- **“Systemic” Innovation Cases of Component Prefabrication**

Like the wall system innovation, we are currently collecting data on a number of other cases of component prefabrication in both the construction and shipbuilding industries. These cases include the “ship to shop” move in the shipbuilding industry, reductions in end-product variety, pre-cut timber home solutions, concrete wall panel elements, and pre-cast elevator shafts.

- **“Systemic” Innovation Cases of the Evolution to Virtual Design and Construction (VDC)**

We conducted interviews with an international sampling of about 20 architecture, engineering, construction and facility management companies to understand the issues surrounding the move to building information modeling. We focused our research on the move to 3D/4D modeling, new workplace planning software, rule-based generation of working drawings, advanced building service design and monitoring, and rule-based selection of window elements.

- **Comparison Cases of “Localized” Innovations**

To contrast with the “systemic” innovation scope which is the primary focus of this research, we also collected data on several “localized” innovations, including; the control room-less elevator, the surface mounted landing call button panel, and the prefabricated wall truss.

- **International Comparison Data on “Systemic” vs. “Localized” Innovation**

We collected quantitative data from multiple sources to test that “systemic” innovations do have difficulty in other countries. Our research suggests that project-based industries both in Finland and in the United States (in a comparison of Scandinavian vs. USA innovation outcomes) have relatively more difficulty with systemic innovation diffusion than localized. However, when localized and systemic innovation processes were compared in Scandinavia and the USA we found that localized innovations in the USA were more likely to negatively impact the productivity of other specialists on the project than in Scandinavia.

## **6. DISCUSSION**

This research addresses the call in the innovation literature for fieldwork and theoretical research to better understand project-based forms of organizations. We reviewed the literature in the project-based motion picture, pharmaceutical, biotechnology and healthcare industries to evidence that project-based industries have difficulty with innovation. We then provided a more detailed review of the innovation literature in the project-based building industry since our case study was based in this industry. By considering the scope of the innovation and how inter-organizational knowledge flows, our research contributes to a debate in the building industry as to whether or not the industry is innovative. Finally, we reviewed the literature relating to innovation scope and knowledge flow which provides a foundation for understanding and analyzing the data we collected.

We collected both qualitative and quantitative data to explore the case of wall system innovations in the residential building industry in the United States. The quantitative outcome data demonstrated that systemic innovations diffuse significantly more slowly than comparable localized innovations in the project-based building industry. We then collected qualitative data on the case of Wall System Builders, Inc. to understand what mechanisms relating to systemic innovations impact the diffusion process. In the case, Wall System Builders must integrate the lumber, plumbing, mechanical and electrical trade labor activities into their organization in order to successfully implement and diffuse the prefabricated subcomponent wall innovation across their organization. When a larger builder acquires Wall System Builders they are unable to diffuse the same innovation across their organization because they are unwilling to integrate the four specialist trade labor groups into their operation.

We identified several constructs that emerged from the case research. The first, “organizational variety,” relates to the constituency of the inter-organizational project team and how it varies from project to project. A second construct identified, “span,” describes the number of specialized project teams that are impacted by an innovation. The “innovation scope,” i.e. whether it is an localized or systemic innovation, provides a final construct. Taken together, the organizational variety, span, and innovation scope provide a framework for understanding inter-organizational knowledge flows and the resulting impact on innovation diffusion. When organizational variety is high and the span of a systemic innovation increases to impact

two or more specialist firms, extra coordination is required for inter-organizational knowledge to flow and accumulate. This explains why systemic innovations diffuse more slowly than localized innovations in project-based industries.

The findings presented herein suggest that the prevalent organizational strategy of focusing on core competencies is not always effective in project-based industries. In cases where innovations span multiple project specialist firms, an organizational strategy of integration may be necessary to reduce organizational variety and thereby increase capability to adopt and diffuse an innovation. Other organizational strategies that would reduce organizational variety for systemic innovations that span multiple specialist organizations include; partnering and co-location of cross-disciplinary teams.

From an industry standpoint, the trend toward increasing specialization and fragmentation continues. Adopting an industry strategy to facilitate the rapid creation of standards for systemic innovation interfaces between specialist groups in the industry would reduce the impact of the span of a systemic innovation. This would facilitate inter-organizational knowledge flows and thereby increase innovation diffusion rates.

## **6. RELATION TO CIFE RESEARCH & GOALS**

This work supports the “Value of Innovative Design-Construction Processes” thrust area which points out that “in comparison to sister fields, the AEC industry continues to lag behind in its adoption of innovative methods.” This research directly addresses this issue. Furthermore, as the CIFE 2004 Call for Seed Research Proposals states, “integration [is] the ‘middle name’ of CIFE.” Improving our understanding of how integrated solutions (which imply systemic changes) can be successfully diffused across the AEC industry is critical to CIFE’s mission. This research directly addresses this issue and begins to build and test a theoretical framework to understand and remedy it.

## **7. INDUSTRY INVOLVEMENT**

The following past and present CIFE members and partners have contributed to this research: Autodesk, Beck Group, CCC, Haahtela, Olof Granlund, Selvaag, Senate Properties, Skanska, Strategic Project Solutions, Tekes, Tekla, VTT, YIT, Walt Disney Imagineering, and Webcor. The authors would like to respectfully thank each of these companies and others for their generous participation in this research project.

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