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LEAN INFORMATION FLOW IN COMPLEX HEALTHCARE PROJECTS AND THE ROLE OF THE "INTEGRATOR" AS INFORMATION FLOW MANAGER

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ABSTRACT

As our society demands more from the built environment, the design and construction of buildings has become more complex and requires project teams to process increasing amounts of information. Nowhere is complexity and information management more critical than in the design and construction of healthcare facilities. However, the construction management literature represents limited knowledge of information flow on projects. To address this deficiency, this research uses an ethnographic study of the design and construction of two complex healthcare facilities to address the two main research aims: 1) To understand the mechanisms and moderators that affect information flow, and 2) To develop a model that can be used to explain and evaluate processes for information flow management.

Because of its long-term, in-depth nature, this study enables the industry to gain a better understand of both the social and technical factors that affect the management of information. Specifically, the analyses found four significant socio-technical factors (i.e. trust, commitment, learning, and common understanding) that have a profound effect on team interactions and the resulting effectiveness of information flow. The key contribution of this research is the development of a conceptual model that illustrates how these four factors interact to affect information flow. The interaction model that was developed links a trust/commitment cycle to a learning/understanding cycle. These two cycles together influence information flow on projects and can be used to explain how characteristics of a project team interaction will affect information flow. In addition, this

model is used to analyze why certain mechanisms (e.g. behaviors, techniques, or processes) resulted in effective information flow while others did not.

There are two important implication of these findings is addressed in this dissertation. The first is related to what these findings mean in terms of the implementation of lean production management principles for information flow. The second is related to the development of a more comprehensive understanding of the "coordinator" or "integrator" role (often called the "project manager"). While traditionally, project managers bring together technical information on the project, there is a significant aspect of social coordination that significantly affects information flow. To this issue, the following research also creates a definition of the integrator based upon both the social and technical aspects of information and information flow. In this capacity, an integrator is responsible for understanding both the factors affecting information flow and how the use of certain tools or techniques can create an environment that fosters the development of trust and learning among the team. The combination of developing descriptive conceptual models and providing more comprehensive definitions of the integrator role make this research critical to furthering our industry's understanding the mechanisms behind information flow and how project teams can make better use of information to improve project outcomes.

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When looking back on the last few years, a lot has happened. There are many experiences that I did not understand or appreciate at the time, but in hindsight make perfect sense. The successes, failures, inspiration, doubt, excitement, and disappointment of the past years – these all have played an essential role in making me the person that I am today. So while I would like to acknowledge certain individuals for their contributions in helping me achieve this goal, I am sure that some of these influences will continue to shape my life for years to come in ways I could never have anticipated.

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Chapter 1

Introduction

1.1 Turning Great Ideas into Reality

The poet Victor Hugo was quoted to say “there is one thing stronger than all the armies in the world, and that is an idea whose time has come.” However, there is one essential factor that is needed for an idea’s “time” to truly have come; there needs to be a means for communicating that idea to those that need to implement the idea. Therefore, without effective information flow, even the greatest ideas never make that critical jump to reality.

Because of its increasing importance, information flow is a topic that researchers in architecture, engineering, and construction (AEC) research have turned their focus to in recent years. This has been illustrated by the increase of research related to building information modeling, continuous process improvement, integrated project delivery, knowledge management strategies, and other technical means of managing information. In his assessment of information research in the AEC industry, Davidson (2004) points out that “the building industry is seen to be recalcitrant in terms of improving its efficiency and adopting innovative ways of working.” He goes on to attribute the inability of the AEC industry to systematically acquire needed information to the highly-fragmented environments and structure in which project teams work. Ultimately, it is this inability to effectively incorporate new information into projects that keeps innovation stemming from both industry and research institutions, from improving project outcomes.

1.2 Sustainability and the Built Environment

One of the most influential trends to emerge within the building industry in the last decade is that of sustainable design. Although, sustainability is hardly a new idea, it has returned to the mainstream consciousness with vigor. The new materials, systems, processes, and considerations brought about by the "green building" movement have only added to amount of information that needs to be processed in the design and construction of buildings. The current emphasis in sustainability has matured from its humble roots in the 1987 United Nation's World Commission on Environment and Development Report and forced the architecture, engineering, and construction (AEC) industry to re-examination of the relationship between buildings, occupant health and performance, and the surrounding environment. Sustainable design is redefining project team roles and creating new areas of knowledge and competence and consequently created a strong need for the industry to better understand the design and delivery of buildings.

Sustainability, or "green design" has changed the perception of buildings in our society. Buildings are no longer viewed as short term investments that simply need to provide shelter from the outside environment with success measured by fast completion and low first cost. Instead they are increasingly being viewed as interactive entities that have long-term effects on the health and productivity of building occupants and maintenance, operational, and energy costs. All of these factors now need to be considered throughout the entire design and construction process.

The challenges posed by mainstream demand for sustainability are transforming the building industry faster than which the industry can keep up. Core shifts in the building delivery process are needed to address greater specialization and integration, management of exponentially increasing information, greater understanding of system and product behavior, and the emergence of new roles and project goals. With these shifts in the industry, there has also come greater ambiguity, complexity, and uncertainty. All of these factors only further increased the need for additional information.

In most building sectors where sustainable goals have been adopted, their has been a shift in the goals of building projects from the traditional three part cost/quality/schedule focus to a five-part cost/quality/schedule/occupant health/environment focus. These new considerations have created a greater need for designers, contractors, owners, and user groups to collaborate with each other throughout the entire delivery process. The multi-disciplinary gathering, analysis, and dissemination of information have challenged the traditional behaviors of designers and contractors. Non-conventional scopes of work and competencies, such as life cycle costing, indoor air quality consulting, and energy modeling, are now emerging as central. This requires traditional roles to be expanded or new roles to be developed. These new and changing roles have created significant ambiguity in terms of who should perform certain tasks and when those tasks should be performed.

In addition to changing roles, there is also a wealth of new information that needs to be considered in the design and construction of sustainable buildings. Products need to be evaluated for their material composition, manufacturing history, effect on indoor air quality, durability, and energy performance. Systems need to be designed in close coordination with other systems to minimize wasteful redundancies, maximize efficiencies and synergies, and to result in controllable and predicable performance. Construction processes need to be reengineered to maximize reuse and recycling, and minimize fumes, dust generation, and waste. In a response to these new criteria, new products without established performance histories and installation procedures are being introduced to the industry at increasing rates. All of these new areas of consideration require project teams to manage more information in the form of additional research, analysis, information dissemination, and plans for implementation.

1.3 Green Healthcare Facilities: "Monsters" of Complexity

Due to their diverse functions, highly specialized design, and critical nature of their use, nowhere are the effects of building design and performance more critical than in healthcare facilities. Healthcare facilities are among the most challenging types of buildings to plan, design, construct, and operate. These facilities typically support sensitive and costly activities such as patient treatment, laboratory and research testing, and food preparation.

The healthcare industry is one of the most significant markets today with over 120,000 buildings in the United States. In 2006, healthcare construction totaled $41 million and these costs are projected to continue increasing as the aging baby boomer population and need to replace outdated facilities fuel further construction. Importantly, healthcare facilities are significant users of resources creating 5 million tons of solid waste annually, and using 515 trillion BTUs of energy per year, 11% of all commercial consumption. However, the most significant costs of hospitals lie in occupant salaries. While building design and construction costs account for 2% of building lifecycle costs over a 30-year period, the salaries of hospital employees account for 92% of the building lifecycle costs. If healthcare facilities can be delivered and operated with green strategies that enhance healthcare worker productivity, then significant savings can be realized in perhaps the largest cost center for these facilities (Phelps et al, 2006). Since most healthcare facilities operate at very slim profit margins, savings due to lower operations and maintenance costs and increased productivity of staff can mean the difference between hiring more staff, better equipment, or even financial survival.

The criticality that the design and construction of healthcare facilities as compared with commercial sustainable buildings can be illustrated with the quality indoor environment. One of the biggest factors in increase healthcare provision costs are medical errors and hospital-acquired, or nosocomial infections. Both medical errors and nosocomial infections rates are problems that are directly or indirectly related to the quality of the indoor environment. These two factors are among the leading causes of death in the U.S., each killing more Americans than AIDS, breast cancer, or automobile accidents (IOM 2001). Medical errors were estimated to cost the U.S. $37.6 million each year with at least $17 million of those errors being preventable (IOM 2000). The Center for Disease Control has estimated that from 2000-2002, the average annual cost of nosocomial infections was $1.71 billion for an estimated 2 million cases annually. This set the national average for nosocomial infections at roughly 10% of total patients with more than 20,000 of those annually affected (13.6%) resulting in death. Improved indoor environmental quality can improve the physical and mental effects of the built environment on stressed staff, sensitive surgical and research procedures, and sensitive immuno-suppressed patient populations.

In addition to being designed to accommodate the operational performance issues described above, healthcare facilities have additional challenges in the design and construction process. Healthcare facilities need to be designed to meet the needs of many different highly-specialized user groups. Designers need to design for state-of-the-art equipment that has not even been designed yet as well as accommodate for unknown future needs of the users. In addition, often design floor layouts based on the latest best practice in healthcare design, such as patient-centered design, family-centered design, color therapy, or some other sort of “healing” design philosophy. On medical center campuses, there are additional concerns of staging construction to not disrupting existing operations and maintaining a safe and healthy environment around the construction site. All of these considerations require project teams to process a lot of information. In most cases, most of the information available to project teams never gets incorporated into the actual project. Unfortunately, this inability to capture valuable information compromises the quality of the final building. Higher quality buildings result in better performing facilities and better performing occupants, which in the case of healthcare facilities can equate to better clinical outcomes.

1.4 Information Management: The Lifeblood of Sustainability in Healthcare Projects

The critical and complicated nature of incorporating sustainability into healthcare facilities only compound the ambiguity, complexity, and uncertainty in their design and construction process. The ineffective management of this overwhelming information load reduces the ability of project teams to translate available information into something that improves the quality of the facility without adding cost or schedule time to the project.

In recent years there have been attempts to organize sustainable design and construction information so that it is easier to implement. The United States Green Building Council's Leadership in Energy and Environmental Design (LEED) Standards provide a voluntary point-based system for assessing the level of project sustainability. LEED offers references and design and construction strategies, but is not really adequate to address the complexity of healthcare facilities. Newer tools such as the Green Guide for Healthcare (GGHC) provides the healthcare sector with a voluntary, self-certifying guide of best practices that designers, owners, and operators can use to guide and evaluate their progress towards designing and constructing high performance healing environments. The GGHC is based off of the well-established LEED NC Guidelines for commercial construction but also includes many of the Center for Health Design's recommendation for design as well as additional guidelines for operation of the facility. The GGHC formally ties together the many complimentary goals of green building and healthcare to provide a building guide that not only results in a building that shelter hospital procedures, but promotes healing, reduces environment-related stress, improves productivity, and prevents sickness through more responsible interaction with out natural environment.

Although these tools and design guides are geared toward facilitating better project outcomes, often they do not. In many cases, this is due to the fact that they just provide more information to an already information intensive environment. While the inability to manage information-intensive environments could result in catastrophic failures, there is also a great opportunity for innovative and successful projects. The difference lies in the projects team's ability to effectively gather, analyze, disseminate, and implement appropriate information. Two critical factors affecting information management within projects are the formal organizational structure and the informal social structure under which teams operate. Research in organizational theory has demonstrated the critical role that formal and informal organizational structures play in an organization's ability to adapt and survive changes in the environment. Similarly, research in the information sciences has shed light on human information behavior and how individuals and groups interact with information.

While there has been substantial research in the organizational sciences and information sciences to understand the mechanisms behind effective information flow, this research is not directly applicable to construction. There are some areas of construction management research that have begin addressing information flow. One of those areas, that of lean construction, focuses on improving the efficiency and effectiveness of processes used in construction and could be valuable in improving the processes for information flow.

1.5 Lean Information Flow

If information, in particular the flow of information, is the “lifeblood” of sustainability in healthcare projects, then the field of lean production has tremendous relevance to understanding the flow characteristics of information movement. Initially developed as the Toyota Production System for the manufacture of automobiles, lean production is a production system that centers on efficient flow as the means to dramatically reduce the cost of production, and greatly increase the quality and customer value in their cars. Womack and Jones (2003) in their seminal work, “Lean Thinking,” articulate three major flows in any production or service operation as being: 1) flow of materials, 2) flow of labor, and 3) flow of information needed throughout the chain of production from raw material to finished product. While lean production has been implemented and researched in construction for over ten years, there is limited emphasis in the use of this approach to understand or manage information flow issues. Nevertheless, the magnitude of improvements achieved at Toyota and others having adopted the lean approach, means that the characteristics of lean information flow need to be studied in the sustainability of healthcare facilities.

1.6 Research Aims

Building sustainable healthcare facilities is an idea whose time has come. The inherent complexity of healthcare projects makes incorporating high levels of sustainability very challenging and difficult to justify in the face of short-term fiscal realities. This often results in poor sustainable decision-making or jettisoning sustainability altogether despite its real and largely proven benefits to the mission of healthcare institutions. At the heart of this problem lie information flows, which are the lifeblood of sustainable projects. Yet, in construction management little is really known about such information flows.

This research seeks to: 1) understand the social and technical factors affecting information flows on construction project interactions and 2) develop a conceptual model that provides a means for describing these interactions so that they can be improved upon. These contributions provide the necessary foundation for more focused research on information flow in construction projects could take place, including lean process improvement.

From data collected during a three-year ethnographic field study, this research has developed a comprehensive description of project environments, understanding of interactions between entities, and other information behaviors to better understand information flows in these complex project environments. This greater understanding is then used in conjunction with the principles of lean production management to outline means of improving information flow. Through improved information flow, the AEC industry can more effectively deliver facilities and incorporate innovations, such as sustainable design and construction methods, on already complex projects.

The following chapter of this dissertation describes a review of the literature that identified the specific research questions. Chapter three describes the ethnographic field study and qualitative analysis methods used in this investigation. Because this methodology is based on having the research topic emerge from the data rather than being tightly prefigured, chapter four summarizes the observations from the field study and performs initial analyses to begin ordering and categorizing them. Chapter five uses illustrations from the field study and a review of supporting literature from related fields to lend internal and external validity to the constructs. Chapter six discusses the application of the constructs to the lean production management framework and develops a comprehensive description of the integrator roles. Chapter seven concludes by outlining the contributions that this research provides to academia and industry and the future research questions.

Chapter 2

Literature Review

This chapter outlines the background research that contributed to the development of the research questions and form the basis for this dissertation. One of the aspects of the methodology that was chosen, is that theories and constructs emerge from the data and are continuously evolving based on new information from complimentary research, further analysis, and additional data collection. For that reason, this chapter only addresses the first step in that process, the development of the research questions. In order to better understand the observations from the field study, they were comparing with reviews of relevant literature from the construction management, organizational science, and information science fields. This comparison enabled the author to link field observations to existing theory, but more importantly to identify gaps in the existing literature. Once this initial review of literature was conducted and specific research questions were developed, then further data collection and analysis focused developing a hypothesis to answer the research questions. Subsequent chapters will address how the data and analysis helped to arrive at the final hypothesis.

This literature review began with a review of research related to the greening healthcare and progressed to trying to understand how new information and innovations are adopted by organizations. Because of the limited research related to innovation and information flow specifically for construction project teams, the literature review expanded to included research from the domains of organizational science and information science. These related domains provided valuable theoretical constructs that shed some new light on certain AEC literature, linked disparate AEC research areas, and identified gaps in the AEC literature. However, much of the organizational science and information science literature was not directly applicable to the AEC industry because of the differences between construction project teams and traditional organizations. Therefore, the research questions that emerged were in part necessary to establish enough of a basic understanding of information flow in the construction project teams so that the extensive literature in related fields could be used to expand the understanding of construction management.

2.1 Greening Healthcare Facilities

In the last decade, sustainable design and construction have become standard best practices in the architecture, engineering, and construction (AEC) industry. Consequently, sustainability research and "green" product development has become one of the most significant sources of new information in the building industry. Many government agencies, academic institutions and corporations have realized the value of green facilities in terms of improved productivity, reduced energy costs, and the moral obligation to reduce the negative effect that the buildings have on the indoor and exterior environments. Due to the critical nature of their operations, healthcare facilities have an even greater responsibility to build facilities that not only reduce negative effects of buildings on the environment and building occupants.

In order to better position themselves with respect to the greening of healthcare facilities, the Penn State Lean and Green Research Initiative (L&G) conducted three phases of initial data collection to get a pulse of what was going on in the industry. The first involved surveying members of the AEC industry to get their perceptions regarding sustainability and healthcare facilities. The second was to assemble members of the AEC industry, healthcare industry, and academia to discuss what research areas would most benefit the AEC and healthcare industries.

The third component was a review of the existing academic and industry literature regarding the role of design and construction on clinical outcomes.

2.1.1 Healthcare Facility Delivery Conference Surveys

In the fall of 2005, the Design-Build Institute of America (DBIA) held a series of regional conferences targeting designers, contractors, and owners that were specifically focused on the delivery of healthcare facilities. In conjunction with the DBIA conferences, Penn State collected survey data from conference attendees. Respondents were asked to select from a provided list of answers regarding the following questions: 1) The benefit of green healthcare facilities that is the most important to them; 2) The two research questions regarding facility performance and green healthcare facilities that are most important to them; 3) The two research questions regarding building occupant performance and green healthcare facilities; and 4) The two greatest barriers to the design and construction of green healthcare facilities. The survey results demonstrate that lower operating costs and improved clinical outcomes are the two main reasons for pursuing green healthcare facilities. These are expected results, however the survey also showed that perceived higher costs of design and construction, current delivery and contracting practices, and facility complexity are the biggest barriers to greening healthcare facilities. Despite overall general alignment of view, there are significant differences in how designers, contractors, and healthcare providers view the benefits, needed research, and barriers related to green healthcare facility design and construction.

2.1.2 Greening Healthcare Roundtable

In late October 2005, the L&G collaborated with other organizations to host a roundtable discussion focused on the greening of healthcare facilities. The roundtable consisted of a consortium of over 40 academics, design and construction professionals, healthcare professionals, and healthcare-related non-profit organizations to try to gain a more detailed understanding for what the major issues were regarding implementing sustainability measures in the design, construction, and operation of healthcare facilities. The consortium decided that the major areas that needed research were the: 1) Relationship between facilities design and clinical outcomes; 2) Cost-value relationship for green features; 3) Development of a more holistic basis for decision making; 4) Need for a data repository for research and industry findings; 5) Development of more appropriate active and passive research methods; 6) Understanding of interdependencies between systems; 7) Minimization of process and material waste; and 8) Means to implement research findings (Phelps et al, 2006).

2.1.3 Greening Healthcare Literature Review

In addition to the data obtained from the industry members through the surveys and roundtable discussion, there was also a review of the available tools, resources, and publications related to the improvement of clinical outcomes through improved design and construction of healthcare facilities. These resources come from a variety of sources including academia, industry, and advocacy organizations and are summarized below.

A combined effort between Texas A&M University and Georgia Tech reviewed over 600 studies that link healthcare performance outcomes to some aspect of design. These studies linked design features such as single occupant rooms, reduced noise, improved lighting and ventilation, and spatial layouts with reductions in medical errors, stress, and pain medication while increasing other types of positive clinical outcomes. The results of this meta-analysis found that facility design can: 1) Reduce staff stress and fatigue and increase effectiveness in delivering care; 2) Improve patient safety; 3) Reduce stress and improve outcomes; 4) Improve overall healthcare quality (Ulrich & Quan 2004). Other research has shown that the actual construction processes employed in the delivery of healthcare facilities can improve outcomes such as infection control (e.g. Stockley et al, 2006).

Industry professionals and industry advocacy groups have also developed references to support the implementation of green design and construction practices in the delivery of healthcare facilities. Karlsberger, the designers of the first LEED Platinum Hospital, has made available through their website a series of white papers as part of their Knowledge Paper Series based on information from their leading edge experiences in greening healthcare facility planning and design. The first paper in the series outlines the five overarching trends in pediatric hospital design as: 1) Flexibility; 2) Patient Safety; 3) Optimal Healing Environment; 4) Technology Integration; and 5) Security and Disaster Preparedness (Karlsberger, 2005). Other papers deal with discoveries that have influenced Children's Hospitals, evidence-based healthcare design decisions, and design of laboratories and emergency departments (www.karlsberger.com).

The need to design for future flexibility has become one of the most important issues in sustainable hospital design. With rapidly changing medical technologies and patient needs, many healthcare facilities are becoming obsolete after 15-20 years. Other industry professionals have echoed the needs to design for flexibility as one of the main measures for delivering sustainable healthcare facilities (e.g. Pressler 2006). Another reoccurring theme in healthcare design that is shared by sustainability is the need to design facilities to optimize the occupant health and productivity. The American Academy of Healthcare Interior Designers recently convened a forum of industry vendors and their clients to discuss current trends in the design of healthy indoor environments. Some of their major areas of focus were on improving both the patient and staff experiences and making use of evidence-based design (Solovy, 2006).

Healthcare design advocacy groups and other special industry task forces have also taken steps to consolidate sustainable design best practices and package them so that they can more easily be assessed and implemented. The Center for Health Design (www.chd.org), in their Pebble Project, has assembled information from over 200 actual healthcare facility new construction or retrofit projects and compared the before and after affects on patients and staff. Much of the information from these studies has been developed into reference materials available through their website and in various publications (e.g. Berry et al., 2004). Another comprehensive tool available to the AEC industry is the Green Guide for Healthcare (GGHC). This tool provides the AEC industry with a voluntary, self-certifying guide of best practices regarding the design and construction of high-performance healthcare facilities. The GGHC is based on the well-established LEED NC Guidelines for commercial construction but also includes many of the findings that resulted from the Center for Health Design's Pebble Project. The GGHC formally ties together the many complimentary goals of green building and healthcare to provide a building guide that not only results in a better building, but one that promotes healing, reduces environment-related stress, improves productivity, and prevents sickness through more responsible interaction with the surrounding natural environment.

There is no shortage of information regarding greening of healthcare facilities or evidence to suggest that implementing these practices could result in an improved facility. The challenge seemed to be in getting design and construction teams in the AEC industry to take a chance and adopt these innovations into their projects. With very complex projects such as healthcare facilities, most project teams are even more risk-averse and cautious about doing anything differently than they have been on past projects. At the heart of getting projects to pursue green strategies lies the more basic question of how to get project teams to incorporate any type of innovation or new information into an already complex project.

2.2 Organizations and Innovation

At a basic level, incorporating new sustainability information into the design and construction of healthcare projects is an issue of innovation for the project team. Therefore the literature in the organization and innovation field provides some important background and insight to the issue of this dissertation. The need for innovation, whether it is products or service innovations, processes, organizational/structure innovations, or decision making practices, comes when there is a perceived difference between an organization's potential and their current state. This can be based on current poor performance or based on satisfactory current performance but a belief that performance can be improved. Zaltman et al. (1973) characterize these as distress innovations and slack innovations, respectively. Distress innovations are a response to poor performance and result in an organization looking internally for ways to cut costs. Slack innovations are not developed to address pressing problems, but rather occur when an organization is looking to enhance their goals, status, or prestige (Zaltman et al., 1973). In both cases, the decision whether to pursue an innovation becomes a strategic decision and has to account for the following (Zaltman et al., 1973):

- Economics such as initial cost, continuing cost, social approval cost, rate of cost recovery, payoff, and the period until the innovation becomes obsolete
- Complexity of the ideas or actual implementations and how easily they can be communicated
- Disruption to existing behavioral patterns (Robertson, 1971)
- Effect on interpersonal relationships within the organization and between organizations
- Compatibility with existing values, experiences, and processes
- Whether the innovation that enables opportunities for other innovations
- Perceived visibility of the risk or advantage
- Degree of commitment required for successful implementation
- Reversibility or ability to pursue phased implementation

Once the decision has been made to implement an innovation or change, there arises the question of what is the best means of implementation. Contingency theory suggests that the success of an organization is contingent on good alignment between the environment and the organizational strategy and structure. The challenge becomes defining the organization's internal factors, the demands of the environment, best adaptation, and best fit. In the organizational sciences, there are two schools of thought regarding this issue. The first is the innovation can be most effectively implemented by modifying the project team structure and the corresponding strategy will emerge (Rumelt, 1974; Mintzberg, 1979). The rationale behind this is that different structures create different managerial cognition and skill sets among managers subsequently influencing the development of strategy (Prahalad & Bettis, 1986). The other school of thought is that organizations modify their strategy and the organizational structure will adapt to fit the change. This is mainly driven by economic efficiency since certain strategies create specific technological, financial, and personnel needs which then require certain organizational structures. Still other researchers have found that strategy and structure both affect each other simultaneously (Amburgey & Dancin, 1994).

Although there has been significant research regarding environment-structure-strategy alignment for traditional organizations, none of it is directly applicable to the unique situation of project teams in the AEC industry. In order to better understand the issues facing construction project teams, a review of relevant organizational science literature and a review of AEC structure and strategy research were performed. Summaries of both organizational sciences and construction management literatures are described in the following sections.

2.2.1 Structure

Organizational science research has explored the interaction between multiple firms in a given environment, and has produced a spectrum of descriptive structural models. Burns and Stalker (1961) indicate that in fairly certain and stable environments, mechanistic types of organizations, such as hierarchies, are most suitable. Hierarchies are characterized by clear lines of authority and departmental boundaries, detailed reporting mechanisms, formal decision making procedures, and situations where management replaces supply and demand. Although the strength of hierarchies lies in their reliability and accountability, they are unable to easily deal with sharp fluctuations in demand or unanticipated changes.

However for more unstable, constantly changing environments where there is a diffusion of authority and multiple parties are responsible for decision making, more organic types of organization, such as markets, are most appropriate (Burns & Stalker, 1961). Markets result from spontaneous coordination between firms based on rational and self-interested actions. While they are very open, markets require limited personal involvement and do not establish strong bonds of altruistic attachments. Markets offer choice, flexibility, and opportunity and create an environment well suited for fast, simple communication and coordination but not necessarily integration. Markets are also highly dependent on prices which are often too simple of a mechanism to capture the intricacies of idiosyncratic, complex, and dynamic exchange. As a result, markets are poor devices for learning and the transfer of technological knowledge (Powell, 1990).

Networks are hybrid systems that borrow structural components from both markets and hierarchies. In networks, transactions occur through groups of individuals engaged in reciprocal and mutually supportive actions. Networks can be complex since an entity is defined by its relationship to other entities. The basic assumption in network theory is that each entity is dependent on the resources controlled by another entity and that by pooling their collective resources everyone can benefit. Essentially, each entity agrees to forgo their right to pursue their own interests at the expense of others so that both benefits and burdens are shared. Networks also rely heavily on exchanges of roughly equivalent value or unbalanced exchanges coupled with indebtedness and obligation which reinforce the connections between firms.

Although the organizational science categorizations of multi-organization structures are useful at a conceptual level, the specific characteristics of construction project teams make direct application of these concepts difficult. There are aspects of hierarchy, market, and network structures that exist in both the design and construction phases, but the actual relationships that result seem to depend on numerous other factors. In order to be able to apply the wealth of relevant information from the organizational sciences, Section 2.2.3 strives to better understand the characteristics of the temporary organizational structures created for construction projects.

In the AEC research literature, there have been numerous studies exploring the effect that multi-organizational contractual structures (i.e. project delivery methods) have on the traditional metrics of cost, schedule, and quality. Most notable is the seminal Konchar and Sanvido (1998) study comparing the three common delivery methods: CM at risk, design-bid-build, and design-build. This study found empirical support across a sample of 351 U.S. building projects that design-build projects performed significantly better than CM at Risk and Design-Bid-Build projects in cost and schedule and faired equal or better in terms of quality (Konchar & Sanvido, 1998). Other than recent studies on partnering, consortia, joint ventures, and special purpose vehicles (Gruneberg & Hughes, 2006), there have not been many studies that look at the role of delivery methods or project organization structure on innovation for larger complex projects. One exception is Pulaski et al. (2003) who showed that the combination of integrated organizational structure and design-build performance contracting improved the implementation of sustainability and constructability knowledge, especially when the two efforts were integrated.

There has been some research regarding the role of organizational structure on small, simple projects. Cheng et al. (2003) looked at determining the optimal project organizational structures based on creating the most efficient communication and coordination relationships between project team members for small teams and simple projects. Dias (1990) determined that for small project teams, a circular organizational structure with high degree of informal interaction and the project manager in the central role (as opposed to apical) is most effective.

Other studies have looked at the organizational structure of specific firms and its effect on enabling improved performance and increased innovation within the firm (e.g. Kenner & Isaak, 2004; Rebeiz & Salameh, 2006). For example, Kini (2000) observed that multi-national design firms need to develop organizational structures that match their expertise in a cost effective manner (e.g. minimize overlapping work, using the full capacities of their existing resources, and enable employees to continually broaden their skills). However, AEC research on organizational structure and innovation has been limited to either small projects or to the context of a single firm and fails to address the complexity of larger construction projects and how to incorporate new information and innovations into them.

2.2.2 Strategy

The other perspective on how organizations can enable innovation is the strategy-based view. One of the primary aspects of adopting innovation is that it requires significant learning on the part of the interested organization and, therefore, the development of learning-based strategies. This section describes the breadth of learning-related organizational strategies that have been developed in the organizational science research and then focuses on the learning-related strategies in the AEC industry.

2.2.2.1 Learning and Strategy in Organizational Science

In order for organizations to survive in changing business environments, they need to be able to understand environmental conditions, learn how those conditions affect their organization, and adapt their structure and strategy accordingly. March (1991) identified exploration and exploitation as the two main types of learning. Exploration involves more distant search for new capabilities whereas exploitation involves local search that builds on a firm's existing capabilities (March & Simon, 1958; Weick, 1969). The type of learning that an organization decides to pursue has an affect on the type of innovations that they adopt (March 1991). For example, in their study of companies adopting process improvement techniques (e.g. Six Sigma), Benner and Tushman (2002) found that process improvement techniques influence a firm's propensity for exploration and exploitation. They found that although exploration is influenced through activities such as improvisation and brainstorming, in many cases cultures of continuous improvement tend to dampen exploration because of its uncertain and distant payoffs. They found a higher propensity for exploitation innovation which makes use of incremental learning and greater coordination and interdependence that come with process management.

One aspect of developing strategies for organizational learning is understanding the drivers for learning and what kind of systems can be developed to enable learning within an organization. From Srivastava's (1983) typology of learning organizations and research by others, several causes of learning have been identified:

- Adaptation to changes in the environment (e.g. Cyert & March, 1963)
- Development of common values and cognitive assumptions (e.g. Argyris & Schon, 1978)
- Development of a common strategy, approach, and goals (e.g. Duncan & Weiss, 1978)
- Learning through repeated experience (i.e. the experience curve)
- Learning based on research and development (Powell et al., 1996)

He goes on to classify six different types of learning systems that develop within organizations as a result of the causes outlines above. These consist of: 1) A single person that acts as the coordinator and is knowledgeable about all aspects of the business (Mintzberg, 1979); 2) Organizational myths and stories; 3) Information seeking cultures; 4) Participative learning systems (e.g. creation of ad hoc committees); 5) Formal management systems; and 6) Bureaucratic learning systems (e.g. corporate training programs).

At a more basic level, it is also important to understand how learning actually occurs. Ingram (2002) breaks interorganizational learning down into three main components: the sender, the receiver, and the relationship between them. Podolny and Stuart (1995) found that it is not just the quality of the knowledge, but also the characteristics of the sender, specifically status, that affect whether others are receptive to it. Similarly, other studies have also found the size and success of the sender organization to affect receptivity of information (Haunschild & Miner, 1997). The characteristics of the receiver also determine the effectiveness of information exchange and learning. Hamel (1991) found that the two most critical receiver characteristics were their intent (i.e. desire to learn) and their receptivity (i.e. their ability to learn). In their conceptual development of "absorptive capacity," Cohen and Levinthal (1990) argue that learning is cumulative and the receiver's ability to make use of new outside information is largely a function of the level of prior related information (e.g. skills, shared language, shared beliefs). In terms of the relationships between sender and receiver organizations, Darr et al. (1995) found that regular communication between organizations increased the opportunities to share knowledge. Other studies have found that the establishment of personal acquaintances between members of different organizations created levels of empathy, familiarity, and trust which also aid the exchange of information (Uzzi, 1996; Ingram & Simons, 1999). The research to date strongly suggests that interorganizational learning is most effective through more integrated relationships rather than arms-length relationships (Ingram, 2002).

2.2.2.2 Learning and Strategy in the AEC Industry

Most innovations in AEC industry involve using known ideas that are available to anyone, so the innovation is not in the idea, but the decision to use it (Nam & Tatum, 1992). They also found that the two major deterrents to innovation in U.S. projects are heavy emphasis on demand-side factors (i.e. owners' requirements) rather than supply-side factors (i.e. technologies available to professionals) and the lack of research and development in construction innovation (Nam & Tatum, 1992). Kangari and Miyatake (1997) outline the major factors that contribute to the development of innovative technologies in Japan: 1) Strategic alliances between construction firms and manufacturing/scientific organizations; 2) Effective information gathering regarding trends and competition within the industry; 3) Developing and maintaining a reputation for innovation; and 4) Technology fusion with ideas from other industries.

Based on the industrial engineering concept of design for manufacture, design for construction involves soliciting constructability input from contractors during design development. Variations of this concept include integrated project delivery methods such as design-build and design-assist, "value engineering", and increased prevalence of constructability reviews. The rationale behind this strategy is that the best time to influences project cost is early in design (Paulson, 1976; Jergeas & Van der Put, 2001). Several researchers have developed tools and classification schemes to better enable the implementation of constructability knowledge (e.g. Fisher & Tantum, 1997; Hanlon & Sanvido, 1995; Pulaski & Horman, 2005). The challenge is that the majority of constructability knowledge (i.e. 83%) is tacit is not captured in any written form which presents difficulties in transferring that knowledge to designers (Hanlon & Sanvido, 1995). This difficulty illustrates why the use of more integrated project delivery methods provide significant opportunities for improved project outcomes.

Continuous process improvement strategies from manufacturing have also permeated the AEC industry. Specifically, the lean construction strategies stems from application of the lean production management principles made famous by Toyota Motor Corp. Lean principles seek to maximize the value generated by processes by eliminating waste or non-value adding activities. Lean considers the three flows of materials, labor, and information. Some of the greatest potential benefits of lean construction are reduced flow variability, reduced process variability, transparency, and continuous improvement (Jung, Kang, & Choi 2006).

In lean manufacturing, techniques such as *kanbans* and *andon boards* are used to facilitate fast, effective information flow regarding unambiguous issues such as the need for more materials or the presence of a problem (Liker, 2004). While these techniques enable manufacturers to efficiently produce products “just-in-time” and can be useful for the construction phase, they are not as effective for more ambiguous and subjective information flows that occur in planning, design, and coordination. With respect to construction, Lapinski et al. (2006) used lean principles and comprehensive process mapping to examine the delivery of sustainable building projects. Ballard (2000a) used lean principles to develop a strategy of avoiding premature decision making by deferring commitments until the last possible moment to reduce waste and maximize value. Tools such as Last Planner begin with reverse phase scheduling which asks the people accountable for the completion of an individual task how long it will take them and then works back into an overall schedule (Ballard, 2000b). Reverse phase scheduling minimizes the wasted time and effort resulting from late completion of one trade that can affect the overall performance of the project.

Although these strategies provide useful practices for improving information flow and implementation of innovation on projects, they only implicitly address the whole social side of the construction industry. Design and construction is a socio-technical process and relies just as heavily, if not more heavily, on social aspects of interaction in addition to technical aspect. The following section describes some of the key features of construction project teams and provides a better context for understanding the need for social and socio-technical research in construction.

2.2.3 Project Teams as Temporary Organizations

As was stated previously, there is a wealth of organizational science research pertaining to the management of organizations, but most of these studies deal with traditional single-firm organizations. While this information may be directly applicable to the parent firms involved with construction projects themselves, the individuals that make up construction project teams also constitute a unique type of organization. Although there are many characteristics that make construction project teams different from more typical organizations, one of the most unique characteristics is the temporary nature of the project teams.

Both design and construction phases of building projects are characterized by a network of multiple firms working together for a relatively short period of time (i.e. a single project). The design phased typically lasts 6-18 months with construction lasting anywhere from 1-3 years depending on the complexity of the project and other factors. In many cases, the firms working together have no direct contractual relationship with each other (e.g. subcontractors). This temporary nature of construction project organizations may be the most significant factor that distinguishes them from more traditional organizations. Goodman and Goodman (1976) define a temporary system as a set of diversely skilled people working together on a complex task over a limited period of time. The short timeframe for collaborations that these project teams experience changes the nature of how they interact with each other. There have been a handful of studies on temporary partnerships, but they are limited to the movie industry (Faulkner & Anderson, 1987; Baker & Faulkner, 1991), knitwear (Lazerson, 1995), bio-tech (Pisano, 1989), investment banking (Baker, 1990), and typical construction projects (Bryman et al., 1987).

Because of the relatively short period of interaction among temporary organization members, there are certain aspects that differ from more long-term interactions. Bennis and Garwood (1983) viewed the fostering of collaborative relationships as the prime function of leadership in temporary systems, which result in more emphasis obtaining suitability and compatibility of personnel. In the absence of previous working relationships, a period of "getting to know each other" is important for individuals to adapt to the procedures, approaches, philosophies of working, and behavioral tendencies of others and their parent organization. This adaptation period is often governed by the contractual relationships between parties, in terms of who adapts to whom and why. As the Bryman et al. (1987) construction study illustrates, subcontracting introduces some difficulty because it fragments involvement within the "team" and puts considerable emphasis upon the need for temporal coordination in developing inter-organizational relationships. For example, by the time subcontractors have gone through the organizational learning curve, they are done with their scope and move on to another project so there is little time for the internal processes that are critical for the development of relations.

2.4 Information Behavior

Because of the fast-paced and temporary nature of project teams, the effective management of information plays a critical role in all aspects of construction projects, especially complex projects. In understanding how people use information (i.e. information behavior), the AEC research community has benefited from certain aspects of research in the information sciences. There are two areas of information science research in particular that are relevant to these situations: collaborative information behavior (CIB) and computer-supported collaborative work (CSCW). In addition to a review of AEC information systems research, the following section also provides insight into the relevant topics from the information sciences.

Information science is a multidisciplinary field that pulls mostly from cognitive and social sciences to explore the ways in which information is gathered, analyzed, disseminated, and used between people, organizations, and within systems. Wilson (2000) defined information behavior as the totality of human behavior in relation to sources and channels of information including both active and passive information seeking, searching, and use. In the AEC industry, there have been many research efforts concerned with developing technological tools and strategies to manage information, however there is scant research regarding actual information behavior within projects. While there are increasing initiatives to study information behavior in construction, information sciences research provides a useful background to understanding these issues, specifically the research in collaborative information behavior may be particularly relevant to the construction industry.

2.4.1 Information Management in the AEC Industry

Similar to the AEC research on organizational structures and innovation, the literature on knowledge and information management is heavily focused on the parent firms rather that actual construction projects. Chinowsky and Molenaar (2005) apply many of the concepts in organizational learning theory to the construction industry. They outline reasons for construction to adopt more of a learning organization culture, specifically: 1) Better performance due to having a better educated workforce; 2) Capture of tacit knowledge from an aging workforce; 3) Globalization and the need to disseminate knowledge; 4) Development of more effective and efficient solutions to client problems; and 5) Evolution and growth of the industry. Additional studies have made the business case that more effective management is that it will increase revenue, shorten design and construction times, improve customer satisfaction, and promote market leadership (O'Dell, 2000; Mertins et al, 2001). A survey by Robinson et al. (2001) of engineering and construction companies in the U.K. outlined the main drivers for better knowledge management as the need to: 1) Encourage continuous improvement; 2) Share valuable tacit knowledge; 3) Disseminate best practices; 4) Respond to customers quickly; 5) Reduce rework; and 6) Develop new products and services

Because of its project-based and tacit nature, AEC firms face challenges regarding knowledge management. Many studies primarily focus on explicit or technical solutions to knowledge management in AEC firms, such as map-based knowledge management systems (Lin et al., 2005), systems to identify barriers to knowledge management (Al-Ghassani et al., 2006), software tools that enable to capture and retrieval of relevant knowledge (Khalfan et al., 2003), and the knowledge worker system (Augenbroe et al., 2001). Despite the research focus on technological solutions, Kamara et al. (2002) cite that the preference within the AEC industry for people-centered strategies in knowledge management and that effective management requires an integration of both technological and social systems. Regarding actual projects teams, there are many characteristics that make information management difficult. Specifically, there are the contractual concerns that there is not enough time, not enough money, not "in my scope", and is not viewed as mandatory. In addition, there are the cultural problems of risk-averse teams adopting cautious approaches to new management ideas, the "not invented here" culture, and a protective "knowledge is power" culture (Carrillo & Chinowsky, 2006).

Despite these barriers, construction research has developed various methods for managing information. Austin et al. (2002) have focused on improving management of information in the design phase. Based on the design structure matrix, their experimental software seeks to identify the optimum sequence of design activities based upon the dependency and availability of design information as defined by the design process model (Austin et al., 2002). Other models developed for concurrent engineering include the Design Process Evaluation Model (Abdul Hassan, 2001). The Conceptual Product/Process Matrix Model developed by Pulaski and Horman (2005), organizes constructability knowledge based on the appropriate timing and level of detail. This model helps to reduce unnecessary discussion and evaluation resulting from information supplied too early as well as rework and missed opportunities that result from information being provided too late. The Building Design Process Model for high performance projects ($BDPM^{HP}$) developed by Magent et al. (2005) outlines a process for delivering a project while maximizing value and minimizing waste.

All of the models, technologies, and strategies that have been developed treat information as an explicit entity that has clear and unambiguous meaning to all those interacting with it. These studies neglect to consider the behaviors surrounding information use especially within collaborative groups. Even in the information sciences, most research has only considered individual information behavior. In the last twenty years, however, there has been increased research regarding collaborative information behavior as networks of small multi-disciplinary teams become more prevalent.

2.4.2 Collaborative Information Behavior

For complex situations, different information is located in different resources but needs to be combined to meet the goals of the project. This information fragmentation results in the need for collaboration similar to how increased specialization and differentiation require greater integration (Lawrence & Lorsch, 1967). However, the nature of collaboration results in human information behavior that is different from how a single individual would seek, gather, process, and apply information.

Collaborative information behavior is defined as “activities that a group or team of people undertakes to identify and resolve a shared information need” (Poltrock et al., 2003, p.239). There are a few key points that make collaborative information behavior (CIB) distinct from individual information behavior (IIB). IIB focuses on a question and its answer and often the searching (i.e. information retrieval) is the last step before finding the answer. In CIB, the focus is not only on questions and answers but also in tying together different pieces of information to find answers. CIB is often driven by complexity and requires members to divide the tasks and focus on a specific part and using information retrieval systems (i.e. searching) is often one of the first steps. Blake and Pratt (2006) have researched the concept of collaborative information synthesis in the context of scientists. Their findings categorized the process for collaborative information seeking into five basic steps: 1) Defining the appropriate question; 2) Searching literature; 3) Assessing the retrieved studies; 4) Combining results from the studies; and 5) Placing the findings in context. Because of the multi-disciplinary nature of these teams and the distinct but complimentary skills that each individual brought to the group, all of these steps were found to require significant levels of collaboration.

As an issue becomes more nuanced and complex, there is a greater need for collaboration, especially where numerous areas of expertise are needed. Whether the situation is an appropriate context for IIB or CIB depends on the complexity of the problem, number of agents interacting, and the nature of the interactions. Specifically, the triggers that cause a shift from IIB to CIB include: 1) Higher complexity of information needs; 2) Environments where information resources reside in multiple systems (i.e. fragmented); 3) Involvement of individuals that do not have the prerequisite knowledge to answer a question; and 4) Lack of immediately accessible information.

Computer-supported cooperative work (CSCW) is another research area that attempts to understand collaborative information behavior. CSCW considers how collaborative activities and their coordination can be supported by technology (Carstensen & Schmidt, 2002). This not only focuses on the tools and techniques used in collaboration, but also the psychological, social, and organizational effects of those tools and techniques. In CSCW, there is a distinction between collaboration and cooperation. Both require that tasks be distributed, but cooperation allows for tasks to be split into independent subtasks while collaboration attempts to construct and maintain a shared concept of the problem (Dillenbourg et al., 1996). Any time that tasks are split into subtasks, there is a natural need for communication which is defined as “the management of dependencies between activities and the support of (inter)dependencies among actors (Bordeau & Wasson, 1997).

Other industries, such as business management and healthcare delivery have greatly benefited from improved knowledge of information behavior and the subsequent information flows within their socio-technical environments. Using grounded observational methods, such as ethnography, researchers have been able to better understand the complex behaviors and interactions that occur in collaborative environments.

2.5 Development of Research Questions

The focus of this research began as an exploration of how to enable the green design and construction of healthcare facilities. A major obstacle to accomplishing that aim is introducing new and innovative information into an already complex and information-intensive project setting. The cognitive limitations of humans make processing large amounts of new information a challenge. While information technologies, such as software, frameworks, and formal processes, help to manage some of that information, the nature of construction projects relies heavily of the understanding and management of social factors.

This review of literature from AEC research and related fields has provided some valuable insight into the technical and social aspects of information flow. However, it has also revealed some important gaps in the research that need to be addressed to further our understanding of these phenomena. While the information science, social science, and organizational science research is more mature in addressing the social and socio-technical aspects of information flow, human-technology interaction, team dynamics, and team effectiveness, the findings are not directly applicable to the construction industry due to the unique characteristics outlined in Section 2.2.3. On the other hand, while the AEC research is specific to construction projects, it focuses primarily on technical or contractual strategies and does not adequately address the social and socio-technical aspects of information flow.

These gaps outline a clear need for AEC research related to the social and socio-technical aspects of information flow. This issue is at the heart of enabling the implementation of sustainability and other innovations in projects which are already sufficiently complex but could benefit most from such innovations. Understanding these aspects are also the gateway to allowing AEC research translate of the wealth of knowledge that already exists within organizational sciences, information sciences, and related social sciences so that it can be effectively applied to construction projects. To address this need, the main questions that this research seeks to address are:

- What are the social and technical factors influencing the effectiveness of information flow on complex construction projects?
- How are these factors interrelated?
- Can a model be developed to explain and evaluate information flow management strategies so that they can be improved?

Throughout the following chapters these questions will be explored. Chapter four outlines the observations and analysis of data, the conceptual models that resulted from those analyses, and a review of research from other fields that supports the conceptual model. Chapter five uses several descriptive accounts from the field study to illustrate how these conceptual models can be used to explain effective and ineffective examples of information flow. Chapter five also outlines the need for certain roles and responsibilities related to using these concepts to better integrate the project team to provide more effective information flow. Finally, the concluding chapter, chapter six, summarizes the findings of this research, outlines the major contributions to the AEC research community and industry, and outlines additional research topics that are needed to continue building upon this valuable research.

Chapter 3

Methods

The following chapter outlines the research methods used to conduct this research. The nature of the research questions developed in the previous section requires the use of observation-based qualitative methods that are described in this chapter. With qualitative methods, it is important to understand that there are certain methods that were used for data collection and other methods used for analysis. Ethnographic methods were used for data collection. Grounded theory was then used to analyze the ethnographic data. As with all observation-based qualitative research, it is also important to understand the sociological perspective of the observer because this is the lens through which the data is collected. Because these methods are not commonly used in construction research, the three aspects of the research methodology are described in detail in the following sections. The second section describes how these methods were used in the field study.

3.1 Qualitative Theory-Building Methods in Construction

The following section provides an overview of the methods used to perform this research. Because the utilized methods are not commonly used in construction research, this section includes the rationale for using qualitative methods, a detailed description of ethnographic data collection methods, a detailed description of analysis using grounded theory, and the underlying sociological perspective that provides the basis for these methods.

3.1.1 Rationale for Qualitative Methods

Traditional construction research methods have enabled focused, and narrow, advances in our understanding of complex and critical issues facing the industry such as making use of new technology or the integration of design and construction. Because of the complex reality of these situations, many traditional research methods attempt to simplify phenomena so that singular components can be observed, described, modeled, and predicted while controlling for extraneous variables. One consequence of this simplification, however, is that complex interactions that influence many of the industry's pervasive socio-technical (i.e. both social and technical in nature) problems still are not well understood.

Ineffective information flow is one of these highly complex problems that are pervasive within the industry (Davidson, 2004). As a consequence, there have been calls from within the industry for researchers to explore the use of non-traditional methods needed to understand these sorts of socio-technical issues. Shield and West (2003) pointed out that current construction research methodologies neglect consideration of social factors, especially in issues involving the implementation and adoption of new technologies. Other researchers have also called for the academic construction community to encourage the use of complimentary data collection and analysis methods to balance out the significant industry bias toward quantitative reporting mechanisms (e.g. Sobel, 1996). These complimentary methods have the ability to more accurately consider social factors that cannot be accurately observed through more traditional construction research methods (e.g. experimental, survey, and case study based empirical methodologies).

Due to the socio-technical nature of the author's research questions, qualitative research methods were used for this research. Specifically, ethnographic methods were used for data collection and grounded theory was used for analysis of the data. Both of these methods are described in detail in the following sections. These methods enabled this research to capture an understanding of the underlying social and socio-technical issues surrounding information flow on complex construction projects.

3.1.2 Data Collection: Ethnographic Methods

Ethnography, or the study and systematic recording of social environments through participant observation, is a method of observing subjects of research in their natural setting. In order to observe individuals' natural behaviors, these studies require longer observation periods (i.e., months or years) to minimize the externally imposed variation caused by having an observer present. The detailed experiences collected during these long durations give researchers a rich understanding of complex phenomena that occur within that specific social environment. Through long-term participation and observation, researchers can develop an understanding of more than just the explicit meaning of words, actions, and artifacts. By having such intimate knowledge about the "society", ethnography enables researchers to understand the tacit meaning that is implicit in the word, actions, and artifacts used by a society.

3.1.2.1 Precedents for Ethnography

Although used very seldom in construction research, ethnographic methods have enjoyed more widespread and influential use in the social sciences, organizational sciences, and information sciences. Ethnographic research has been effective in sociological research to understand issues such as the formation and organization of gangs (Whyte, 1993) and the treatment of skid row men by the jail and legal system in the 1960's (Spradley, 1970). In the study of organizational behavior and management, ethnography has been used in numerous top business journal publications regarding studies in: the evolution of structure and control in newly formed self-managing teams (Barker, 1993); norms developed by bill collector regarding expression of emotions to debtors (Sutton 1991); barriers and opportunities that knowledge creates regarding innovation in new product development (Carlile, 2002); cultural conflicts in multi-culture organizations (Gregory, 1983); and risk and blame in disaster sensemaking (Gephart, 1993). Ethnography has been extensively used in the information sciences to understand collaborative information behavior and computer-supported cooperative work (e.g., McDonald and Ackerman, 1998; Orlikowski, 1992; Reddy et al., 2001). In construction research, there have also been a number of innovative researchers used ethnographic methods, (Table 3-1).

Table **3-1**: Sample of Publications in Construction Journals Using Ethnography

Classified various types of proactive and reactive means by which contractor issue claims for additional payments. They also found that the "culture of claims" stems from the high level of competition within the industry and the need to bid low and make up profit elsewhere.	Rooke et. al. 2004
Proposed using ethnography to analyze global project to identify how institutions (e.g. work practices, legal regulations, and cultural differences) affect projects and how conflicting institutions interact and result in higher project costs.	Mahalingam & Levitt 2004
Found that innovations in coordination between firms in clean room construction projects resulted from partnerships that continue onto other similar project and reduced complexity through replacing multiple formal lines of communication with more direct informal lines.	Shields & West 2003
Found that tensions between academic "engineering knowledge" and experiential "site knowledge" and lack of understanding of existing mental models led to attitudes of suspicion or resentment in terms of the implementation of lean practices in construction.	Seymour & Rooke 2001
Studied women's career under-achievement in large UK construction companies and found that different initial perceptions of the construction industry and a strong male-oriented culture were key factors.	Dainty et. al. 2000
Found evidence that social networks research is applicable to the design process. Specifically, observed that informal structures determining work activity and the use of subtle 'role' playing in problem-solving	Lloyd & Deasley 1998
Found that CAD learning and experimentation in firms leveled off at suboptimal levels due to issues of communication and management. These findings were used to develop explicit recommendations to CAD users and vendors.	Bhavnani et. al. 1996

3.1.2.2 Ethnographic Data Collection Methods

According to Lofland and Lofland (1995), the overall goal of ethnographic methods is to collect the "richest possible data". Richness of data comes from observing behavior in many different manifestations, such as data collected through interviews, team discussions, incidental conversations, observations, documents, and non-verbal communication (Ball & Ormerod, 2000). Specific data sources are outlined in Table 3-2.

Table 3-2: Data Sources Used in Ethnographic Research

Artifacts	Project artifacts provide instances of project information that have been formally captured. They include the drawings, specification, and reports that formally capture project decisions and information, meeting minutes, requests for information, and change orders.
Critical Incidents	Critical incidents arise throughout the project and can have significantly affects cost, schedule, quality, or other critical goals. These incidents usually stem from project characteristics and data from events preceding or following an incident provide valuable insight to the system behavior.
Questions	Questions arise because information that is needed is not available. Similar to the collection of critical incidents, questions present insights to the shortcomings of the information management system.
Semi-structured interviews	Data from interviews allows for a better understanding of the everyday social experiences that members of the project team encounter. Through structured interviews, team members have the opportunity to share their rational thoughts about certain topics (i.e. what they "should" do).
Open, Contextual Interviews	These less formal interviews capture less rational and more instinctual responses of team members on certain topics (i.e. what they "feel like" doing).
General Observations	Despite what team members think that they should do, or feel like doing, they may act quite differently. General observation is best suited for understanding what members of the project teams actually do and how they interact

Using a combination of techniques will allow for data from one technique to further support or enrich data collected from other techniques to create a rich description of the technical and social processes that occur within the project team. By collecting data from both the systems level and individual level, the interactions between the various parts of the system can be analyzed in a more holistic way. Additionally, the use of multiple data collection methods (e.g. formal interviews, contextual conversations, and observation) allows for the comparison of rational, instinctual, and unconscious behaviors will also help develop a comprehensive description required to understand the phenomena.

3.1.2.3 Maintaining Validity and Reliability of Data

As with any methodology, ethnography provides unique opportunities as well as challenges. The two major challenges in ethnography are: 1) maintaining consistency, rigor, and respect of these methods among researchers that may not be familiar with these methods; and 2) demonstrating validity and reliability of the data.

In terms of maintaining rigor and respect for ethnographic methods, one of the pioneers in healthcare informatics ethnography, Forsythe (1999), outlined common misconceptions that outsiders have regarding ethnography. Her main points are that: 1) Ethnography is not a haphazard method of simply writing about one's observations; 2) Ethnography is actually quite counterintuitive because it requires researchers to explore issues that insiders take for granted such as implicit constructs and tacit knowledge; 3) Methodological rigor is essential to collecting and interpreting information from explicit (i.e. verbal) and implicit (e.g. behavioral and non-verbal) sources to create empirically grounded theories. Among the ethnographic studies cited in Table 3-1, many of the studies that did not make use of social scientists seasoned in ethnography suffered from lack of methodological rigor. The common flaws in these studies were: deriving conclusions from limited time at the setting (e.g. a few meetings); stopping the analysis at open coding; and primary focusing on the ethnographic interview rather than a spectrum of collection techniques. Of the studies that provided strong "grounded" theories, there is a need to outline and perform follow-on research to test and strengthen the theories.

The other major challenge in ethnography is demonstrating both validity and reliability of the data from a single site. Whereas validity convinces the reviewers that the data collected is accurate and meaningful, reliability (or generalizability) convinces reviewers that although the data only comes from a single site that they are also applicable to other sites and situation.

Validity is crucial because it is what gives the data its relevance and meaning. Golden-Biddle & Locke (1993) describe validity in terms of three factors: authenticity, plausibility, and criticality. Authenticity convinces readers that the researcher was indeed part of the culture by using features such as vignettes and *invivo* codes (e.g. slang and industry-specific terms). Plausibility allows readers to accept the findings by having them "make sense" to them. Finally, criticality further convinces readers by causing them to re-examine their own assumptions that they had possibly take for granted. Developing a grounded theory, by its nature, provides significant opportunity to validate the researcher's understanding of observations and the implications. New observations either provide validation of the researcher's understanding or present inconsistencies that challenge it. Although validation occurs naturally in the ethnographic research process, Creswell (2003) outlines additional strategies for validating data and constructs:

- Triangulation using different data sources.
- Member checking to determine the accuracy of findings.
- Use of a rich, thick description to convey findings.
- Clarify the researcher's bias through self-reflection
- Present discrepancies that run counter to themes
- Spend significant time in the field.
- Peer debriefing to enhance accuracy.
- Use an external auditor to review the project

Reliability (i.e. generalizability) is also critical because it provides stability and consistency of results under similar conditions. This is a particularly important issue for construction ethnographic studies given that the research is conducted on a single site but needs to generate concepts that are applicable to the understanding of other sites (e.g., off-shore mining platforms and residential construction). The three main types of reliability are outlined in Kirk and Miller (1986). The first type, quixotic reliability, consists of a single method of observation continually yielding an unvarying measurement. The problem with this type of reliability is that it can lead to trivial or misleading data (e.g. broken thermometer). The second type, diachronic reliability, involved stability of an observation through time. However, in some cases it would be expected for observations to change over time. Finally, there is synchronic reliability which is similarity of observations for a phenomenon at a given point in time. This type of reliability can be more helpful when it fails because it forces the observer to figure out how different qualitative measurements at the same time could be simultaneously true.

As with validity, the process of ethnographic research inherently addresses reliability concerns. The richness of the data provides an ideal environment for understanding the same phenomenon by different means (i.e. triangulation). Several strategies for triangulation outlined by Denzin (1978) are listed below in addition to the way their application to this research:

- Data triangulation involves corroboration of observations at different times, in different spaces, or of different persons.
- Investigator triangulation requires having multiple researchers in the same investigation.
- Theory triangulation entails arriving at the same interpretation of the phenomenon through different theoretical scheme.
- Methodological triangulation involves using more than one method to gather data.

One important issue to discuss is the use of a single site. For an in-depth field study, a single site does not provide a conflict between validity and reliability because both issues can be addressed through the richness of the data. Validity requires that the researcher provide enough detail to convince others that the population has been sufficiently understood. Reliability also requires significant detail, but its purpose is to provide enough context and nuance that others will understand what aspects of the unique situation are generalizable to similar situations.

3.1.3 Methods of Analysis: Grounded Theory

The method of analysis used in this research is grounded theory. Grounded theory is the systematic development of theory *from the data* through inductive and deductive thinking. To better understand grounded theory, it is useful to contrast it with other methodologies. Whereas many of the analysis methods currently used in construction research develop a model first (e.g., by defining a specific research objective, hypothesis, or relationship) and then structure research to collect and analyze data (e.g., an experiment, survey, case study) to prove or disprove the model, grounded theory is experientially different. In contrast, theory-building methods, such as grounded theory, develop the theoretical model that emerges *from* continuous observations and analysis of the data (Figure 3-1).

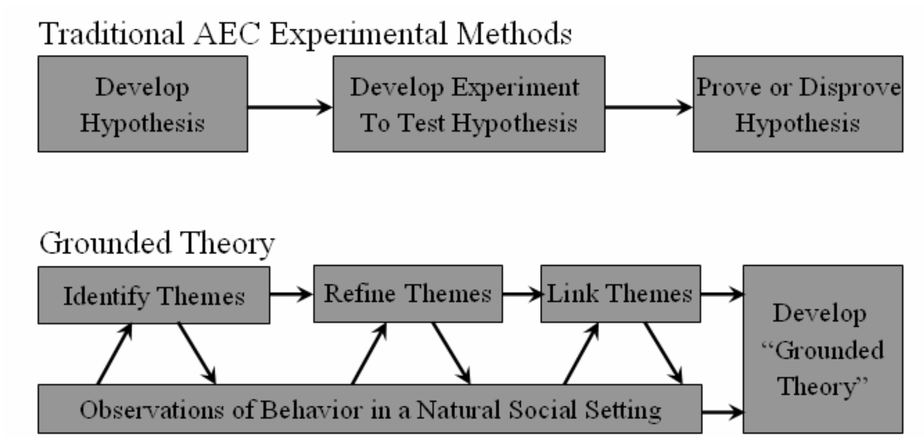

Figure 3-1: Comparison of Traditional AEC Analysis Methods and Grounded Theory

In the case of quantitative methods, researchers isolate certain variables by use of controls to create repeatable conditions and use those controlled conditions to provide data that either prove or disprove a prefigured hypothesis. Although these methods assume rational and predictable behavior, they negate certain aspects that make up the full "reality" surrounding construction industry phenomena, especially when emotions, subconscious thought processes, or complex interrelationships are involved. Even many qualitative research methods are inadequate to describe some complex social or socio-technical phenomena. Questionnaires and surveys only provide a characterization of one point in time and do not capture how attitudes and values might change over time. Surveys have the additional limitations of requiring respondents to fit their answers within a limited range of answers rather than voice their true thoughts. Observations of subjects in lab studies or other "artificial" environment do not include all of the factors present in the subject's natural environment that may be critical to the behavior of the subjects. Even short-term observations of case studies do not provide enough context to understand the social and socio-technical components of observed phenomena.

In instances, where the nature of the research problem is to understand the full complexity of a phenomenon, theories need to be derived from observation of the phenomena in their natural setting. Methods of analysis, such as grounded theory, enable researchers to develop concepts from observational data and link those concepts to generate a theory. For these reasons, grounded theory is well suited to enable researchers to understand complex social and socio-technical phenomena that are too multi-faceted to fully grasp using other methodologies that seek to simplify and control phenomena in order to understand them. Table 3-3 provides a comparison of various types of methodologies.

While all of the methods described in Table 3-3 are valuable for various purposes, there is a need for complimentary methods that allow for analysis of the full complexity present on construction projects (Raftery et al., 1997). Traditional analysis methods in construction research rely on deductive analysis where the data is analyzed according to an existing framework to prove or disprove a prefigured hypothesis. Grounded theory, on the other hand, uses inductive analysis to discover patterns, themes, and categories in one's data so that the findings emerge from the data.

Table **3-3**: Comparison of Different Research Types

Research Type	Methods	Characteristics	Logic for Drawing Conclusions
Quantitative (Deductive)	Experiments, statistics, simulation, surveys, questionnaires	Short procedures, controlled for extraneous variables, often large sample sizes	Measurement and quantification between independent and dependent variables; establishment of causal relationships between variables
Qualitative (Deductive)	Observation, case study, open-ended surveys	Short-term studies, smaller sample sizes, selective control exercised over extraneous variables	Structured observation and qualitative analysis of data to either support or disprove a prefigured hypothesis
Qualitative (Inductive)	Observation and interaction with participants, e.g. ethnography	Long-term study of a single environment, consideration of all variables to capture full complexity	Theory emerges from observations of populations in their natural setting, known as grounded theory

This emergent nature allows the findings to be continuously developed, refined, and linked until a "grounded theory" is built. Because these theories emerge from data collection of a social environment in its full reality, they result in insight and understanding that would not be possible through other means. These methods allow researchers to study phenomena such as: 1) behaviors that arise due to social conditions; 2) behaviors that are not directed toward the attainment of organizational or managerial goals; and 3) cognitive activities such as problem solving and other team-oriented activities that otherwise would not be possible due to methodological limitations (Ball & Ormerod, 2000). This process relies on the researcher's ability to interpret the data, view social phenomena holistically, and use complex reasoning that is multi-faceted, iterative, and simultaneous (Creswell, 2003).

3.1.3.1 Key Attributes of Grounded Theory

Grounded theory research operates upon the notion that the theory explaining a phenomenon can only be derived from the detailed observation of that phenomenon in its natural context. There are two assumptions that reinforce the need for grounded theory in the explanation of complex social and socio-technical phenomena: 1) A system's properties cannot be adequately understood independently of each other; and 2) Deep understanding of social and socio-technical phenomena can only happen through observation of them in their natural state. Developed by sociologists Glaser and Strauss (1967), grounded theory specifically stresses that: 1) The importance of long-term field studies to discover what is really going on; 2) The existence of complexity and variability in human action; 3) A realization that people act based on meaning and that the meaning is defined and redefined through interaction; 4) A sensitivity to the importance of the evolving and unfolding nature of events (i.e. process); and 5) An awareness of the interrelationship between conditions (i.e. structure), action (i.e. process) and consequences (Strauss & Corbin, 1998).

Grounded theory enables researchers to understand complex social and socio-technical phenomena because the iterative nature of the analysis allows for continuous focusing and refinement of data collection. Coding and the ethnographic interview are the two prevalent techniques for ordering, refining, and linking data into a theory.

3.1.3.2 Coding

In addition to the richness of the data, the real value of ethnographic data is illustrated through coding. Coding is the process of microanalysis that examines and interprets data at a minute level (e.g. at the word or phrase level). Open coding, axial coding, and selective coding are sequential methods of coding that build upon each other to develop a theory.

Open coding is an analytical process used to identify concepts, their properties, and dimensions inform the data. (Strauss and Corbin 1998, p.101) Data is "opened" by first breaking it down into discrete incidents or ideas and categorizing them based on their meaning. Additional incidents are grouped based on comparison with the existing categories.

Once the data has been "opened", it needs to be realigned through axial coding based on its properties and dimensions. Axial coding is the process of relating categories to their subcategories to form more complete and precise explanations of phenomena (Strauss & Corbin, 1998, p. 124). Using these conceptualizations of the observed incidents, an ethnographer can begin to discover relationships among categories (e.g. why, how come, where, when, how, or with what results). These relationships elucidate the interaction between structure (i.e. why) and process (i.e. how) for a given phenomenon and serve as the basis for developing an overarching paradigm. The critical components needed to develop a paradigm include the conditions, the actions/interactions, and the consequences. Conditions are sets of events that act as catalysts (i.e. causal), moderators (i.e. intervening), or mediators (i.e. contextual) for a phenomenon. Actions and interactions demonstrate how an individual responds to conditions. They can be either strategic actions (i.e. purposeful) or routine actions (i.e. habituated) and may or may not be coordinated with other actions (i.e. interactions). Lastly, consequences are responses to a situation that may affect the phenomenon.

After the data and relationships between the data have been further explained then the theory can be integrated and refined through selective coding processes. Explained phenomena are integrated into a theory by identifying a central theme and relating the other observed phenomena to the central theme. Strauss and Corbin (1998) outline techniques for discovering the central theme include developing diagrams, writing a story line, or reviewing and sorting through memos. As the explained phenomena are integrated with the central theme, the theory can be refined for internal consistency and gaps in logic.

3.1.3.3 The Ethnographic Interview

The “ethnographic interview” is another technique of analysis. Ethnographic interviews are not standard interviews. They are carefully crafted so that they not only serves as means of data collection, but also can be used to begin ordering and categorizing that data. Spradley (1979) describes the goal of the ethnographic interview as using descriptive questions to draw explicit and implicit cultural knowledge from informants who are speaking in their own terms about issues that are pertinent to them. From this descriptive knowledge, an ethnographer can identified domains in a given culture (i.e. open coding). These domains need to be refined by informants through different types of structural questions that clarify how informants organize knowledge (i.e. axial coding). The refined domains can then be used to create a taxonomy of the domain and its subsets. Following the development of a taxonomy, follow-up questions can be used to systematically develop characteristics and meaning for each component and outline relationships between components to create a complete paradigm (i.e. selective coding). Due to my lack of experience with this analysis tool, the overwhelming majority of analysis was conducted through microanalysis rather than ethnographic interview.

3.1.3.4 Empirical Grounding of the Emergent Theory

By its nature, ethnographic research produces theories from observation. However, one of the most important factors in evaluating a theory is its empirical grounding. Empirical grounding ensures that enough detail has been provided that given similar sets of conditions, similar processes will be observed and explained by the theory. It allows for future studies to validate and build upon the original study. Below are key questions outlined by Strauss and Corbin for the evaluation of a theory's empirical grounding: (1998, p.270)

- Are concepts generated? What are their sources?
- Are concepts systematically related?
- Are there many conceptual linkages and are the categories well developed? Do categories have conceptual density (e.g. many properties and dimensional variations)?
- Is variation built into the theory (e.g. the study of multiple phenomena)?
- Are conditions under which variation can be found built into the study and explained? For example, economic factors, policies, regulations, social movements, trends, culture, social values, etc.
- Has process been taken into account?
- Do the theoretical findings seem significant, and to what extent?

- Does the theory stand the test of time and become part of the discussions and ideas exchanged among relevant social and professional groups?

The strengths of ethnography rely on effective collection of rich data and systematic processing of data to develop empirically grounded theories. The conventions detailed above provide the structure for researchers to perform the academically significant and methodologically rigorous research needed to improve our understanding of complex phenomena in construction.

3.1.4 Underlying Sociological Paradigm

With any research, it is important for the researcher to understand their assumptions about the nature of the world. This is especially critical in research dealing with behavioral aspects of social phenomenon. The previous chapter outlined the research questions developed by the author. However, it is also important to understand the observer's view of the world and how I believe that it operates at a more philosophical level. Burrell and Morgan (1979) outline three critical questions that researcher must address to understand their own biases and assumptions about the nature of social organizations. These questions are outlined below:

- The ontological question: Is "reality" something that can be investigated externally to the individual? In other words, is reality something objective that can be perceived by any observer or is it a product of individual cognition?
- The epistemological question: How can a person begin to understand the world and communicate that understanding to others? Is knowledge hard, real, and able to be communicated in a tangible form or is it softer, subjective, spiritual or transcendent and based on experience and insight?

- The human nature question: What is the relationship between humans and their environment? Do humans respond mechanistically and deterministically to their environment (i.e. are a product of their environment) or do they have a more creative role and "free will" to create their environment?

Because the research is the main instrument in observation-based qualitative research, the researcher's belief regarding the issues above influences the types of methodologies that best compliment the researcher's perspective. Those that see the social world as relative, only understandable through experience, and subject to the free will of individuals will tend to favor subjective accounts generated from "getting inside" situation (Burrell & Morgan, 1979). Conversely, those that see the world as absolute, perfectly describable, and deterministic will tend to favor methods that emphasize the importance of basing research on systematic protocols and techniques (Burrell & Morgan, 1979). Although, the author feels that reality is a close balance between these two perspectives, he does believe that there are certain universal concepts that strongly influence our actions and therefore tend to favor the former more subjective view.

The other dimension that influences an individual's perspective is their belief regarding whether the natural state of the world is stability and order or change and conflict. Order is conceptualized by a regulatory perspective that focuses on stability, integration, and functional coordination. Conflict, on the other hand, is conceptualized by a radical change in perspective that focuses on change, conflict, and disintegration. Regarding this spectrum, the author tends to favor the regulatory perspective. Based on the paradigms outlined by Burrell and Morgan (1979), the schools of organizational analysis that complement the author's beliefs fall with the realm of ethnomethodology and symbolic interactionism (see Figure 3-2). Ethnomethodology is grounded in the study of everyday life and seeks to understand everyday phenomena that are taken for granted. Symbolic interactionism focuses on the properties of an interaction and operates under the assumption that humans act toward something based on the meaning it has for them and that meaning changes through social interaction (Blumer, 1969). These schools of thought establish the basis for the methods for data collection and analysis that were used in this research and will be covered in the subsequent sections.

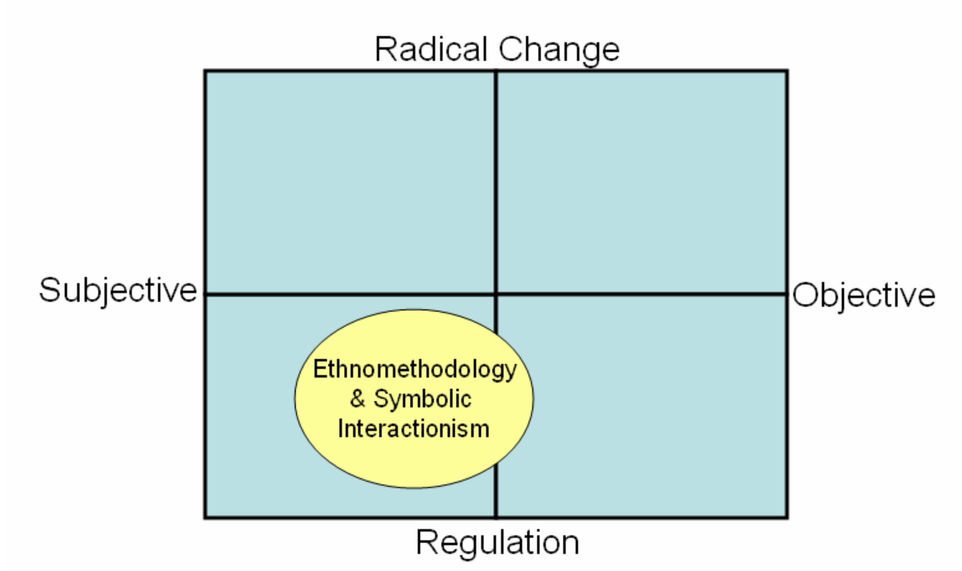

Figure 3-2: The Schools of Organizational Analysis that Provide a Basis for this Research (Based on the paradigms developed by Burrell & Morgan, 1979)

3.2 Field Study Description

3.2.1 Description of Projects

In 2002, the Pennsylvania State University (PSU) and Hershey Medical Center (HMC) updated the 10-year campus master plan. Among several retrofit projects and new construction projects, there were two major projects that were proposed for construction. These two projects consist of a five-story Cancer Institute and an adjacent seven-story Children's Hospital that together would become the new "face" of the campus and further two key aspects of the HMC's mission: pediatrics and cancer treatment. In 2004, HMC and PSU began conducting feasibility studies for these projects and hired Boston architects, Payette Associates, to begin the conceptual design process. As the projects progressed, Gilbane Company was brought on as the construction manager and later as the general contractor. Because of the high profile nature and coordination that was needed between the two projects, the key members of both project teams were the same. The chance to observe the project teams and delivery process for these two complex facilities provided a valuable and unique opportunity for a long-term field study.

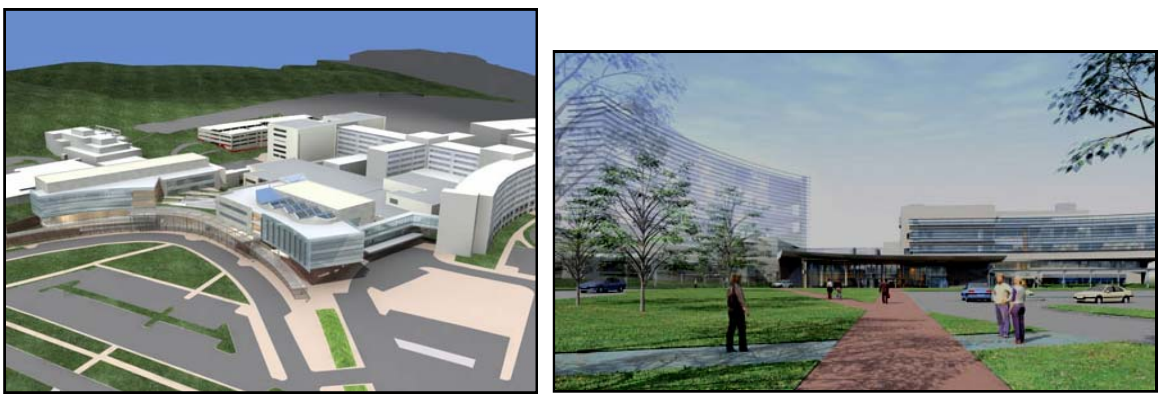

Figure 3-3: Architectural Renderings of the Cancer Institute and Children's Hospital

The Cancer Institute will be a five-story, 175,000 square-foot facility with three floors of patient care space and two floors of research, laboratory, and office space. The anticipated occupancy date is April 2009 and has a budget of $130 Million. The program spaces for the first floor include outpatient clinics, 14 exam rooms and support spaces, infusion stations, private treatment rooms for infusion, and a day hospital for chemotherapy treatments. Adjacent to the Cancer Institute there will be a "healing garden" that provides a quiet retreat for patients that may be at the Center for several hours. The second floor will include another outpatient clinic with 14 exam rooms and 16 infusion stations, clinical lab with phlebotomy stations, a radiology suite, administrative support spaces, and a clinical trials office for collection of data, planning, and research on new therapies and drugs. The third and fourth floors will include more research spaces and office and will be connected to the existing hospital through a bridge on the third floor. The basement will include radiation therapy and will require the construction of specialized linear accelerators.

The Children's Hospital is currently in schematic design and awaiting formal approval from the PSU Board of Trustees in September 2008 to solidify the scope and budget. Current plans are based on inclusion of pharmacy, food services, public lobby spaces, operating rooms, hematology/oncology suites, pediatric intensive care units, pediatric intermediate care units, and general medical and surgery beds.

Because of the proximity to existing hospital and emergency department, these projects also require significant coordination with hospital operations and the Emergency Department retrofit. These projects also required the relocation of helipad and significant site work and utility upgrades. In addition, both projects share the same site, many of the main utilities, and need to be LEED Certified as part of a University-wide mandate.

3.2.2 Field Study Participants

Because of the close interrelation of these two projects, many of the individuals are involved with both projects. The firms and individuals that make up the project team members in this field study come are listed in below:

- Payette Associates (Boston, MA)
    - Array Healthcare Facilities Solutions (King of Prussia, PA)
    - Kurt Salmon Associates
    - Polterneri & Tang
    - Bard, Rao, & Athanas (BR+A)
    - Gannet Fleming (GF)
- RDLA
- PSU Administration (PSU-Admin)
- PSU Architecture (PSU-Arch)

- PSU Project Managers (PSU-PM)
- HMC Administration (HMC-Admin)
- HMC Facilities (HMC-Facilities)
- HMC User Groups (HMC-Users)
- Gilbane Construction Managers (Gilbane)
- Gilbane General Contractors (Gilbane-Field)
- EIC Consultants (ICRA)
- Facilities Dynamics Engineering (Facilities Dynamics)
- Architectural Testing Inc. (ATI)
- Williamson & Associates (Williamson)
- Subcontractors (Subs, Subs-PM)
    - National Metal & Glass (National)
    - Hershocks
    - Penn Installations (Penn)
    - Cost Company (Cost)
    - Houck Services (Houck)
    - W.G. Tomko (Tomko)
    - McClure Company (McClure)
    - G.R. Sponaugle & Sons (Sponaugle)
    - Swisslog
    - S.A. Comunale (Comunale)
    - Intercon Automation (Intercon)
    - Wohlsen Construction Company (Wohlsen)
- Building Code Officials (Code)
- Office of Planning and Architecture (OPA)

3.2.3 Collection of Data

Observations and interaction with the field study site took place over a three year period. Involvement with the Cancer Institute extended from the end of design development to the middle of construction. During the same period, involvement with the Children's Hospital spanned from the review of the feasibility studies and initial user group interviews to the planning and schematic design (see Figure 3-4). In terms of collecting observations from across the phases of the delivery process, these two projects provided fairly comprehensive coverage (see Figure 3-5).

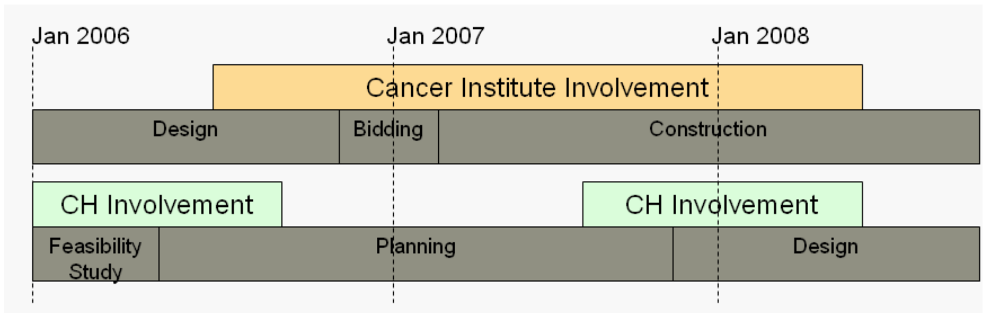

Figure 3-4: Actual Timeline of Involvement with Field Study Projects

In terms of data collection, there were three main phases. Phase one included a review of

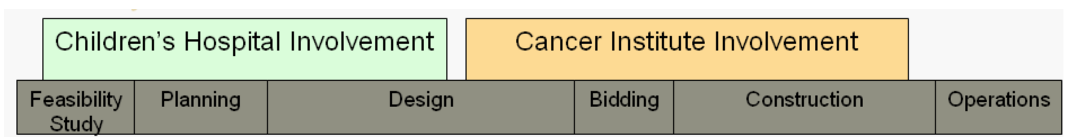

Figure 3-5: Coverage of the Delivery Process in Terms of the Field Study Projects

literature and the state of the industry related to innovation in healthcare design and construction. Phase two included initial involvement with the field study. Phase three involved more detailed and targeted involvement with the field study. These three phases are described in detail in the following sections.

3.2.3.1 Phase One Data Collection: Background Data

Before any involvement with the field study, there was a significant amount of background research that was needed. This data collection included extensive review of existing literature regarding current trends, research, and emerging best practices in healthcare facility design and construction. Specifically, this review focused on how innovative healthcare projects were incorporating sustainable design features and the effect that those features had on facility performance and clinical outcomes.

This phase of data collection also included surveying individuals involved with the design, construction, and operation of healthcare facilities. The author attended three regional conferences held by the Design-Build Institute of America that were focused on the delivery of healthcare facilities and administered surveys to get a sense for the critical issues facing the industry. In addition, meetings were held with key staff members at the existing Hershey Medical Center's Children Hospital to better understand the way occupants use the facility and the general effects that design and construction have on their performance. On the 26-28 October 2005, a roundtable meeting was held with over 40 key members of the building industry, green design community, healthcare industry, academic institutions, and government agencies to identify areas of research that could improve the delivery of healthcare facilities. As a result of this Roundtable, the author was able to built contacts with the individuals involved with the projects that would serve as the field study for this research.

3.2.3.2 Phase Two Data Collection: Initial Observations

The second phase of data collection took place during the first year and a half of involvement with the field study. Involvement with the actual field study project began in January 2006 with a review of the feasibility analysis for the proposed new Children's Hospital. In the subsequent weeks and months, my involvement with both the Cancer Institute and Children's Hospital increased. From January 2006 to October 2007, data was collected from critical meetings such as bid reviews, design reviews, planning sessions, project update meetings, user group meetings, etc. During this time, I collected artifacts from these meetings (e.g. meeting minutes, supporting documents, etc.) along with notes of observations. These observations enabled the identification of key issues and the main mechanisms related to information flow, understand the details of the projects, and develop relationships with the various entities involved with the projects.

When the information flow on these projects was analyzed, the amount of information that was being ignored and lost was overwhelming. Some of the early themes that began to emerge from these initial observations were the role of trust, broad understanding, commitment to decisions, respect, insecurity, and the role of group dynamics and interpersonal skills in coordination. During this time, these themes were further developed which allowed the research to focus on three areas that seemed critical: 1) The types of information that were needed and made available, 2) The effect of behaviors on information behavior, and 3) The role of ambiguity in information behaviors. The critical situations for information flow into the project were coordination meetings where diverse functional groups were present. These coordination meetings were where much of the information was shared and lost within the project. In order to develop these themes more, subsequent observations were focused on various scopes of work that required significant coordination; specifically, the building envelope systems, the mechanical/electrical/plumbing (MEP) systems, commissioning, and the infection control risk assessment (ICRA) program.

During this time, the author also worked to gain the trust of the field study participants. In addition to attending meetings, trust was built through talking one-on-one with the key individuals and secondary individuals involved with the issues being discussed in the meetings. Early in this phase, it became apparent that aligning too closely with any one entity in the project could arouse suspicion by others. As a means of addressing any perceived issues with trust, the author would take more opportunities to talk with the distrusting entity and ask them their perspective or even visit their office to better understand their perspective. In most cases, this seemed to be effective except for a few members of the construction management firm. These situations were regarding scopes of work that were plagued by problems and the lack of trust seemed to stem from their defensiveness in having an observer taking note of their difficulties. Although one-on-one interactions with defensive individuals seemed to be affected, their behavior in the meetings did not seem to be affected due to the fast-paced nature of the meetings.

3.2.3.3 Phase Three Data Collection: Focused Observations

The third phase of data collection took place from October 2007 until June 2008 when the author spent at least one day a week at the field study and observed behaviors in and out of meetings. Detailed notes of regularly scheduled meetings and major coordination and design review meetings were collected; specifically those related to building envelope coordination, MEP coordination, ICRA implementation, and commissioning. In addition to the notes and artifacts collected from those meetings, open, contextual conversations and semi-structured interviews of various project team members were used to gain clarification and insight into their perspectives regarding certain issues. There were also a several web-based project management systems that were reviewed to better understand specific phenomena of interest. In total, the involvement with the field study yielded:

- 1000+ hours on site observing behaviors and interacting with the project team
- Attendance at 150+ key meetings
- Extensive notes regarding 65+ meetings
- Semi-structured interviews with 12 key project team members
- Numerous informal interviews (i.e. casual conversations) with project members
- Collection and review of 3000+ pages of meeting notes, plans, and other written artifacts
- Review of web-based project management systems that were used specifically to manage requests for information, submittals, rolling completion lists, and commissioning requirements.

3.2.4 Methods of Analysis

From the collected data, there were several analyses that were conducted to better understand the phenomena that were being observed in the field study. Through more focused observation, conversation with field study participants, and microanalysis of meeting notes, the author was able to identify themes, refine and further develop them, and then link them into generalizable conceptual models that emerged from my observations. The most valuable means of generating these theories was through the process of coding that was described in previous sections. For this field study, coding was performed through two means: 1) Increasingly focused observation and conversations with participants and 2) content analysis of field notes.

3.2.4.1 Coding Through Additional Observations and Conversations

As was mentioned earlier, coding is the process of microanalysis that examines and interprets data at a minute level. The content analysis discussed in the following section provides a more structured microanalysis of the data. However, throughout the three-year involvement with the field study, there were some less formal analyses of the observations. Every few weeks, the main themes were summarized to identify sub-themes, patterns, links between themes, hierarchies, critical questions or missing data. This summary provided the opportunity for the author to consolidate his thoughts regarding the field study and further focus subsequent observations. For questions or missing data that could not be understood through direct observations, there was additional casual interaction with project team members to get their thoughts and reactions to gain better understand what had been observed.

3.2.4.2 Coding Through Content Analysis

In addition to the refining that happened through further focus of observations, there was also a content analysis of the detailed notes from 65 meetings. Content analyses are used to describe and make inferences about the characteristics of communication (e.g. trends in communications content, patterns of communication, etc). The specific reasons for performing content analyses were two fold: 1) To be able to quantify occurrences of various themes and how they relate to other factors such as the entities involved with the project and project phase, and 2) To be able to classify and compare large samples of information behaviors to help identify patterns and characteristics. In order to do this, two databases were created: one related to information needs and information types and another related to ambiguity and behaviors.

The information type database was created by reviewing each line of notes and inputting each instance where specific "pieces" of information were shared by a person. These notes resulted in 1065 separate "pieces of information". Each piece of information was coded as either being asked for by a potential receiver (i.e. an information need that pulls information from others) or being shared by a "source" (i.e. information that is being pushed into the conversation). In some cases, there were several closely related comments made by other people so a piece of information may have several sources. The database also included the date, meeting name, phase of project delivery, and scope of work regarding the instance when these pieces of information were asked for or shared. The first concern was categorizing the information into types. Through several iterations, there were at six major information types that emerged. By classifying each piece of information within those types, the definitions for each information type could be refined to cover all types of information that were observed. It should be noted that due to ambiguity, some pieces of information were classified a several information types. For example, a general comment about sheet metal flashing may have performance, aesthetic, and constructability issues, so it was classified as all three. Once these categories were developed and refined, patterns emerged regarding what entities were concerned with which types of information throughout the various phases of the project. Although there may be some inherent bias in this analysis due to the fact that the coding stemmed from notes of meetings in which the author was continuously focusing my observations, this analysis still provided support for the developed concepts and yielded some additional insights.

The second database that was developed was an ambiguity/behaviors database. Using the same pool of detailed notes, 335 instances were identified that either illustrated a specific interpersonal behavior or a type of ambiguity. These instances were classified according to whether they were behaviors, cases of ambiguity, or both. Each instance was described in terms of what was observed in general terms (e.g. bringing up unrelated information to cover for not understanding what someone else asked for) as well as the specifics of the vignette in which it was actually observed. Through analyzing these collections of instances, I was able to identify prevalent types of ambiguity and types of behaviors were identified and could then be classified. Similar to the information type classifications, these classifications could be used to categorize the data and then refine and link the emergent concepts.

3.2.4.3 Validity and Reliability of Analysis

As was discussed in previous sections, providing both validity and reliability in communicating the qualitative research comes from the richness of the description. However, there were also several strategies used to triangulate and provide validity, reliability, and subsequently increased confidence in the analyses.

These strategies used to provide validity on this field study are outlined below:

- *Triangulation using different data sources*. Data was gathered from direct observation, interview of participants, written and web-based artifacts, and supplemental research of research in related areas.
- *Member checking to determine the accuracy of findings*. As concepts were generated, they were shared with members of the project team to obtain their feedback. In most cases, their feedback was valuable in refining the concepts further or validating the findings. In some cases, their feedback was not useful regarding conceptual development, but provided additional insight into behaviors within the project team.
- *Use of a rich, thick description to convey findings*. Where possible, descriptive examples have been included to give readers illustrations of how various concepts were generated from observations of the field study.
- *Clarify the researcher's bias through self-reflection.* Early in the data collection process, the author found himself focusing on certain aspects of the project based on my own expertise. Once this was realized, he made a concerted effort to observe all aspects of the interactions. This was helped by allowing project team members to elaborate on their concerns and thoughts through interviews and conversations that made me more aware of issues that may have previously been beyond my perception.
- *Spend significant time in the field*. The extensive involvement with the field study is outlined in previous sections of this chapter.
- *Peer debriefing to enhance accuracy*. Throughout the project, meetings with advisers helped to refine my focus and highlight additional questions that need to be addressed.

Similarly, there were also several strategies used to ensure generalizability of the research findings. These strategies are outlined below:

- *Data triangulation involves corroboration of observations at different times, in different spaces, or of different persons*. Data from the field study was collected for: 1) Two different projects (i.e. the Cancer Institute and the Children's Hospital), 2) During different phases (i.e. planning, schematic design, design development, procurement, preconstruction, and construction), 3) Regarding different scopes of work (e.g. building envelope systems, MEP systems, infection control/prevention, and commissioning), and 4) With different people (i.e. even though many of the firms involved stayed the same, some personnel changed from phase to phase).
- *Theory triangulation entails arriving at the same interpretation of the phenomenon through different theoretical scheme.* Many of the concepts that emerged from the field study observations were supported by research findings in other academic areas. These findings by others were not directly applicable to the situations observed, but the similarity in findings suggests that there are similar phenomena at work.
- *Methodological triangulation involves using more than one method to gather data*. As was stated in previous section of this chapter, data was collected through direct observation, informal and semi-formal interviews, review of artifacts, review of related academic research, and content analysis.

Based on the methods described in this chapter, the following chapters explain how the constructs were generated from the ethnographic field study data. Chapter four describes the data that was collected from the field study, the analyses, and the constructs that emerged. Chapter five uses vignettes from the field study to illustrate the constructs and develops a description of the role of the integrator based on the research findings. Chapter six discusses the implications of the research finding for improving information flow in the context of lean process improvement.

Chapter 4

Observations & Analysis

The overall goal of this research is to understand the phenomena associated with information flow so that strategies can be developed to improve the management of information on complex projects. However, in order to improve any process, it is essential to develop a detailed and accurate understanding of the existing processes. The first section of this chapter provides a description of the components and mechanisms that were observed to provide the basis for information flow in construction project teams. After establishing that basis, subsequent observations and analysis focused on certain critical components of information flow processes. Therefore, the second section of this chapter focuses on understanding interactions between project team members and presents a conceptual model to explain those phenomena. The final section of this chapter includes research from related fields that demonstrate support for the conceptual model.

All of the concepts discussed in this chapter emerged from data from the field study and its analysis. In this chapter, the concepts will be discussed in general terms. However, in the discussion chapter that follows, specific vignettes from the field data will be used to illustrate these concepts. It should be noted that some key terms used throughout the rest of the document may be unfamiliar to the AEC industry. Some of the terms have been borrowed from related academic fields. These terms are explained in general terms below:

- *Boundary objects* – this term is borrowed from the information sciences and describes an object used to facilitate collaboration by explicitly capture information from on group of individuals and disseminate it to other individuals. Objects such as drawings, specifications, models, reports, RFIs, etc. constitute common boundary objects on projects.

- *Pull* – this term originated in industrial engineering as part of lean process improvement technique and has more recently been applied to lean construction theory. It describes the concept of making the need for something the impetus for its creation, as opposed to creating something and then finding a need for it (e.g. a question pulls information by requiring an answer, whereas an unsolicited comment pushes information into a discussion).
- *Knowledge Base* – the knowledge possessed by an individual used to rationally interpret a situation.
- *Values* – the knowledge possessed by an individual used to interpret a situation through non-rational or emotional means
- *Mental Model* – The way an individual organizes their knowledge base
- *Frame of Reference* – the combination of knowledge and value-based understanding

4.1 The Components of Information Flow

Before exploring ways to improve information flow, an understanding of how information flow actually occurs on projects had to be established. The easiest way to develop this understanding was to consider the requirements for flow. In a general sense, flow of any type requires four components. It requires a starting point, an ending point, a path between the two, and a driving force. For information flow, the starting point is the source of the information, the end points are the intended receivers of the information, the path is the interaction between the two, and the driving force is a mutual relevance of the information to both source and receiver.

The following sections describe how each of those critical components was demonstrated within the field study.

4.1.1 Sources and Receivers

In construction projects there are two main categories of sources and receivers: people and boundary objects. Both people and boundary objects are necessary for complex projects because each provides complimentary capabilities that are needed to manage large quantities of information. The human brain has a tremendous capacity to store information (i.e. long-term memory), recognize patters, and extract new meaning from information (Stacey, 2000: p.169). However the brain is extremely limited in its ability to process new information (i.e. short-term memory). In the course of a discussion, individuals are confronted with a lot of new information, but only a small percentage of that new information can be processed at a time. To lessen these human limitations, groups use boundary objects to supplement human cognitive abilities. Boundary objects enable teams to capture information so that individuals can continue processing it later. Boundary objects also allow individuals to focus on making sense of new information rather than trying to remember existing information.

In terms of their roles in information flow, there are certain characteristics of both people and boundary objects that determine the types of information that are potentially available and the likelihood that that information will actually become available. For example, an individual may have useful knowledge from a past project, but there may be a several reasons why that information is never made available to the current project. The following section describes those critical characteristics and sets up the foundation for the following section on interactions.

4.1.1.1 People

Tacit knowledge is knowledge that is only possessed by certain individuals and is not easily communicated to the rest of the organization. The tacit information possessed by people involved with a project provides the primary source of information to a project. However, the information that an individual actually contributes depends on their identity with the project. A person's identity is a composite of three different roles: their contractual role, their informal role, and their social role. These roles influence: 1) the type of information shared by the individual, 2) the amount of information shared, 3) the quality of the information shared, and 4) the perceived quality of their information contributions by others.

An individual's contractual and informal roles are related to the technical aspects of their information contributions. Contractual role is something that is based on the relationship of an individual's parent firm to the project. It doesn't matter who is representing the firm, the contractual expectations are still the same. As a result, a firm's contractual role outlines the types and amounts of information that an entity is expected to contribute to the project, e.g. an architect is contracted to lead the design process interpret the design intent to the rest of the project team to consider.

Informal role is based on all of the technical knowledge that and entity brings to the project. This is completely based on the individual. Although their contractual role may provide an indication of their breadth and depth of technical knowledge, and individual's actual level of knowledge could be quite different. This knowledge, or functional background, is based on the individual's past projects, previous career roles, formal training, and other experiences that provide related areas of expertise. Functional background affects the type of information and the quality of the information that is contributed to the project. Because an individual's functional background may involve areas of expertise that are different from their contractual role, this may create constructive or destructive conflict among project team members depending on other factors that will be discussed later.

In addition to the above technical factors that affect an individual's project identity, there are also factors that are more social in nature. These social factors may up an individual's social role on a project. Although social role is primarily based on individual traits, it is also dependent on the dynamic that results from interacting with other individuals. For this reason, as the project progresses, social roles change as members are added, lost, replaced, or take less prominent roles. The two major social factors are status and personality. Status can come an individual's age, authority, level of knowledge, or social influence. It has an effect on the perceived quality of the information that they contribute, the relative importance of that information, and its effect on the value stream. The other major social factor is personality which influences a person's general disposition and the way that they interact and are perceived by others.

4.1.1.2 Boundary Objects

The other main types of information source/receiver are boundary objects. In the information sciences, the term "boundary object" is used to describe an information artifact that spans two or more groups and thereby serves as mechanism for group coordination (Star, 1989). In the field study, there were 63 different types of boundary objects that were observed. Although most of the information available to a project comes through the people involved, boundary objects play a complimentary role that is vital in enabling information flow.

While boundary objects do not create new information, they capture information from others and order it so that it can be used to disseminate that information to another group. In essence, boundary object act as mediators of information. Whereas a *moderator* influences the interpretation of information but keep the information intact, *mediators* completely capture information potentially causing the actual information to change based on the mediators characteristics. As a result, understanding the characteristics of a boundary object becomes important in understanding their role in information flow. Similar to people, boundary objects also have a technical role and a social role. Their technical role is defined by their structure and a social is defined by how central they are to project (i.e. interrelation with other objects) and people's familiarity with using them. As was mentioned above, the structure of the boundary object determines the properties of information that it captures and makes available for use. The specific properties of information include: 1) Type of information, 2) Level of abstractness, and 3) Richness of information.

Because certain boundary objects are used during particular phases or introduced by particular entities, they tend to be geared toward specific types of information. For example, objects used during construction, such as schedules, budgets, and logistics plans are structured to both pull and push information that is primarily useful for construction. The same is true for other boundary objects designed to capture information related to design, performance, or strategy. More complicated or less familiar objects also create a need for significant administrative information that further increase the project information load.

Another characteristic of boundary objects is the level of abstractness in the information that they intend to capture. Boundary objects fit into four main types, those that capture: 1) Intent; 2) Process description; 3) Condition description; and 4) Conformance. Intent objects capture and disseminate the goals and abstract properties of an aspect of the project (e.g. basis of design documents and qualitative user group studies). Process description objects, such as action plans, describe the specific tasks that make up the entire process, the roles and responsibilities of various individuals involved with a scope of work, and how those individuals will be temporally coordinated. Condition description objects, such as drawings, provide information regarding the physical properties and spatial coordination of a certain scope. Finally, conformance objects provide information regarding whether the description met the intent and whether reality met the description (e.g. design review comments, site visit reports, and testing reports).

Another aspect of boundary object is the richness of the information that can be captured by them. In design and construction, richness can be categorized by how many dimensions an object can capture and communicate (e.g. the three spatial dimensions, time, cost, responsibility, explanation, and in some cases alternatives could be considered an additional dimension). Objects that encompass more dimensions provide richer information and are more valuable. However, these objects also become more complex and often require specific expertise, significant cost, or specialized equipment to utilize them.

While the structure of a boundary object affects the properties of the information it intends to capture, there are other properties that are more “social” in nature and influence an individual’s willingness to add information to or use information from boundary objects. Similar to the way that a person’s status and personality can influence their perceived importance, boundary objects also have supplemental factors affecting their perceived importance and subsequent influence on the information flow in a project. The three major factors are necessity, familiarity, and their relationship with other objects.

In terms of necessity, if an object is required by contract as either a deliverable or a tools that is mandated by the project leadership, then its use becomes a necessary part of the delivery process. In some cases, an even more significant determinant of boundary object influence is the familiarity that the project team has with the boundary object. Objects that are commonly used on all projects and are known and understood by all entities tend to be used more frequently and become a more central part of the process. In order to get a sense for which boundary objects have more influence in projects, the objects that were observed in the field study were classified as those that were: 1) Required and expected, 2) Optional but expected, 3) Required but innovative, and 4) Optional and innovative (see Figure 4-1). This figure was developed from observations in the field study. The intent was to better understand the interrelation of boundary objects within the study. The figure illustrates some interesting findings: 1) that there are certain objects that are of critical importance both in terms of capturing information from multiple sources and in terms of providing information to multiple sources (e.g. drawings and specification); 2) there are some noteworthy relationships between objects, specifically there are certain objects that are tightly coupled (i.e. dependent on each other) and others that are nested (i.e. smaller objects that combine to make up a larger object); and 3) when considering the types of information that each object captures, there are some wasteful redundancies (e.g. drawings/specification and the shop drawings/submittals).

Another determinant of how influential an object is in the delivery process is its relationship to other boundary objects. Objects that are closely related in terms of the type of information that they require become a greater influence on the overall information stream. Specifically, there are objects that use information from other objects, provide information for other objects, or are used in conjunction with other objects.

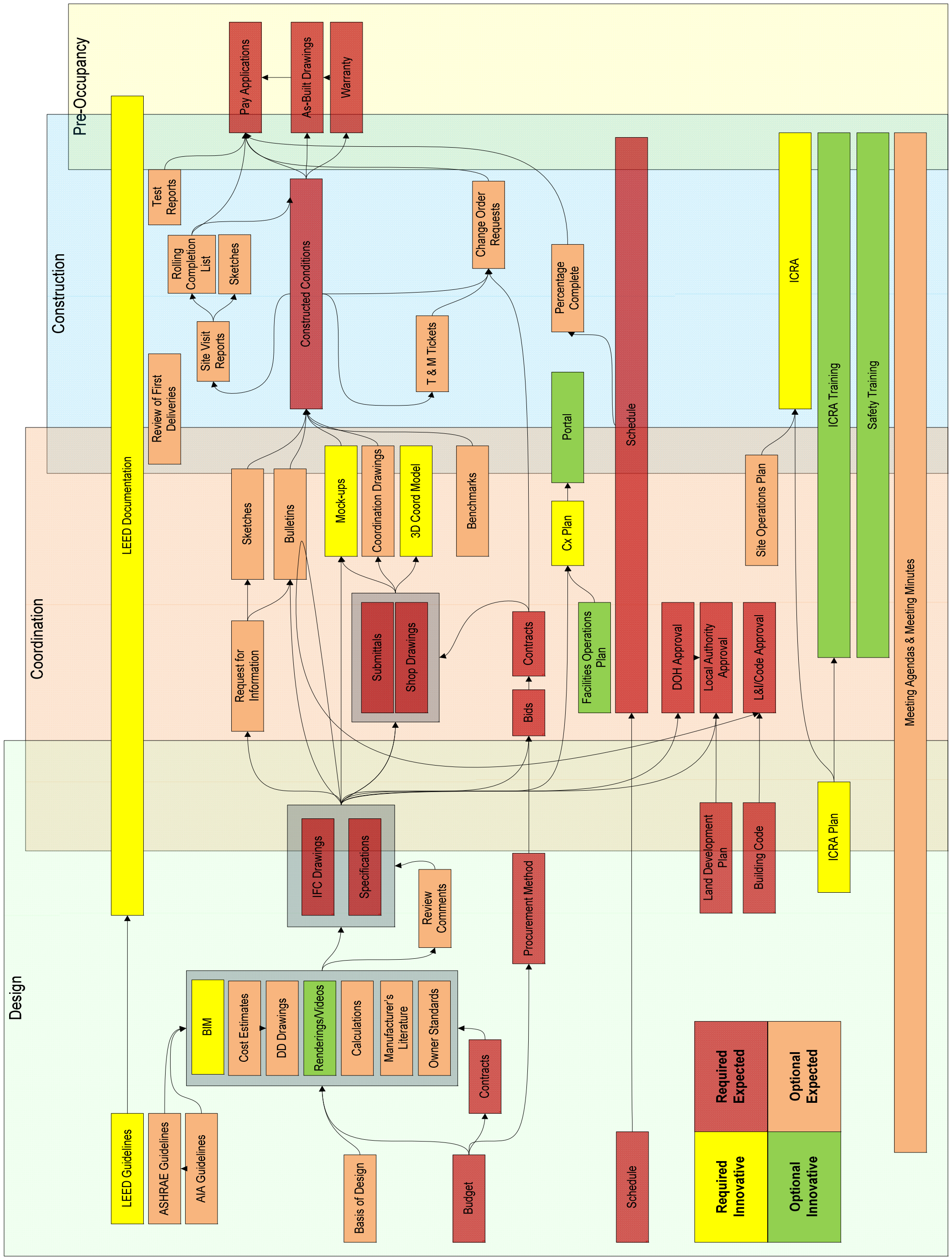

Figure 4-1: Relational Map of Boundary Objects with Characteristics

4.1.2 Interactions and Information Flow

Because of the complex nature of information behavior, having the right people and objects involved with the process only creates an *opportunity* for information to add value to the project. Due to the nuances of communication, the presence of valuable information does not guarantee that it will be used. Understanding interactions, or the means by which individuals share information with each other, is at the heart of understanding the factors that influence the effectiveness of information flow. There are a number of factors that shape how effective an interaction is. The combination of people and boundary objects creates the opportunity for three different types of interactions: interpersonal, person/object, and object/person. This section explores the interrelated factors that affect interactions.

4.1.2.1 Interpersonal Interactions

When people interact with each other, there are several ways that information can be provided and received. Figure 4-2 depicts this phenomenon. The interactions that occur can result in a situation where information provided by an individual is accepted, dismissed, or ignored. Of the information that is accepted by the receivers, it can be fully understood, partially understood, or misunderstood where the receivers can be either aware or unaware of their partial understanding and misunderstanding. If aware, they have the opportunity to ask for clarification or search for additional information. If unaware, then the incomplete or incorrect understanding may lead to problems in later interactions. Alternatively, information can be rejected or ignored when the receiver does not perceive the value of the information being shared by the source. Rejected information comes through conflict and is a conscious determination that the information is not valid based on differences of opinion or perceived untruth. Ignoring, on the other hand, is a more passive process where information lacks perceived value due to the receiver's lacking the proper knowledge base (i.e. cannot establish relevance), poor communication from the source, or lack of trust in the source. The potential outcomes of shared information and the moderating factors that were observed are shown below in Figure 4-2.

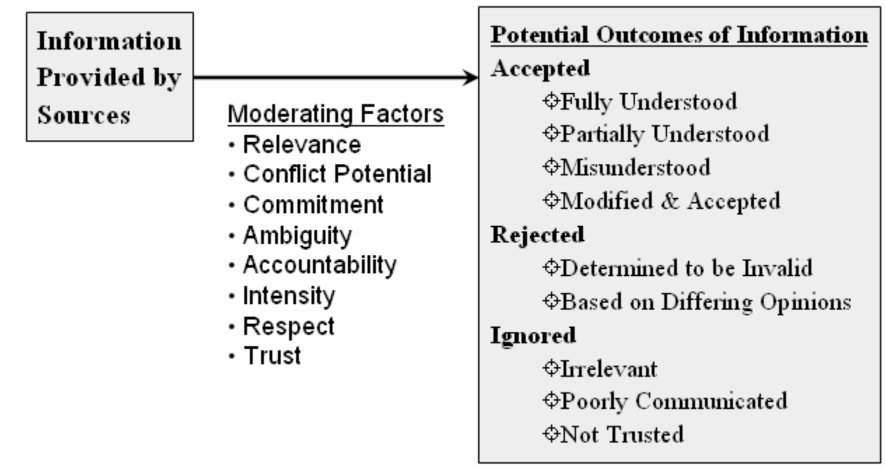

Figure 4-2: Possible Outcomes of Interpersonal Interactions

4.1.2.2 Interaction with Boundary Objects

As people interact with boundary objects, there are certain outcomes that result from the combination of people and objects. In the use of boundary objects, there are actually two complimentary types of interactions that take place: Person to object (i.e. capture of information) and object to person (i.e. use of captured information). As depicted in Figure 4-3, boundary objects act as a mediator of information between two individuals or groups and therefore end up serving as both a source and receiver by proxy. As was mentioned earlier, information from the human source is captured by the boundary object and is modified based on the structure of the boundary object. As a result, the information available to the human receiver may be different from what was provided by the source. This two-part transfer of information introduces two opportunities for information loss or misinterpretation. However, any information that is accurately captured remains available to the project and is less likely to be lost or subject to bias.

With boundary objects, there several possible outcomes and moderating factors for information flow (see Figure 4-3). In the person to object interaction, information can be captured accurately, captured inaccurately, or not captured. Information that is not captured is unavailable to any potential users of that boundary object and lost to the project unless communicated by another means. Information that is captured, whether accurately or inaccurately, is available to users and can be interpreted accurately, interpreted inaccurately, or ignored. The factors that contribute to determining these outcomes are listed in Figure 4-3.

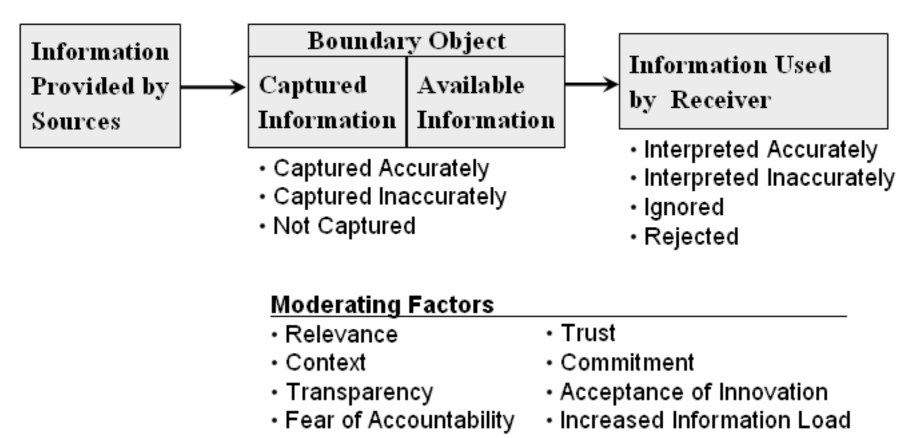

Figure 4-3: Possible Outcomes in Person-Object and Object-Person Interactions

4.1.3 Mutual Relevance

The last component needed for flow is a driving force. In information flow, the driving force is a mutual sense that certain information is relevant, shared by both the source and receiver. From the past experiences of the project member, they may have a general sense of what information is relevant during various phases of a project. However, this is often not specific enough to develop strong mutual relevance regarding information during individual interactions. This is especially true for complex projects that have significant amounts of new and novel information, such as the projects in the field study. Because the diversity and uniqueness of the field study projects and teams, it was a challenge to develop a mutual sense of relevance for a lot of information. However, there were several mechanisms that emerged that were effective in helping to establish and build mutual relevance. The first was through providing information that is directly related to the topic currently being discussed, rather than shifting the conversation to another topic prematurely. The second is by framing new information in terms of how it pertains to the concerns of others or linking it to information provided by others in the project team. The third means of establishing mutual relevance was asking questions. Questions are an effective tool for pulling information from others to address information needed by the person asking the question. Finally, mutual relevance could be established my making a conscious effort to clarify ambiguity and develop a common understanding among the project team before engaging in detailed discussions of debates regarding an issue.

4.2 Understanding Interactions

Conversations with industry members outside the field study seemed to validate the notion that interactions provide the primary means for information flow. However, the actual mechanisms that enable information to flow are not well understood both within construction practice and academia. For this reason, focused data collection and analysis of that data was conducted to gain a better understanding of the phenomena that occur during interactions. The first analysis looks at what types of information are provided during interactions. The second analysis looks at the fate of information shared during interactions and whether or not it ends up being incorporated into the project. The third analysis looks at determining what the key moderators of interactions are and how they affect information flow. A fourth analysis looks at the major barrier to information flow, ambiguity, and how it can be better understood and addressed.

4.2.1 Analysis of Information Types

During the course of the field study, I attended over 150 coordination meetings. From the detailed notes of the last 65 meetings, I performed a content analysis to determine what types of information where being shared by the project team members. From the notes, I was able to generate a database of 1065 specific "pieces" of information. Each "piece" was a specific topic that was brought up by a person present at the meeting (e.g. The flashing shown on detail 4 on sheet A8-22 needs be tied into the air and vapor barrier above). While some of these pieces of information may have been brought up but not actually accepted by others, the data still provide useful insight into the types of information that project team members consciously or non-consciously felt was important and therefore shared with others.

Through the process of coding that was discussed in the methods chapter (section 3.2.4.2), the database was reviewed and several categories of information emerged. These categories included the expected design, constructability, and performance information types as well as strategy-related information. However, there were many piece of information that did not fit into those types and therefore resulted in the emergence of two additional information types: administrative information and communication information. Through placing each piece of information into a type, more detailed descriptions for each type could be developed. Due to the ambiguity, there were several cases where information was categorizes as multiple types. This process yielded the following descriptions of information types:

- ***Strategic Information*** – the main purpose of this information is to establish the direction and relationships between all members of the project team. The main subcategories are: 1) Goals and priorities, 2) Planning (major future meetings and relation to future/concurrent projects), 3) Organizational Structure/Contracts (roles and responsibilities), 4) Definition of project scope, 5) Budget.
- ***Performance Information*** – the main purpose of this information is to understand how the building will function during its lifecycle. The major subcategories are: 1) Durability/serviceability, 2) Facilities operations/maintenance, 3) User group operations, and 4) Future flexibility, and 5) Acceptable levels of risk
- ***Communication Information***– the main purpose of this information is to enable informal communication throughout the project team. The major subcategories are: 1) Process at meetings (agenda), 2) Assumptions/History about an issue, 3) Responsibility for specific tasks (not bigger picture responsibilities), 4) Coordination/timing of tasks (non-construction related), and 5) Behavioral/expectation management.
- ***Administrative Information*** – the main purpose of this information is to fulfill explicit requirements of the project organizational structure, formal processes, or external approvals. The major subcategories are: 1) Use of boundary objects, 2) Formal processes, 3) Approvals, and 4) Training.
- ***Constructability Information*** – the main purpose of this information is to translate the design intent in to a building. The major subcategories are: 1) Interpretation of intent, 2) Determining means and methods, 3) Intra-project coordination (construction-related), and 4) Inter-project coordination (construction-related).
- ***Design Information*** – the main purpose of this information is to represent the architectural intent of the building. The major subcategories are: 1) Materials and

systems, 2) Layout and orientation, 3) Transitions and interactions between systems, 4) Intent, and 5) Guides and standards (voluntary - not required).

In addition to developing information types, this analysis also provides illustrations of trends regarding what information was prevalent during different phases of project delivery as well as which entities where contributing that information. The first significant illustration (Figure 4-4) is a general profile of the relative importance of different types of information during different phases. Figure 4-4 gives insight into what types of information were being shared throughout the various phases and implies that certain types of information are more important during different phases. Particularly of note is the significant percentage of administrative and communication information that is being shared in all phases. These information types do not add any direct value but constitute about one third to one half of the total information being shared. Also of note is the small percentage of constructability information that is shared during design.

The second significant illustration is a breakdown of what entities were providing most of the information during each phase (Figure 4-5). In this figure, the diversity of information sources in design and construction is notable. Also, it is of interest that there is an absence of information contributions by the architect during construction.

The last illustration is of the type of information each entity, in this case the construction manager, was providing during various phases (Figure 4-6). This gives insight as to the types of information that were important to that entity. Of particular interest is that the construction manager was primarily concerned with administrative and communication information and provided relatively little constructability information despite being the entity that would also serve as the general contractor.

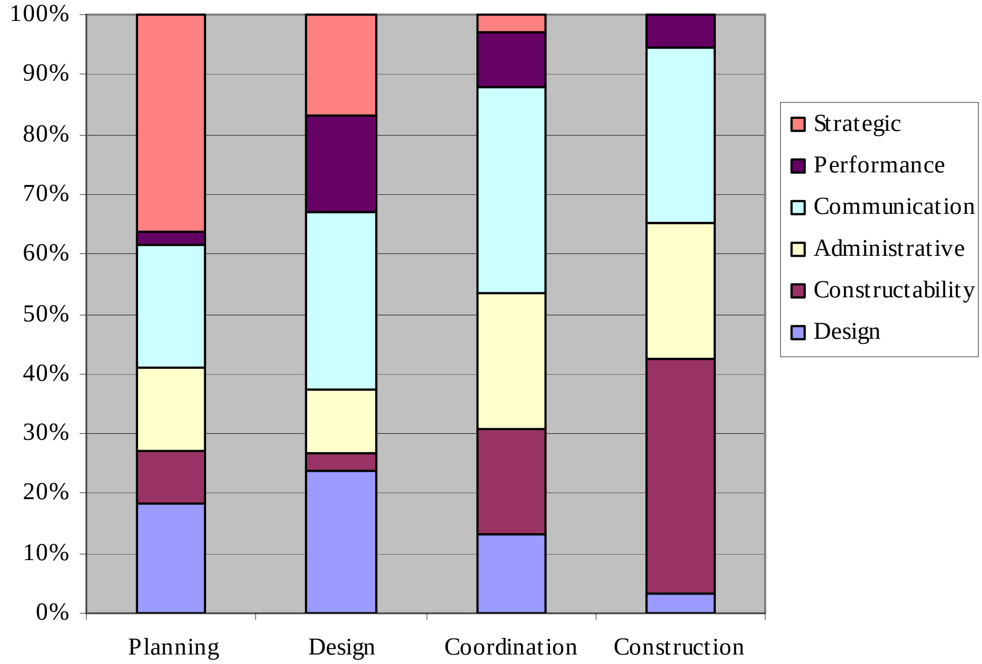

Figure 4-4: Information Contributions by Type and Phase

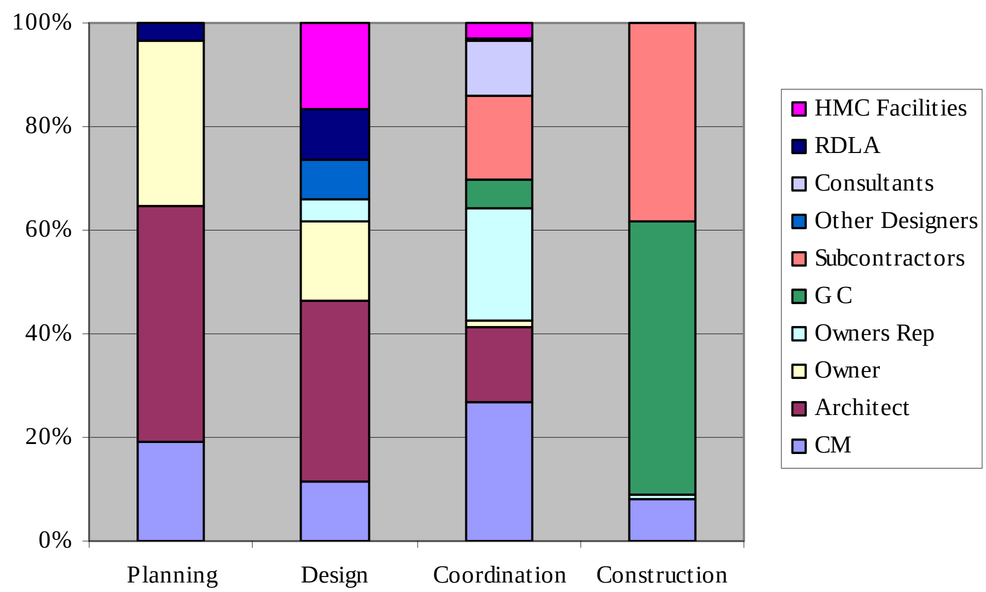

Figure 4-5: Information Contributions by Entity for Each Phase

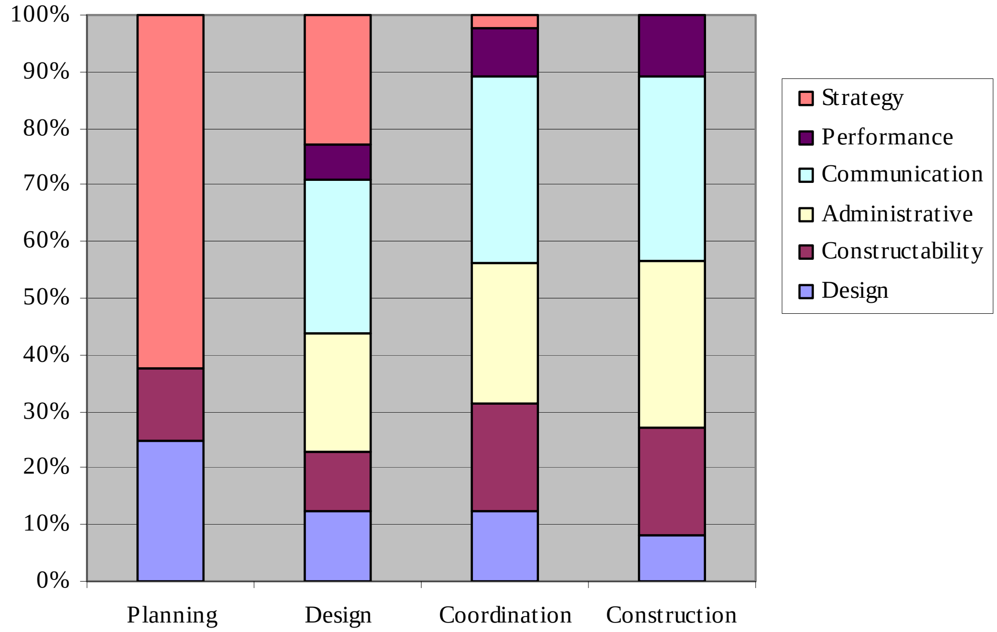

Figure **4-6**: Information Contributions of the Construction Manager During Various Phases

This analysis considers the information that was captured in the author's notes of the interactions (i.e. meetings). As was mentioned earlier, the fact that that information was shared during the interactions did not necessarily mean that the information was actually incorporated into the project. In order to understand what happens to information provided by project team members during these interactions, a second analysis was performed.

4.2.2 Analysis of Potential Outcomes Regarding New Information

To better understand what happens to information during an interaction, a model of interaction inputs and outputs was developed. Through the course of subsequent observations, the model was refined until it could be used to accurately illustrate any interaction (Figure 4-7). From these observations, there emerged several fates that could befall new information.

For a given interaction, there are several information inputs that provide information to an interaction. These include: 1) the collective memory of the people involved with the interaction; 2) information explicitly captured previously by boundary objects currently being used in the interaction; 3) parameters set by past decisions; and 4) new information provided by individuals and boundary objects present at the interaction. All the information that goes into an interaction either translates into: 1) a modified collective memory (i.e. tacit knowledge capture); 2) modification of explicit knowledge captured in boundary objects, 3) decisions; or 4) waste (see Figure 4-7).

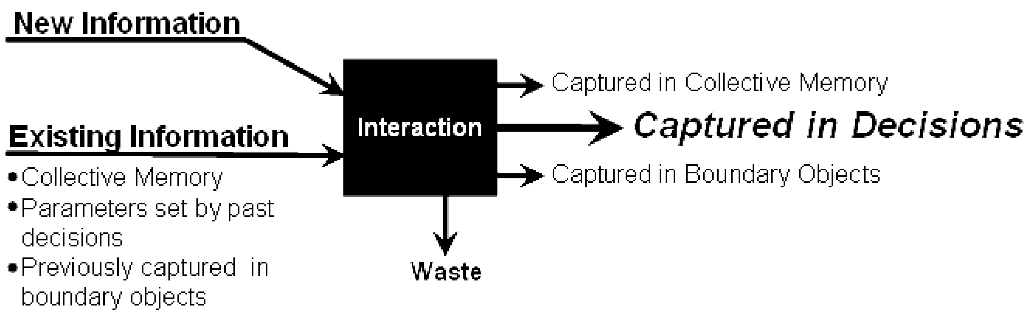

Figure 4-7: Inputs and Outputs of Information in Interactions

As was mentioned in the section regarding interpersonal and person/object interactions, there were three basic outcomes of information: it could be ignored, rejected, or accepted. Information that is shared during an interaction but ignored by the rest of the group simply results in waste; it was shared, but made no impact on the project and has essentially disappeared from the project unless reintroduced by some other means. Information that is rejected may be captured in some people's memory, but will not be captured in boundary objects or decisions. Information that is accepted ends up being a part of the collective memory, captured in boundary objects, or captured in decisions. In cases where information is captured in memory or boundary objects, it is still available but has not actually been incorporated into the project yet. It is only when that information is accepted and captured in a decision that it truly becomes incorporated into the project.

Therefore, in order to incorporate information into the project, it needs to first of all be shared by a project team member and made available. Once it has been shared, then it needs to be accepted and understood by other project team members to the point were it can be captured either in memory or in boundary objects and eventually incorporated into the project through project decisions. The fate of information in an interaction greatly affects the outcome of a project. As a result, understanding what happens in the interaction is of critical importance. Although individuals in the field study all acknowledge that productive interactions are key to project success, not much is known about what occurs during an interaction to determine that success. Thus, one is left with the image of the interactions occurring as that of a “black box:” information goes in and it comes out, but what changed, how it changed, and even changed by whom, is not clear. The following analysis strives to look inside the “black box” of the interaction and begin to understand the factors that influence interaction effectiveness.

4.2.3 The Interaction Model

Throughout this research, there were a number of moderating factors that affected the outcome of interactions. While numerous moderators where identified, they could be narrowed down to four major interrelated factors: Trust, commitment, learning, and common understanding. These key factors determine what information and individual shares, how they share it, how it is received, and subsequently play a vital role in determining the effectiveness of future interactions.

Trust and commitment are closely related factors. *Trust* involves having positive expectations about another’s future actions when an individual is vulnerable to those actions. *Commitment* is the strength of an individual’s identification with and involvement in a particular organization. Trust and organizational commitment research from the organizational behavior literature explains that together these constructs affect a person's values regarding the project, such as: 1) how they view others in the project team, 2) how they view their own role in the project, 3) how much effort they are willing to put forward, and 4) their sense of association and interest in the project. A review of this literature is found in the last section of this chapter.

In terms of the more cognitive factors, the literature closely relates learning with an individual's existing understanding of a subject (Stacey, 1999: 169). *Learning* occurs when processing new information changes an individual's range of potential behaviors. Understanding is based on an individuals existing knowledge and existing range of potential behaviors. *Common understanding* comes from the overlap of what is relevant to an individual, what is relevant to other team members, and what is relevant to the project in general. Together learning and understanding form an individual's mental model. Mental models determine how a person: 1) evaluates new information, 2) links new information to their existing knowledge, and 3) categorizes and orders information for the project. These four factors, in conjunction with knowledge of how humans process information to make decisions, provide the key to understanding the phenomena that occur within interactions.

4.2.3.1 The Dilemma of Bounded Rationality

People are rationally bounded; i.e. they are only capable of understanding a limited about of information (e.g. Stacey, 1999; Hambrick & Mason, 1984). To cope with bounded rationality, people need to filter the overload of information to which they are subjected in a situation. The model of strategic choice developed by Hambrick and Mason (1984) provides a useful context to understand this phenomenon (Figure 4-8). In a given situation, there is a lot of information available. In order to be able to process that information, we need to ignore the unimportant information. First, we rely on our values and mental model (i.e. combine to form our frame of reference) to filter the information based on what is most important to the individual. Based on their frame of reference, people only become aware of a subset of the total information available. From that information, they further filter information based on what they feel is important. The remaining information is what they use to interpret the situation and make decisions. Because of differing frames of reference, different individuals can be exposed to the same situation and the same information and derive very different ideas about the best course of action.

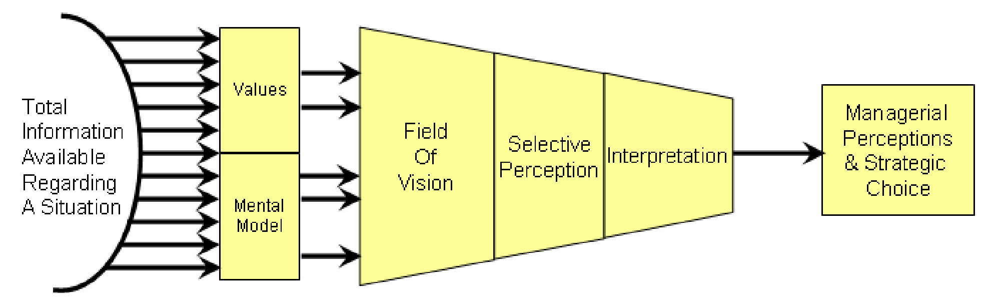

Figure **4-8**: Model of Strategic Choice Under Conditions of Bounded Rationality (Adapted from Hambrick and Mason, 1984)

4.2.3.2 Converging Frames of Reference

The main purpose of project team interactions is to share information and make decisions. Because of bounded rationality and the diverse perspectives that need to be brought together in a project, arriving at a common understanding and universal commitment to a decision can be challenging. The types of interactions that take place can either ease or make more difficult these challenges.

Throughout the course of interacting with other project team members, there are several resulting outcomes. In addition to discernible outcomes discussed in the earlier section (e.g. decisions, revised boundary objects, and modified collective memory), there are also outcomes that, although seldom realized, play a critical role in determining the effectiveness of subsequent interactions. These unrealized outcomes relate to how the people valued the experience (i.e. how they felt), and how they valued the information (i.e. what they learned). These two valuations affect: 1) the amount, type, and quality of information shared in subsequent interactions, 2) the interpersonal dynamic between team members, and 3) the willingness of individuals to share and accept information. Throughout project delivery, there are countless interactions. As a result, interaction effectiveness becomes one of the most crucial factors in determining the outcome of a project. As individuals interact, there are two interrelated cycles that can either improve or adversely affect the development of trust, learning, information flow effectiveness, and the eventual project outcome.

Through detailing over 300 documented behaviors of project team members during interactions and analyzing how there were affected by the valuation of both the experience and the information, a model was developed to describe the phenomena that were being observed (Figure 4-9). This model takes the two valuations that are constantly occurring throughout an interaction or series of interactions (i.e. of the experience and of the information being shared) and links them to the four major moderators that were observed. The resulting model can be used to explain and evaluate the outcomes related to information flow of an interaction or series of interactions.

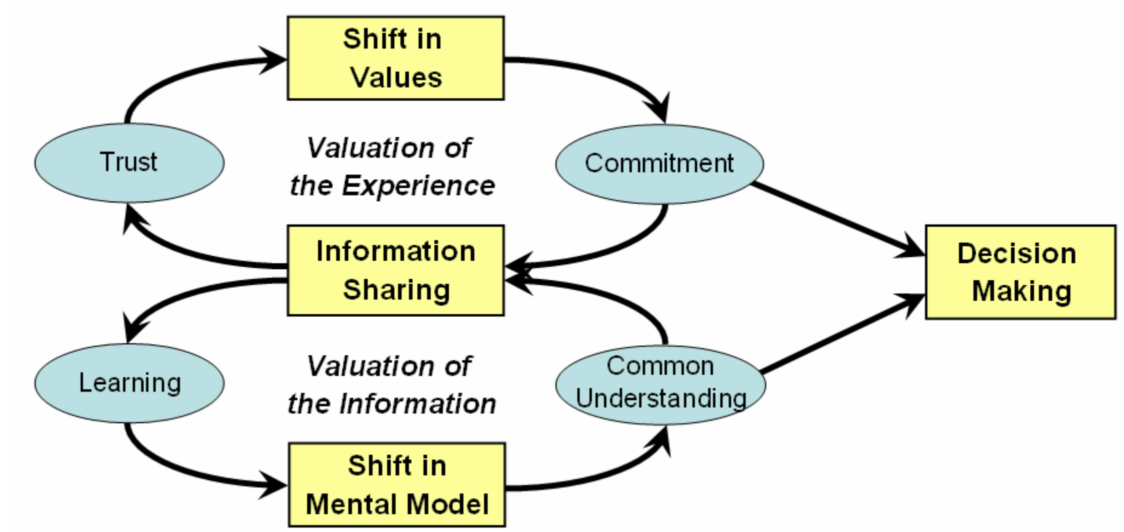

Figure 4-9: Interaction Model: Trust and Learning Cycles

4.2.3.3 Valuation of the Experience: The Trust Cycle

The valuation of the experience has to do with how the individual felt during the interaction. Some of the critical factors of an experience include: 1) how the individual was received by the rest of the group; 2) the individual's perception of others in the group; and 3) changes in trust and commitment that result. Based on the experience of each interaction, there can be a shift in an individual's values toward the project. An individual's values toward the project affect the quality and amount of information that an individual will share with the rest of the team as well as the type of reaction the individual will have to information shared by others. Prior to experiencing several interactions with a group of people or particular individuals, there is a default level of trust that a person will have toward other people and boundary objects based on their past experiences. This association can be based on past experiences of working with others from the same firm, second-hand accounts of the individuals or firms, or from past experiences with others that have served similar roles on past projects.

As project team members interact, the means by which project team members share information or their receptiveness to the information contributions of others affects the building of trust. These includes issues such as whether individuals feel: 1) Their contributions are valued by others; 2) They are being treated fairly; 3) There is team and individual accountability; 4) Individuals expectations are being met; and 5) Project team members show a commitment to team goals above their own personal goals.

Increased trust allows people to be more open to other viewpoints and facilitates a convergence of values regarding the project. Decreased trust causes individuals to grasp more tightly to their individual values. Convergence of values results in individuals having greater identification with other team members and the project in general. In turn, greater identification with the team creates stronger commitment to the team outcome. Subsequently, commitment affects all aspects of information flow. It influences how much effort an individual will put into making sure that their information is valid and relevant, understanding the information from others, and working toward the goals of the project. Commitment also affects the amount of effort that an individual will put toward learning and trying to understand other perspectives.

4.2.3.4 Valuation of the Information: The Learning Cycle

The value that an individual places on the information being shared in an interaction is what enables learning. As a result, the “value” of information depends on its relative significance to a specific individual and learning occurs when that individual internalizes the information and incorporates it within their own mental model. An individual’s propensity to learn depends on: 1) Their willingness to learn; 2) The clarity and perceived quality of the information; 3) The relevance of the shared information to their existing mental model; and 4) An individual’s trust of the person providing the information.

The influence of learning on an individual's mental model depends on the significance of the information to that individual. "Single-loop learning" involves adding new information to an individual's existing knowledge base (Stacey, 1999: 174). "Double-loop learning" involves a higher level of understanding that shifts an individual's mental model so that they process and interpret both new and existing information differently than before learning (Stacey, 1999: 174). As higher-level learning occurs, mental models shift. If mental models converge, individuals become more aware of how their information relates to others and to the project in general and this awareness results in sharing of more relevant information, which feeds future cycles of learning and building trust.

Because of the complexity of some projects, a wide spectrum of individuals with very diverse mental models is needed to process the information within a project. Their effectiveness depends on having good communication amongst the team, which relies on having a shared understanding of information. Since most team members come from different functional backgrounds, they do not always have a common understanding and often need to reframe the information shared by others in terms of their own knowledge base in order to understand it. For this reasons, it is necessary that team members learn from each other and develop enough of an overlap in their mental models to understand and learn from the information that others are providing.

4.2.3.5 Interdependence of the Trust and Learning Cycles

Although the trust cycle is responsible for convergence of values and the learning cycle for convergence of mental model, neither can happen in isolation from the other. In fact, they are intimately dependent upon each other. Trust and commitment can only be strengthened through greater understanding of others, which depends on learning. Similarly, learning can only occur through trusting the information provides by others and having a commitment to working toward improved project outcomes. As a result, factors that affect one aspect of the interaction model end up affecting all aspects. In many cases, differences in opinion and personality conflicts appear to be the factors affecting these cycles. However, the data revealed that the type and amount of ambiguity was actually the underlying cause affecting the trust and learning cycles.

4.2.4 The Problem of Ambiguity

As the previous sections explain, establishing a common understanding is essential to information flow because it establishes mutual relevance for new information, which enables the right information to flow at the right time. However, information flow is not like materials or labor flows. Because of its nuance and context-dependence, the notion of the "right information at the right time" is much more subjective and vulnerable to ambiguity. Ambiguity opens up room for various individuals to interpret a given situation in different ways so that there is no clear response to a given situation. Mischel (1977) defined this phenomenon in terms of "strong" versus "weak" situations. "Strong" situations are ones in which the environmental stimuli (e.g. information) are so clear that there is little room for personal interpretation and the required action is obvious to all people involved. "Weak" situations on the other hand, leave much more room for interpretation and therefore the proper course of action is more dependent upon an individual's frame of reference (i.e. their values and mental model). In construction, due to the wide spectrum of disciplines involved and tremendous amount of ambiguous information, most situations are very "weak" situations. This makes convergence of team values and mental models even more critical to enabling effective information processing and decision-making.

4.2.4.1 Types of Ambiguity

The analysis that was conducted to better understand ambiguity followed a similar process of developing the information types. From detailed notes of sixty-five coordination meetings, a database of more than three hundred ambiguous situations was complied. From those situations, categories of ambiguity could be developed. The first series of analyses yielded twenty-two different types of ambiguity. Subsequent analyses allowed those twenty-two types to be grouped into five major categories outlined below:

- **Goal Ambiguity** – The goals, or overall motivating factor, may consist of one or a combination of the following: 1) *Overall project goals*; 2) *Individual project goals*, and 3) *Individual personal goals*.
- **Approach Ambiguity –** This deals with overarching themes that guide decision-making processes. The major subcategories are: 1) *Level of risk*; 2) *Level of innovation*; 3) *Establishing priorities* to serve as a basis for decision-making; and 4) *Process for achieving goals*, i.e. understanding how various activities fit into the overall project.
- **Role/Responsibility Ambiguity** – This deals with the roles and responsibility that a person/firm has in a project regarding information. The major subcategories are: 1) *Formal Role,* i.e. per contract; 2) *Informal Role* based on actual expertise; 3) *Social Role,* i.e. the role that they play in group dynamics; 4) *Discretion,* authority to make decisions; 5) *Motivational,* i.e. how to affect how someone will act; 6) *Translational,* e.g. best way to translate meaning from person to person, person to object, or object to person); and 7) *Expectations* of individual performance or behavior, e.g. being proactive, comprehensiveness, or effort).
- **Critical Issues Ambiguity** – This deals with the understanding the effect that one critical issue has on other related issues or the project in general. The major subcategories are: 1)

Spatial (in the same physical area); 2) *Temporal* (between phases); 3) *Dimensional* (i.e. cost, performance, aesthetic, and contractual); 4) *Scope* (e.g. area, project, campus, master plan); and 5) *Historical* (understanding of past events).

- **Validity/Appropriateness Ambiguity** – This type of ambiguity has to do with the perceived validity/applicability/appropriateness of an object for the given issue. The main subcategories are: 1) *Assumptions*; 2) *Tools*; 3) *References*; 4) *Interpretations* or other subjective inputs; and 5) *Behavioral Speculation* (how people with actually act – e.g. end users, other team members, or the market).

4.2.4.2 Hierarchy of Ambiguity

While every interaction included some sort of ambiguity, some of the discussions that ensued were viewed as productive and valuable while others were unproductive and frustrating. One of the major factors in determining the difference between productive and unproductive conflict, seems to be whether the discussion targeted the appropriate level of ambiguity. The data suggests that there are certain fundamental issues that require a common understanding in order to have substantive discussions about more specific issues. For example, without knowing the goal of a project it is difficult to develop or evaluate an approach for achieving that goal. In this example, if the discussion is focused on debating what approach should be taken without clarity in terms of goals, then the discussion will be frustrating and relatively unproductive. Without a shared understanding of the goals, there is nothing to establish the basis for discussing the merits of different approaches and each person will base their interpretation on their personal interests. However, if the team first establishes clear goals, then ambiguity in terms of approach can be addressed more productively. Similarly, once the approach is clarified, then the roles and responsibilities of each project team member regarding approach can be clarified and then there can be more substantive and respectful discussions regarding critical issues and the validity of information.

Based on these observations, a hierarchy of ambiguity emerged (Figure 4-10) where more fundamental issues (i.e. ambiguity levels 1-3) need to be addressed before there can be substantive discussions regarding more specific level issues (i.e. ambiguity levels 4 and 5).

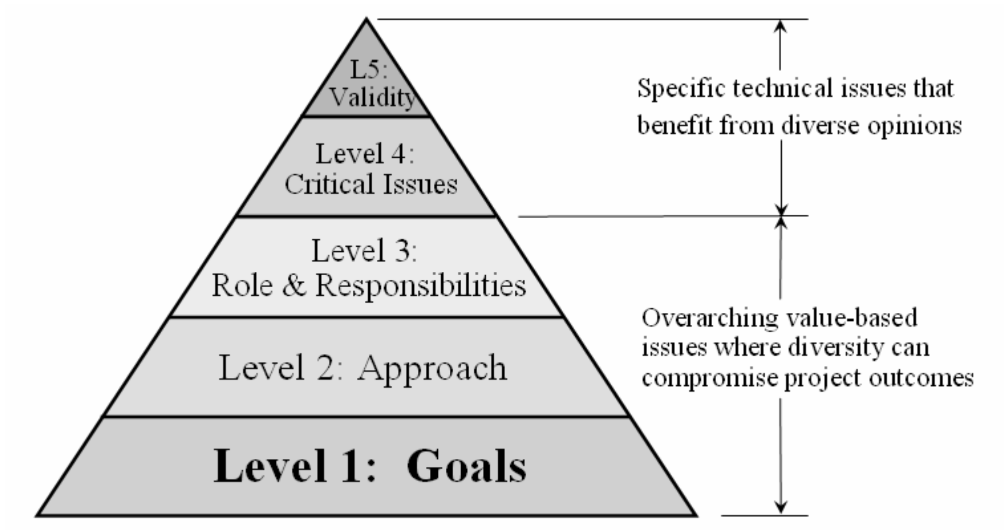

Figure **4-10**: Hierarchy of Ambiguity

Most of the discussions observed in the field study, entailed ambiguity dealing with levels four and five. However, in most cases, these discussions also carried unaddressed ambiguity regarding levels one through three that compromised the team's ability to have productive discussions about level four and five issues. Intellectual conflict and diversity of opinions regarding critical issues and validity are critical to providing quality information to the project. However, without clarifying more fundamental issues these discussions also hit upon more personal and value-based issues and can negatively affect trust, commitment, and the effectiveness of future interactions. For these reasons, targeting the appropriate level of ambiguity is one of the most critical factors affecting the outcome of the trust and learning cycles.

4.2.5 Summary of the Full Interaction Model

The analyses described above provide a more detailed and comprehensive understanding of information flow in complex project. Of this improved understanding, the key conceptual contributions are the development of interaction model with its trust and learning cycles. This model outlines the factors that affect the fate of information in an interaction and subsequently how that information can be incorporated into the project. By using this model to evaluate current coordination practices, steps can be taken to improve the effectiveness of team interactions. The critical interrelated factors of trust, commitment, learning, and common understanding determine how effectively information flows in and interaction. As a result, project teams that understand how to create environments that are conducive to building trust and learning will make better use of available information and more effectively incorporate that information into the project through improved decision-making.

Chapter 5

Findings

This chapter demonstrates how internal and external validity were provided for the interaction model developed in Chapter 4. The first section of this chapter uses situations from the field study to provide internal validity for the concepts developed in the previous chapter. These situations are described and then discussed in terms of how they perform in the trust and learning cycles. The second section of this chapter uses a review of literature from related fields that support the constructs developed in the previous chapter to provide external validity. Finally, the last section of this chapter compiles characteristics that were observed to be effective throughout this research to create a description of an "integrator" role that is needed on complex projects to provide more effective information flow.

5.1 Illustrations of Trust and Learning Cycles

After developing the interaction model, internal validity was provided by using the model to explain dozens of interactions from the field study. The following sections use a few vignettes from the field study to illustrate how the conceptual model can be used to understand and explain interaction effectiveness. These vignettes include coordination meetings that deal with various scopes of work, such as: 1) Site utilities relocation, 2) 3D MEP coordination, 3) implementation of infection control risk assessment measures, 4) coordination of the trades on-site, 5) building envelope coordination, 6) design review meetings, and 7) Value-engineering meetings.

5.1.1 South Shell Utilities Coordination Meeting

A major coordination issue that faced both projects was the routing of major utilities from the existing hospital to the Cancer Institute. These utilities had to run through the future construction site for the Children's Hospital and as it had been originally planned, this work would have needed to be performed twice: once to get the Cancer Institute to be operational and then the utilities would need to be relocated during the construction of the Children's Hospital at significant inconvenience to the Cancer Institute. As a result, the project team tried to figure out a solution that would allow for the utility lines to be installed only once without delaying the completion of the Cancer Institute.

To address this challenge, the project team held several meetings between the MEP engineers, construction manager, contractors, architect, HMC facilities personnel, and the owner. In one of the earlier meetings, twenty-five high profile project team members were brought together for two hours with the intent of developing a plan, yet very little was actually accomplished. Much of this had to do with the meeting's lack of organization, but there were also some particular behaviors that negatively affected the ability of the group to understand the situation and make decisions. First, although there was an agenda for the meeting, it was not followed. Instead, the discussion shifted depending on what the person speaking wanted to focus on. Throughout the meeting, the following process would occur: 1) someone would ask a question; 2) others would contribute information that they knew about the subject; 3) as the group began getting into subject areas where their was uncertainty, someone would shift the conversation to something that they were more sure about but was unrelated to the original topic of discussion; and 4) the discussion would shift to the new topic without any conclusion, decisions, or explicit understanding of what was needed and who was responsible for resolving the previous issue. The group's failure to have enough discipline to follow the agenda and maintain focus on the key issues created several difficulties in building trust and learning. First of all, since individuals and the team in general were not being held accountable for developing solutions, there was no reason for team members to admit their lack of knowledge regarding certain issues, offer sensitive information, or compromise their personal goals for the meeting. Secondly, since there was no one responsible for keeping the discussion focused, the conversations shifted to whatever topics vocal individuals wanted to discuss. This undermines trust and team commitment by putting the individual ahead of the project and devaluing the relevant information that was just provided by others without capturing that information in a decision. Third, by keeping the discussion away from uncertain or contentious issues, there is little opportunity for others to learn, clarify ambiguity, and capture new information that is needed to establish a common understanding.

During this meeting, there were some particular individual behaviors that appeared to be detrimental to the effectiveness of the meeting. One of the individuals from the construction management firm kept giving reasons why they could not do something, but offered no indication of why or what could be done instead. The first concern with this behavior was that everything was phased in the first person singular (e.g. “I can’t partially excavate the site…) instead of referring to the firm or the project team. This extreme focus on the individual instead of the team was first of all strange and distracting to some of the attendees and secondly, set a precedent for putting the individual ahead of the team and project which compromises the building of trust. Also, some people at the meeting became frustrated with this individual’s unwillingness to explain what the critical issues were regarding why something could not be done. These behaviors kept the rest of the team from being able to learn what the concerns were and subsequently kept them from being able to provide more relevant information that might have led to solutions.

In addition to these interpersonal issues, there were also person/object interaction problems. The appropriate reference materials were missing from the meeting, so simple questions such as trying to recall what was decided in the meeting two weeks prior or the current location of certain utilities resulted in long ambiguous discussions full of personal opinions and speculation. These issues could have been easily avoided by simply looking at a set of drawings or the previous meeting's minutes, but these objects were absent from the meeting. The architects did have some basic background drawings that they pinned up on the wall to use as aids to point out and explain certain issues. However, the architects didn't want to mark up the drawings, so there was no formal capture of what was discussed in the meeting and everyone would have to rely on their individual recollections for the next meeting rather than having a collectively-developed, formal capture of the meetings discussion. As a result, a two-hour meeting that cost more than $10,000 in billable hours, resulted in no decisions, lots of questions, but as a consolation everyone now had "a better understanding of what the issues were." Unfortunately, the next meeting was not held for several weeks, so the "better understanding" faded as each person slowly reverted back to their previous understanding and much of the next meeting was also spent trying to reach a consensus regarding many of the same issues that had been discussed at the previous meeting.

5.1.2 Infection Control Risk Assessment Plan Implementation

One of the most successful aspects of the Cancer Institute project was the implementation of an ambitious and proactive infection control risk assessment (ICRA) plan. The project was able to accomplish this because the ICRA consultant that was brought into the project had developed a detailed plan regarding the roles and responsibilities of al the project team members regarding ICRA throughout the various phases. The consultants had a full-time person on-site all the time and he attended many different meetings, walked the construction site everyday, and spoke individually with the different people involved with the project from the administrators at the hospital to the laborers in the field. The consultants also set up a training course that all construction personnel were responsible for attending prior to their being allowed on-site. For specific scopes of work that posed significant concerns for infection controls (e.g. driving piles outside the existing operating rooms, removing stone panels on the exterior wall of the emergency department, etc), the consultants worked together with construction and hospital personnel to understand their needs and develop ICRA plans in an iterative nature that helped both entities achieve their goals and support the best interests of the project. These plans were then effectively communicated to the entities involved to get their feedback and buy-in and the implementation of the plans was strictly enforced. In addition to creating ICRAs for specific scopes of work, there were also more global measures that were taken. Some of these, such as prohibiting the use of tobacco products and beverages with sugar on-site required continuous enforcement and had to be carefully addresses as to not negatively affect morale and motivation.

There were several aspects of the ICRA program that contributed to its successful implementation. The first was that the consultants had a well thought out plan that created less uncertainty, allowed them to focus their attention toward more dynamic and unpredictable factors, and enabled them to present their plans to others with more clarity. This enabled the consultants to have more time to learn about the needs of other project team members and provided a reference to help them explain their needs to others. The training program also provided some initial exposure and learning to ICRA concepts, its importance, and what was expected of project personnel before they ever stepped foot on site. This ensured that everyone on the site had at least a basic understanding of ICRA and set the basis for building upon that understanding. In addition, the consultant’s full-time presence on-site, regular attendance at various meetings, and interaction with all project personnel showed respect for others and their opinions and helped facilitate trust between the ICRA consultants and the rest of the project team. This made it easier to explain the rationale for certain measures and to hold people accountable for their actions. When construction workers were reprimanded for having soda on-site, it was because they knew it was not allowed, understood why it was a hazard (i.e. sugary liquid spills foster mold growth), and had decided to do it regardless of the risk. In addition, the inclusive and iterative process of putting together an ICRA for a specific scope of work resulted in both construction and hospital personnel learning about the concerns of the other and developing a mutually agreeable plan. The inclusive nature of this process also fostered trust through showing that each person's input was valued.

5.1.3 Three-Dimensional MEP Coordination Process

Traditionally, the coordination of the mechanical, electrical, and plumbing (MEP) scopes is provided by the contractors and is performed by overlaying their shop drawings on a light table to see where there might be conflicts. In recent years, more sophisticated projects have used 3D models to coordinate the designs and identify potential field clashes (e.g. places were a pipe runs into a steel beam or a duct). The owner's representative for the Cancer Institute wanted to utilize 3D coordination for this project because of its complexity.

In addition to the construction manager's MEP coordinator, the owner also brought in a graduate student from the University to serve as the 3D model coordinator. The student used a program to combine the various 3D models from the different subcontractors into a master model that automatically identifies clashes. The MEP coordination meetings were held every two weeks, during which they would resolve look at the various clashes and use the model to work out solutions. The subcontractors would then have a week to make the changes, add new information, and upload their updated drawings so that the model coordinator could combine them to identify the new clashes for the next meeting. Although this process took much longer that traditional 2D coordination, by the end of the coordination process, the subcontractors had developed great relationships with each other and had a much more thorough understanding of their own systems and the other systems. This translated into greatly improved construction outcomes. As the superintendent put it "they are ahead of schedule, they actually like each other, and the work looks great."

In terms of the trust and learning cycles, this situation also provides some interesting cases. First of all, through their continuous interaction, the subcontractors got to know each other pretty well and those relationships continued in to the field when they were actually installing the systems. In addition to just getting to know each other, the sense of group accountability that developed from resolving hundreds of clashes in the model helped to build trust because they were working together to find the optimal solution for the project. The complexity of the 3D model enabled them to reduce ambiguity and deal with more factual information rather than personal preference. Second, having to constantly find solutions for group problems enabled them to learn a lot about their own systems, other systems, and how they affect each other. In addition, the ability of the 3D model manager to quickly manipulate the model enabled that boundary object to truly compliment the people; since the model manager was responsible for the technological aspects of the coordination process, the subcontractors could focus on what they knew best which was providing constructability information. The holistic understanding that model manager gained about the project also made him a valuable entity in terms of asking questions or offering suggestions that helped the team make the best all around decision. As a result, despite that the all of the MEP subcontractors acknowledged that this was the most complicated project that they have ever coordinated, the project outcomes were much better than had been anticipated.

5.1.4 Foremen's Meetings

Another interesting example is that of the foremen's meetings. These meetings are held every week and consist of having all the foremen from the different trades meet together with the project superintendent. The superintendent uses the same format every week, so individuals know what to expect and what to be prepared for. Although he jokes around with the foremen before the meeting, during the meeting he expects people to be on time, come prepared, and keeps the meeting on task. As the go through the updates, he holds people accountable for their actions, but also gives them praise when it is due. He is most demanding of his own staff, and holds them to a higher standard that the trades. This discipline and fairness, first of all, increases everyone's trust in the superintendent and the value of the meeting, and secondly creates a predictable situation so that everyone knows what is expected, what information they are responsible for, and they can focus on understanding what is being discussed at the meeting rather than uncertainty about the process and expectations.

Several times throughout the meeting the superintendent goes around the table and asks each person individually if they have any comments related to an important issue. As a result, each person feel like an important part of the meeting and the project, they get to know each other, and feel more like a team. They also don't need to worry about interrupting or shifting the topic of discussion just to bring up heir concerns because they know that they will have an opportunity to share their thoughts.

The superintendent also puts a lot of importance on the meeting minutes. For example: 1) the previous week's meeting minutes are used as the next week's agenda; 2) all the information discussed is accurately captured in the meeting minutes; 3) he uses the minutes as a primary source of information for several other coordination meetings; and 4) he makes sure that they are correct and tells everyone if there was a mistake in the previous week's minutes. As a result, the foremen also make sure to provide accurate information at the meetings because they know that it matters.

Based on the interaction between the superintendent and the foreman, there is a high level of mutual respect. The foremen will often do things that are out of their scope because the superintendent asks them to do it for the good of the project. The foremen's meeting also seems to set the tone for the relationships out on the site. For example: 1) a handful of trades do not regularly attend the meeting and as a result are nor well respected by the other trades or viewed as part of the "team"; 2) the "office staff" (e.g. certain project managers and the ICRA consultant) that do attend the meetings are respected by the trades and have a much better likelihood of getting the trades to address their concerns; and 3) regular attendees often speak up for each other in the meetings and also help each other in the field by volunteering to do work that is not in their actual scope.

5.1.5 Building Envelope Coordination

When the construction drawings were at 75% completion, the owner's representative performed an internal review of the building envelope design and provided a long list of specific comments to the architect. Many of these comments were regarding some very complex but architecturally significant details that were lacking significant detail. Based on his experience on numerous past projects, he made it clear to the architects that the lack of detail was unacceptable. Based on these interactions with the owner representative, the architects felt threatened because they didn't actually know how to address the issues. Because of the harsh tone that the owner's representative took with them, the architects became defensive and even less willing to acknowledge their lack of knowledge. As a result, most of the comments were completely ignored. Because he felt these issues were critical to the project, the owner's representative hired an outside consulting firm to review the drawings and also added significant performance testing requirements to the project. The consultant's report highlighted many of the same issues, but because this was perceived by the architects as the owner's representative pushing his agenda with more force, it only increased the architect's defensiveness and expanded their strained relation into many other aspects of the project. It got to the point were the architect stopped offering any sort of non-essential information out of fear of criticism and minimized their interaction with the project team to what was absolutely necessary. In addition, decisions ended up being made in the absence of either the architect or the owner's representative, but always ended up coming up again because whoever was absent from the decision making process would not accept the decision. As one of the construction managers put it "we can't kill anything on this project." This dynamic essentially brought progress on the job to a halt for a short time.

The interactions between the architects and the owner representative created a vicious cycle. Because of the owner representative's own expectations, he shared his concerns but in a harsh way that caused the architect become defensive and distrust the owner's rep. The architect could have taken the opportunity to ask for explanations regarding the issues that the rep was concerned with, but didn't. The combination of not being willing to learning and distrust caused each person to hold more tightly to their existing mental models and values rather than beginning to understand each others. It made the owner's rep push even harder for his priorities and the made the architect closed himself off even more – they became more extreme in their own differing perspectives. This kept them from developing a common understanding and decreased their commitment to the project that just reinforced the cycle. Slowly, both entities got more and more frustrated with each other, the project in general, and others involved with the project.

In addition, the boundary objects that were being used were inadequate. Much of the problem was the over reliance on two dimensional drawing and written reports. With the complexity of these systems, there was no way to effectively figure out and convey the full design in 2D. The architects were stuck trying to figure out three and four-dimensional problems in two dimensions which lacked the appropriate structure and the complexity of the discussions was lost in trying to explain these issues on paper.

Fortunately, for the project, a new owner's representative was phased in, subcontractors were selected, and a new building envelope consultant was brought in review the drawings but through the construction manager. At this point, the design was still in poor shape that negatively affected the quality of the bids and resulted in the new consultant's report being essentially the same as the past two reviews. However, in addition to issuing the report, the consultant also facilitated several design review and coordination meetings. When he talked to the architect, he used their terms and made efforts to show that he understood their goals or asked them for their thoughts. He did the same in his conversations to the contractors and the owner. He also made subtle efforts to make sure that each entity understood the concerns, expertise, and capabilities of the others and in many cases "translated" information that one person provided so that it was more relevant to the specific needs of other. The consultant used 3D sketches to explain what the concerns were and work out solutions with the other team members. The consultant was very skilled at drawing quick three-dimensional isometric sketches – as he put it "the isos help smoke out the complexity." Once he drew the sketch up on the white board, it became obvious what the missing information was and the sketches also served as a mechanism to pull needed information from the team which could then be capture and made available for others involved with the project to understand the envelope design. As a result, the team started to better understand what the issues were and began sharing information more openly and working together to develop solutions that they were all happy with and could commit to – a totally different outcome from the earlier situation.

The interactions with the consultant created a completely different outcome. Because the consultant showed that he valued the opinions of the others by bringing up issues that were of concern to them, using language familiar to them, and asking them questions – he earned their trust and they began to share more information with each other. The consultant also took the time to explain specific issues so that others could learn. He drew connections between the concerns of one party and the concerns of others and how they both affected the interests of the project. The consultant took time to establish a basic level of trust and learning by helping others understand some basic issues. As a result, he set in motion virtuous trust and learning cycles. Because they trusted the consultant, others shared more information which created additional trust as well as learning which in turn made them feel like valuable parts of the project and better understand the project which further enables them to share better quality and more relevant information. The use of coordination meetings, 3D, and sequence sketches (i.e. 4D drawings) were more effective processes and boundary objects and were more appropriate to address the social and technical complexity of the issues. The 3D and 4D sketches, however, relied on the consultant because no one else on the project team was as adept at developing those sketches quickly. Because he was present, the other individuals could just focus on providing relevant information while the consultant dealt with the technical aspects of the drawings.

5.1.6 Children's Hospital Design Review Meetings

During the early part of the design phase for the Children's Hospital, there was a major meeting with over twenty high-profile attendees that was held at the architect's office in Boston. The goal of this meeting was to review the entire design to date and provide feedback to the designers. The morning was spent reviewing the different floor plans and making decisions on what to do about certain spaces. However, at some points in the discussion, topics emerged for which there was not clear expert so in essence everyone became an expert and pushed their own uneducated opinions. One of these topics was the linen cart storage space on the first floor. After spending over 30 minutes speculating as to the preferences of linen cart handlers before the discussion was dropped without conclusion because it wasn't going anywhere and everyone was getting frustrated with each other.

In this first part of the meeting where the group was reviewing the floor plans, there were a couple characteristics that kept some of the discussions from being productive. The first was that there was no clear goal or basis for making decisions in terms of the intent of the design and what would be most valuable to the end users. This ambiguity caused people to interpret the situation based on their own personal values and understanding rather than working toward a common goal. Because these discussions ended up being personal in nature, they resulted in much more frustration that only intensified the urge to push for personal preferences. The second issue was that there were some issues, such as the linen cart storage area, where there was no existing knowledge of what the key issues were. Without that basis for understanding, there was no way to have a substantive discussion. This missing information should have generated a list of specific questions that became the responsibility of specific project team members to address. For example: 1) the hospital facilities personnel should have been charged with meeting with the linen cart handlers to better understand their preferences; 2) the architects should have done more research to figure out what the state-of-the-art is in linen cart storage design; and 3) the hospital administrators should have made a decision whether they wanted to use valuable programming space for cart storage or implement more efficient processes so that some of that space could be utilized for more valuable uses.

After the floor plan review, the conversation moved to the review of the exterior design of the building. When architects put their rendering of the Children's Hospital up on the wall, initially the same types of comments that had plagued many parts of the discussion all morning began to emerge again – personal preferences, uneducated opinions, etc. For example, one of the administrators for the hospital even made the comment, "Everyone likes trees, but I just think that the trees on the rendering are too big". Thankfully, the chief planning architect from Penn State – a soft spoken man with a self-deprecating sense of humor and an amazing ability to cut very clearly to the heart of an issue, asked some very poignant questions – he doesn't always say a lot, but when he does he always starts off asking questions to make sure that he understands the issues. He started off – "Maybe I get the dummy of the day award, but what is the intent of the design?" He then asked about the different materials that made up the wall systems and what their significance was in helping to realize the architectural intent. The architect answered his questions and elaborated on some of the issues to explain further. The Penn State planning architect built off of the architect's answers to ask more specific related questions. His questions came across as genuine, because although he had a detailed understanding of architectural theory, be was truly interested in understanding the thoughts that had gone into this specific project. Also, the systematic and incremental manner that he asked his questions not only help the others understand the basis for the design and converge on their understanding of what the architecture was supposed to convey, but his asking questions also empowered the architects to explain their thoughts and goals behind the design that were not clear to the group earlier. This series of questions and comments enabled others to understand the architectural goals, the approach for how these goals were being incorporated into the design, helped more clearly define the depth of the architect's role in developing the design. Now the group had a much clearer basis for addressing the critical issues regarding the exterior wall design and a much more substantive discussion ensued.

5.1.7 Cancer Institute Value Engineering and Design Review Meetings

At two points in the Cancer Institute delivery process, the owner's representative facilitated two-day intense value engineering sessions with the goal of bringing the design back within budget while maintaining as much value as possible. These sessions were held toward the end of design development and toward the end of construction drawings. The owner's representative invited all individuals involved with the Cancer Institute project to attend. The impetus for these meetings was to reconcile the scope of work reflected in the current drawings with the target budget. These meetings were set up as two full days back-to-back with everyone in the same room. The general sequence of events proceeded as follows:

- The owner's rep would begin by reviewing the process map that he had created which included the major goals for each phase;
- The owner's rep would then explain that the overall goal of the meetings was bring the project back within the target budget while maintaining as much value as possible. In the second set of meetings, the group needed to cut $30 million out to maintain the original $100 million budget;
- The owner's rep would go around the room and ask each person to introduce themselves and share their main personal concern or goal for the meeting;
- Everyone would review the current design and the two estimates that had been provided by the construction manager and the architect's cost consultant. Discrepancies between the two budgets would be reconciled.
- The group would break into smaller groups charged with focusing on a certain scope of work. This usually consisted of an exterior cladding/site work/interiors group and a MEP group. Each group was responsible for developing a list of options to be considered for value engineering.
- The two groups would reconvene as one large group and they would debate and modify the developed options until they had brought the budget back to the target amount.

The beauty of these sessions is that all the decision-makers were present, these included the principals of the various design firms and the administrators of the hospital and university. These were the people that had the knowledge to evaluate options and the discretion to make decisions. In addition, there was a strong tangible goal and an understanding of the overarching priority: meet the budget first and then incorporate as much value as possible. The daunting nature of the goal and the short intense period of time in which it had to be accomplished (i.e. two days), created a strong sense of shared fate. Coupled with the initial sharing of personal goals and concerns, this created an atmosphere where the meeting goals governed over personal goals, but the personal goals had to be taken into account in order to develop solutions that could be agreed upon. The transparency of reviewing the budgets line by line provided a means for letting others learn about the cost impacts of various design features and helped develop trust in the estimates and estimators by checking of numbers and getting additional feedback. Trust in the estimators was critical for the next day's discussions regarding evaluation of the various value-engineering options and making final decisions. The use of breakout groups also enabled better cohesion of individuals interested in specific scope areas and enabled more focused and interesting discussions. In addition, although there was an overall goal for the two-day meeting of reconciling the actual budget with the target budget, the event was structured such that each section of the meeting had its own subgoals to maintain motivation and provide a sense of accomplishment but also to ensure that the groups was being held accountable for working toward the final outcome.

5.2 Support from Related Research

In addition to validating the constructs through vignettes, a review of literature from related fields was also conducted as a means of providing external validity to the concepts.

Specifically, this literature review pulls from existing research in organizational theory, organizational behavior, organizational strategy, and information science.

The first section deals with the dilemma of complexity and the need for greater diversity among teams that are dealing with complex situations. The subsequent sections summarize literature related to conflict, schemas, and commitment that serve as proxies for interactions, mental models, and commitment, respectively. Although none of the studies link the constructs of learning, trust, commitment, and common understanding as described in the model, they each support portions of the model.

5.2.1 Complexity, Diversity, and Conflict

There has been substantial research in the organizational sciences regarding management in complex situations. Much of this research has focused on the need for diverse expertise to handle complexity and the constructive or destructive conflict that results. Lawrence and Lorsch (1967) described the complexity dilemma: As situations become more complex, they require greater differentiation and specialization that in turn requires greater integration. The paradox exists in that an individual or group of individuals (e.g. top management teams) are expected to integrate and arrive at decision regarding information that was too complex to thoroughly understand in the first place. Research suggests that an organization's ability to evaluate and utilize outside information is largely a function of their level of prior related knowledge (Cohen & Levinthal, 1990). Therefore, management teams require greater numbers of executives with more specialized knowledge in specific functional areas.

The major problem with such diversity is that individuals have their own values and cognitive base (i.e. mental model) that they use to interpret a situation (Hambrick and Mason, 1984). These differing values and mental models create what Mischel (1977) described as a “weak” situation where the best course of action is not clear and individuals make decisions based on their personal interpretations, as opposed to a “strong” situation in which the proper course of action is clear regardless of personal differences. Other studies have also demonstrated that ambiguous situations cause individuals to rely more heavily on their own past experiences (Cyert & March, 1963), actions that are familiar to them (Axelrod, 1976), or actions that reflect their functional backgrounds (Kimberly & Evanisko, 1981). As a result, there is often significant conflict that results from these individuals trying to interpret complex situations and develop a collectively agreed upon course of action.

Although this dilemma has been described in homogeneous organizations (i.e. single firms), it is even more pronounced in construction project teams where individuals have differing educational backgrounds, parent companies, roles, goals, and perspectives. Even within the context of a single firm, researchers have argued whether diversity results in positive outcomes. Some studies have shown that diversity in teams leads to creativity and more effective decision making (Bantel and Jackson, 1989), while others have shown that diversity results in worse communication and less effective decision making (O’Reilly, Snyder, and Boothe, 1993). These conflicting findings have let to research aimed at better understanding the moderators that affect interactions and the subsequent outcomes of teams.

There are three scopes of organizational science literature that are particularly relevant to the issue of interactions. As was found in the focal research of this dissertation, there are tightly coupled interactions between several factors that affect the outcomes of interactions. The following sections summarize literature from conflict research, schema (i.e. mental models) research, and commitment research to support the concepts represented in the trust/learning interaction model. These areas of research were chosen because they most closely represent the important constructs of interactions, mental models, and values, respectively.

5.2.2 Conflict

Dirks and McLean Parks (2003 p. 285) define conflict as "the interaction of interdependent entities who perceive opposition in goals, aims, and values and who perceive the other entity or entities as potentially interfering with the realization of these goals." In construction project team interactions, these types of interactions are ubiquitous. The predominant predictor of substantive conflict in the diversity: Diversity in terms of demographics (e.g. age, ethnicity, gender) or in terms of information (e.g. based on functional area, education, tenure with firm) (Jehn et al., 1997; Jehn et al., 1999). To aid in understanding the nuances of conflict, social science research has identified three major types of conflict:

- *Substantive Conflict*: Differences in viewpoints, opinions, or approaches to a task (Pelled et al, 1999; Jehn and Mannix, 2001).
- *Affective Conflict*: Personality or interpersonal conflict characterized by anger, frustration, or uneasiness (Pelled et al., 1999; Walton and Dutton, 1969).
- *Process Conflict*: Conflict over how something should be done concerning duty, responsibility, accountability, or resource delegation (Jehn 1997; Jehn et al., 1999).

Although conflict has a negative connotation, there are aspects of conflict that are beneficial. Substantive conflict is mainly technical in nature and has been shown to lead to positive task-related outcomes such as decisions outcomes (Amason, 1996), decision comprehensiveness (Simons et al., 1999), constructive communications (Lovelace et al., 2001), task progress and efficiency (Tjosvold & Du Dreu, 1997, Wong et al., 1992), and performance (Jehn, 1994, Shah and Jehn, 1993). These benefits are even greater for non-routine tasks (Jehn, 1995). Other research has shown that teams in positive environments that are committed to common goals experience lower levels of substantive and affective conflict regardless of diversity

(Watson, Clark & Tellegen, 1988). Trust moderates the extent that substantive conflict translates into affective conflict. For example, in low trust situations there is a lot of translation into affective conflict, but in high trust situations there is neutral or positive interpretation of the substantive conflict that prevents the transfer into affective conflict (Simons &Peterson, 2000). Also, individuals in high trust relationships tend to evaluate their relationships with much longer time metrics than those in low-trust relationships and therefore can discount a single negative incident more readily (Holmes & Rempel, 1989).

Affective conflict is more personal in nature and is increased by demographic diversity (Jehn et al., 1997) and functional background diversity (Pelled et al., 1999). Affective conflict has been shown to have detrimental effects on the free and open exchange of information and other relational outcomes such as satisfaction, commitment and cohesiveness, respect, and trust (Earley & Moskowski 2000, Jehn and Mannix, 2001; Jehn 1994; 1995; 1997; Jehn et al., 1999). It also has a negative effect on task-related outcomes such as perceived performance, actual performance, and efficacy of communicative and planning activities (Earley and Moskowski, 2000; Shah and Jehn, 1993; Jehn, 1994; Jehn et al., 1999).

Process conflict tends to have a negative effect on task outcomes and relational outcomes such as increase propensity to leave (Jehn, 1997; Jehn et al., 1999), role ambiguity and perceived fairness (Jehn, 1997), decreased cohesiveness, trust, and respect (Jehn and Mannix, 2001) and satisfaction and commitment (Jehn et al., 1999). The combination of high affective and process conflict can be especially detrimental. In these cases, parties clash personally while also disagreeing about responsibilities and accountability that diverts energies from the task at hand. This is illustrated in the excerpt from Dirks and McLean Parks below (2003: 302):

> "The combination of high affective and process conflict and high substantive conflict over a non-routine task may be particularly deadly. In this situation, high affective and process conflict results in personal clashes among the parties (affective conflict) who are

> unwilling or unable to specify responsibilities and accountability (process conflict). Information will be hoarded, ideas will be suppressed, and the high levels of conflict on all fronts will result in fractious and contentious discussions. As a result, the group is unlikely to resolve their differences and performance is likely to suffer."

The research findings above demonstrate that while differing understandings of a situation create conflict, there several other factors that affect whether that conflict translates into positive or negative outcomes. The social dynamic within the group, particularly the presence or absence of trust, seems to be a major influence on the type of conflict that will result from the interaction. However, the type of conflict has significant affects regarding the commitment to the project, commitment to the team, future information sharing, and social dynamic.

5.2.3 Schemas

One of the major factors influencing the effectiveness of an interaction is how the various individual interpret the situation. Part of their interpretation comes from their cognitive understanding of the situation, while the other part comes from their values or feelings about the situation. In terms of their cognitive interpretations, it is necessary for managers to continuously refine and adapt their understanding of a situation, especially in rapidly changing, information intensive environments (Eisenhardt and Martin, 2000). Hambrick et al (2005) also observed that when demands are greater, situations require executives to be more comprehensive, but that the cognitive limitations of executives create the need to limit the amount of information and cognitive processes required of them. One means of addressing these two conflicting issues is through the use of schemas. Schemas, or mental models, provide the basis for understanding a situation and for limiting the amount of information that an individual needs to process.

There are four types of schemas that have been identified in the organizational behavior literature. The first is the self schema or the cognitive categorizations about one's self that are derived from past experience. The second type is the person schema, or how individuals categorize people. Fong and Markus (1982) found that people with a self-schema for a given attribute also specifically note it in other people. The third type is a script schema that outlines the appropriate sequence of events in a given situation (Lord & Foti, 1986). Scripts impact memory, perception, and judgment and allow for comprehension and inference making (Schank and Abelson, 1977; Gioia and Manz, 1985). The final type of schema is a compound person-in-situation schema that outlines the expectations of how an individual will behave in a situation. This compound schema can be created and results in a much richer understanding of situations (Cantor, Mischel, and Schwartz, 1982).

Developed through past experiences, schemas allow individuals to reduce the amount of information that they need to process by simply plugging limited new information into their existing model to determine their course of action. In team environments, it is necessary for individuals to agree to a common course of action. For this reason, team members need to learn from each other and the situation to develop complimentary schemas through which they can arrive at a common decision.

5.2.3.1 Schemas and Learning

In order to modify schemas, individuals must go through a process of learning (Stacey, 1999: 169). Therefore, as environmental complexity decreases, individuals can first engage in lower level learning (i.e. single-loop learning) that applies the same mental model to new information, and then can engage in higher level learning (e.g. double-loop learning) which involves two feedback loops: one related to learning about the consequences of actions and another that relates to changing the underlying assumptions that make up a schema. There are several environmental issues that affect an individual's ability to learn. Blumer (1969) found that the frequency and intensity of interaction between individuals affects their respective filters through which they interpret a situation. Fiol and Lyles (1985) found that learning, especially double-loop learning cannot happen in environments that are too complex and dynamic because it is a sensitive process that requires a balance between change and constancy.

5.2.3.2 Schemas and Common Understanding

Mental models, or schemas, are built from experience with relevant instances and they become more abstract, complex, and organized with greater experience (Fiske and Taylor, 1984). Expert schemas contain more information that beginner schemas (Lurgio and Carroll, 1985) and allow for more links among elements (McKeithen, Reitman, Reuter, and Hirtle, 1981). These studies were further supported by Cohen and Levinthal's (1990) description of absorptive capacity that states that an organization's ability to learn is based on its ability to link new knowledge to its existing knowledge base.

In order to make group decisions, it is essential be able to transmit the information to others. Because transfer of information to others is inefficient and prone to bias and distortion, common understanding is also needed for effective communication (Dearborn & Simon, 1958). These hazards only increase in environments with greater uncertainty (Lawrence & Lorsch, 1967; Tushman, 1977). As a result, there needs to be sufficient knowledge overlap to ensure effective communication (Dearborn and Simon, 1958; Katz and Kahn, 1966; Allen and Cohen, 1969; Tushman and Scanlan, 1981).

However, Van Der Vegt and Bunderson (2005) argue that expertise diversity can be threatening and uncomfortable to individuals and make it difficult for some members of a multidisciplinary team to engage in critical interaction processes. They posit that a key moderating factor affecting the relationship between expertise diversity and team learning or the development of common understanding is the level of collective team identification (i.e. the emotional significance that members of a given group attach to their membership in that group). Teams with greater social integration will be more willing to subjugate personal interests for team goals that will improve team task performance (Harrison et al., 2002). Harrison et al. (2002) also suggest that in order to create highly effective, diverse teams should focus on maximizing differences in knowledge, skills, and abilities while minimizing differences in job-related beliefs, attitudes, and values.

5.2.3.4 Schemas and Trust

Trust also plays a role in enabling individuals to adjust their schemas. Not only does it influence the perceived psychological safety of a team environment, but it also impacts how another party and their actions are perceived in retrospect (Dirks & Ferrin, 2001). In addition to mental models, trust also impacts one's interpretation of events or behaviors. Rousseau et al. (1998) define trust as "a psychological state comprising positive expectations about the behavior or intentions of another party, when one is vulnerable to that party" (p. 395). Trust facilitates the willingness to take a risk in a relationship and involves the estimation of future behavior. Risk taking can manifest itself in cooperative behavior, sharing sensitive information, bringing up a controversial idea, investing resources or sharing knowledge with another party. Trust facilitates these behaviors through a cognitive, conscious calculation of risk (Kramer, 1999) where perceptions of another's character impact one's willingness to take risks (Mayer et al., 1995) and fear of being exploited (Dirks, 1999). These findings have implications regarding the amount and types of information that individuals share with others. The effects are selfreinforcing as individuals that felt trusted by others also tended to be more trusting of others (Blau, 1964; Robinson, 1996).

There are also several studies that explain phenomena related to the psychological safety required for individuals to learn. One of the most prevalent effects is the perseverance effect, or a resistance to change a schema even in the face of contrary information (Fiske & Taylor, 1984). This effect often persists even when an individual is informed their supporting evidence is false (Ross, Lepper, and Hubbard, 1975). Other research has shown that telling people to modify their schemas does not work, whereas individuals are more likely to modify their schemas if they are led to understand the need for change and decide to change on their own (Lord, Lepper, and Thompson, 1980; Anderson, 1982). Cohen and Ebbesen (1979) found that the reason a person is engaged in an experience (i.e. their goals) affect their selection of schema. Higgins, Rholes, and Jones (1977) found that priming, or providing previous exposure to a particular schema, will affect their evaluations of subsequent evaluations.

5.2.4 Commitment

Because and individual's values can be difficult to observe, commitment provides a useful proxy for one's values. Organizational commitment is defined as the relative strength of an individual's identification with and involvement in a particular organization. This identification can be characterized by: 1) a strong belief in and acceptance of the organization's goals and values; 2) a willingness to exert considerable effort on behalf of the organization; and 3) a strong desire to maintain membership in the organization (Porter et al., 1974). Steers (1975) found that organizational commitment is a critical factor in determining the overall effectiveness of an organization.

5.2.4.1 Types of Commitment

In order to better explain commitment phenomena, Meyer and Allen (1991) categorized commitment into three classes: affective, continuance, and normative commitment. They describe the three types of commitment as different psychological states, specifically:

> Affective commitment refers to the employee's emotional attachment to, identification with, and involvement in the organization. Employees with a strong affective commitment continue employment with the organization because they want to do so. Continuance commitment refers to an awareness of the costs associated with leaving the organization. Employees whose primary link to the organization is based on continuance commitment remain because they need to do so. Finally, normative commitment reflects a feeling of obligation to continue employment. Employees with a high level of normative commitment feel that they ought to remain with the organization.

In another meta-analysis, Meyer et al. (2002) found that all types of commitment are affected by personal characteristics. Affective commitment is influenced by work experience; especially those that make the employee feel psychologically comfortable (e.g. approachable managers, equitable treatment) and enhanced sense of competence (e.g. challenging tasks and feedback) (Allen & Meyer, 1996). Normative commitment is influenced by socialization experiences, but may also be strongly influenced by earlier experiences (Allen & Meyer, 1996). Buchanan (1974) identified four factors of socialization that affect the strength of commitment: interaction with superiors, interaction with peers, peer group cohesion, and group attitudes toward the organization.

Research has shown that affective and normative commitment have positive correlations with desirable work behavior (i.e. attendance, performance, and organizational citizenship behavior) whereas continuance commitment has a negative correlation with performance and a near zero correlation with organizational citizenship (Allen and Meyer 1996, Meyer et al 2002, Katz 1964). Commitment of members to a given organization has been shown to affect turnover, job satisfaction, motivation, and individual performance (Koch and Steers, 1976; Mowday et al., 1974; Mowday et al., 1982).

5.2.4.2 Factors Affecting Commitment

There are several factors affecting the type and level of commitment that an individual feels toward an organization. Research has shown that, ideally, it is best for organizations to have strong affectively committed individuals (e.g. Steers, 1975). O'Reilly and Chatman (1986) found that the two major mechanisms affecting affective commitment are identification and internalization. Identification is based on exchange, where a member's desire to remain in an organization and their willingness to exert effort is due to the benefits that they receive from their relationship with the organization. Internalization has to do with shared values between an individual and the organization and is related to other issues of person-organization fit. Gellatly et al. (2005) found that the level of affective commitment sets the "tone" for the other types of commitment because it frames whether the normative or continuance commitment is viewed in a positive or negative context. When affective commitment is high, normative commitment is positively related to intent to stay and organizational citizenship behavior and is viewed as a "moral obligation". In contrast, when continuance commitment is high, normative commitment is perceived as an "indebted obligation" has a weak positive relation to intent to stay and a negative relation to organizational citizenship behavior.

However, there are numerous factors that can cause changes in commitment type. If an individual's expectations differ from their actual realization, this can trigger dissatisfaction or disappointment that in turn results in decreased commitment (Buchannan, 1974; Rousseau, 1995). Inequity, for example, or even the perception of inequity has been shown to negatively affect trust in the organization as well as organization commitment. Procedural justice (i.e. perceived fairness of the process) was a more closely correlated to commitment and trust, whereas distributive justice (i.e. perceived fairness of the outcome) was more closely correlated to satisfaction (Folger and Konovsky, 1989). Similarly, Folger and Bies (1989) outlined seven key managerial responsibilities (i.e. truthfulness, justification, respect, feedback, consideration of employee views, consistency, and bias suppression) that are needed to create a sense of trust and fairness between leaders and group members.

Chapter 6

Discussion

Our society's perpetual drive for increased effectiveness and efficiency has resulted in countless technological innovations of the centuries. From the wheel and inclined plane to building information modeling and GPS-guided excavation equipment, innovations in materials, systems, and methods have enabled the design and construction of astonishing structures. However, these would have not been possible without proper management. In the last century, managerial and organizational innovations such as mass production, multi-functional organizations, strategic networks, integrated design, and continuous process improvement have greatly improved the quality and quantity of new ideas that help to further increase effectiveness. It is this last item, process improvement, specifically lean production management, that sets up the conceptual framework for the following discussion. This chapter gives a brief overview of the philosophy behind lean production management and then outlines the implications of these research findings for the "leaning" of information flow on complex projects.

6.1 Lean Production Management Philosophy

While influenced by many different organizational and production theories, the philosophy behind lean production management was developed and made famous by Toyota Motor Corp. This philosophy of incremental process improvement has enabled Toyota to significantly cut cost and delivery times while simultaneously improving quality to become the top automaker in the world. Their success has come from a disciplined focus on understanding what parts of their processes create “value”. Any part of the process that does not create value is viewed as waste and should be eliminated. Major sources of waste include: mistakes that need to be corrected, provision of unwanted products or services, unneeded processing steps, needless movement of materials and personnel, waiting for services that are not delivered on time, and production of goods or services that do not meet the needs of the customer (Womack & Jones, 2003). Lean philosophy outlines five basic steps for understanding what process steps create value or waste and how the process can be continually improved. These steps consist of:

- *Specifying value* as defined by the end customers
- Identifying the *value stream* and the specific actions for the process
- Making the value-creating steps *flow* towards the end product
- Letting the end users *pull* the end product through the value stream
- *Pursuing perfection* in every aspect

The following section will discuss the implications of this research on lean information management. This discussion will be structured in three parts. The first will consider the specification of value. The second will consider the identification of the value stream. The third will focus on enabling the flow of value and touch upon the aspects of flow, pull, and pursuing perfection. In order to tie this discussion more closely to existing lean literature, each of these sections will include some of the 14 management principles that Liker (2004) outlined in his analysis of Toyota’s development of Lexus and the Prius. These management principles encompass the various aspects of lean philosophy and provide a useful structure with which to discuss the implications of this research on lean information management.

6.2 Defining Value

At the heart of lean production management is the understanding of what constitutes value to the project. In the field study, there were a number of factors that affected the collective definition of what the project team considered valuable, i.e. explicitly stated goals, informally implied goals, and formally implied goals. In most cases, these goals did not provide clear direction, so individuals relied on their particular experiences to interpret the situation. This increased emphasis on the individual, creates a situation were individual goals or the goals of an individual's parent firm may take higher precedent than project goals and as a result compromise the overall quality of the project.

6.2.1 Influences on Value Definition

As the analyses in Chapter 4 illustrate, it can be quite difficult to identify what information is valuable. On a given project, value can be considered in terms of the entire project, a particular phase, or even a single meeting. In any case, there are three factors that come together to define value on a project: 1) Value can be <u>explicitly stated</u> through clear project goals; 2) Value can be <u>informally implied</u> based on the mainstream expectations of the industry, i.e. what was of value on past projects; and 3) Value can be <u>formally implied</u> based on the boundary objects used by the project team, e.g. if a manufacturer's warranty is needed, then the information required for the warranty becomes valuable. As the factors listed above are interpreted by all the individuals involved with the process, there is a <u>socially constructed</u> definition of value that emerges. This definition is based on the collective priorities, knowledge bases, and personal values of the project team. Because all these factors have to be interpreted, if they create an ambiguous definition of "value", then the effect of each individual's perspective is much more significant. However, if the factors create a strong sense of what is valuable, then that leaves less room for variability due to individual interpretation.

Depending on the clarity of the above contributors, the most influential component in specifying “value” may be the socially constructed aspect. Each individual has their unique perspective that establishes the lens through which they interpret the situations around them. These perspectives depend on the individual’s past experiences, knowledge, and values, but are also constantly changing based on new experiences. An individual’s current perspective determines the types of information and questions that they consider important and in the absence of clear goals from other sources, an individual defaults to their own personal goals or the goals of their respective firm. The collective perspective resulting from interaction between individuals creates a fluid and ambiguous socially constructed definition of what information is considered important to the project. This definition is usually not explicitly acknowledged and it changes as individuals and the intensity of their involvement changes.

6.2.2 Principle 1: Focus on Long-Term Goals

The first lean management principle states that management decisions should be based on long-term goals, even at the expense of short-term goals. First, this requires that goals be explicitly stated and clearly understood by all individuals involved in the decision-making process. Second, this establishes a prioritization of goals and a basis for decision-making. Third, it provides a context within which to clearly outline individual roles and responsibilities related to achieving the project goals. This principle addresses the three most fundamental types of ambiguity and establishes a basis for substantive discussions regarding technical issues. Establishing and enforcing clear goals also begins to develop a common understanding and mutual commitment among project team members.

In lean theory, value considered in terms of what is valuable to the end user. In the case of healthcare facilities, the end users are the patients and the staff and "value" is anything that enables better clinical outcomes. While staff input was requested early in the design phase through a series of user group meetings, they mostly provided their preferences in terms of spatial layout, equipment specification, and aesthetics. There was little understanding of what aspects of design could improve their performance. Much of this is due to hospital staff not understanding links between facility design and facility performance as well as the design personnel not having a good understanding of healthcare processes. As a result, the staff focused on their personal preferences and the designers tried to accommodate as many opinions as possible while also pursuing their architectural goals. This compromise, however, resulted in many missed opportunities because the lack of clear goals did not enable the project to focus the collective energies of the project team on the creation of long-term value.

6.3 The Value Stream

Once clear goals define the source of value to a project, a process for incorporating that value into the project needs to be established. The "value stream" is defined as the set of all the specific actions required to bring a specific product from conception to the final product intended for the end user (i.e. project delivery). This requires that the steps of the process are understood and the means for adding value during each step are understood.

6.3.1 Defining the Value Stream

Initially, the value stream is identified by mapping out the activities that constitute a given process. When the process map is completed, each activity can be evaluated in terms of its contribution to the end user value. The people and boundary objects involved with each activity determine the types of information that are available within the activity. In order to get a sense for the potential information stream, the people and objects involved with different activities can be overlaid with process maps (see Figure 6-1). Although this map illustrates that information is that is potentially available, it does not necessarily mean that it will be shared or that it is valuable. However, it does provide a useful tool for planning which is critical to understanding the value steam. Figure 6-1 is a process map of the design process used in the field study and reflects that actual participants and boundary objects present in each part of the process. This process map can be compared with the analysis of what information was actually shared (see Figures 4-4, 4-5, and 4-6) to gain a better understanding of what information was actually shared.

6.3.2 Principle 2: Create Continuous Flow to Identify Problems

The second lean management principle involves create a continuous process flow to bring problems to the surface. This implies that value should continuously be added to the project and that any failure to add value identifies a problem. Regarding the value steam, this suggests that in addition to mapping out activity, there should also be a plan for the deliverables (i.e. value) that are expected to result from that activity. This requires that managers not only plan out activities, but also consider what the purpose of each activity is and what resources (i.e. people or boundary objects) need to be present to realize the purpose. The establishment of more immediate goals also provides a more tangible focus for team commitment and common understanding. This also requires that the activity goals be developed with the long-term project goals in mind.

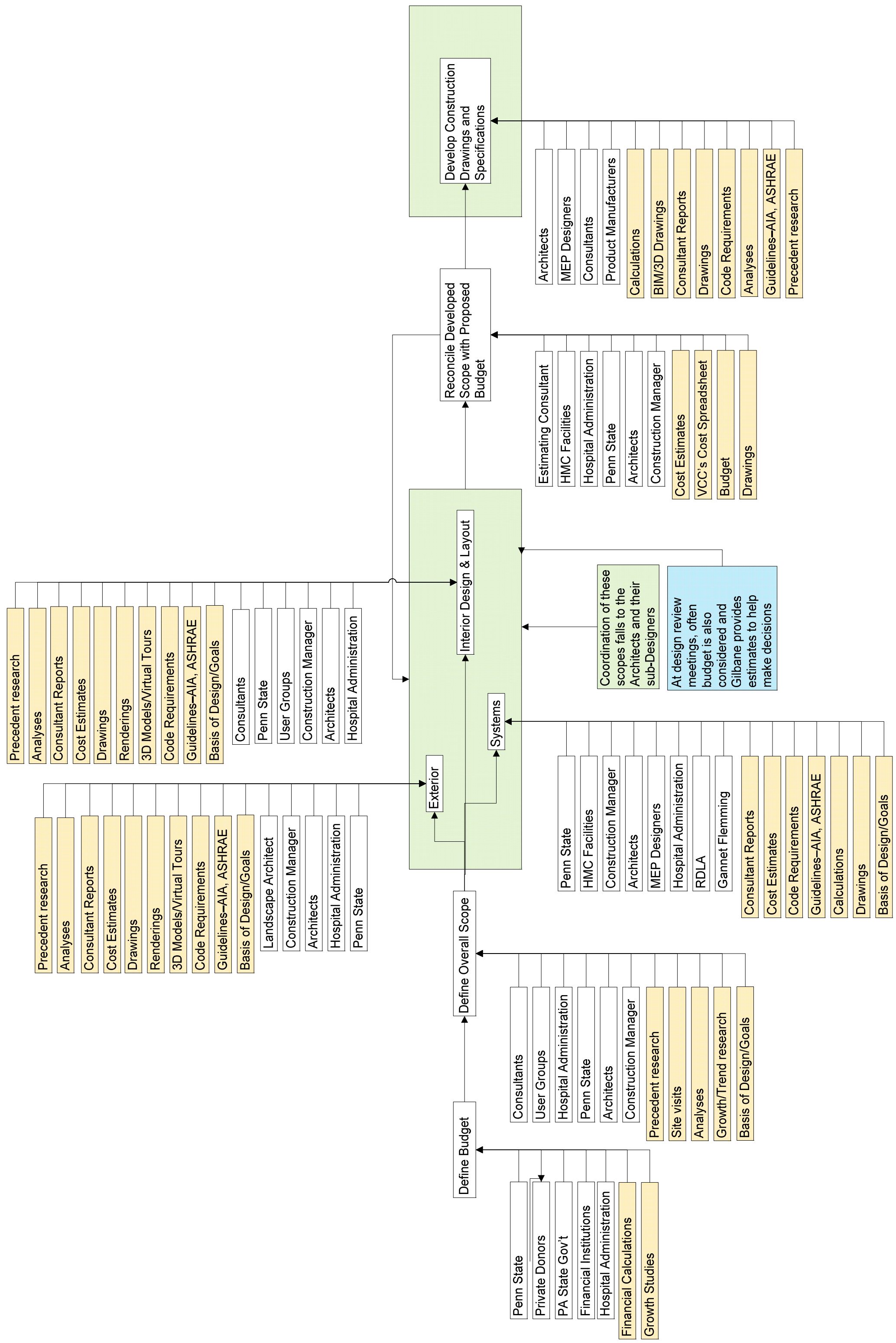

Figure 6-1: Design process map with the people and boundary objects shown

6.3.3 Principle 3: Use "Pull" Systems to Avoid Overproduction

The third lean management principle is to use a "pull" system to avoid overproduction. With information flow, overproduction refers to the providing more information than is needed. Excess information creates additional ambiguity, information overload, and compromises the ability of the project team to more effectively process valuable information. The combination of establishing explicit goals for each activity and clear roles and responsibilities for each entity create a means for pulling the right information from the right entity at the right time. Additionally, the strategic use of boundary objects can also serve as a mechanism to pull the right information from the right people at the right time.

There are two other aspects regarding the "right information at the right time". In lean terminology, this is known as "just-in-time" production. While this principle works well for material flows, labor flows, and simple, unambiguous information flows, it is not directly applicable to more complex, ambiguous information flows. Because there is a significant element of trust that is required to understand and accept new information and trust involves the management of expectations, individuals need to have time to prepare for and anticipate the introduction of new information. In terms of value stream planning, this requires that when individuals or roles within a team change (e.g. from phase to phase), that there be a period of overlap to facilitate convergence of mental models and values. This convergence will enable the information to be interpreted more accurately by new members and help maintain trust between team members; both of which help to improve future information flow.

The second aspect of this is that where there are activities that involve many diverse individuals, it is important to have frequent, intensive interactions to facilitate convergence of mental models and values. These interactions need to be planned so that there is enough time between them so that individuals can process the new information to converge on their frames of reference, but not too much time between interactions such that they revert back to their prior frame of reference.

6.3.4 Principle 4: Level out the Workload

Proper planning can also help with leveling out the workload for the various entities involved in the project. Detailed plans that outline the expected deliverables from each entity for each activity provide a sense for the workload that each will be confronted with. Upon evaluating the process map, activities or responsibilities can be shifted to better balance the workload. Alternatively, additional resources can be allocated to help meet the demands of the project. Through detailed planning, these bottlenecks can be anticipated and addressed before they create problems with in turn negatively affect other aspects of the project. In addition, similar to the Last Planner concept (Ballard, 2000b), the entities that will be performing the work can look at their future workload to provide feedback as to their actual ability to meet their responsibilities. In order to do this effectively, it requires that entities trust each other and are willing to provide accurate information about their ability to meet their responsibilities as well as step in to help others in the interest of the long-term project goals.

6.3.5 Principle 5: Use Visual Controls To Expose Problems

In lean manufacturing, the use of visual controls to expose problems is an effective means of instantly and unambiguously communicating problems or potential problems. While this has some valuable direct application to the construction phase, the information used in design and coordination is more subjective and ambiguous. While this makes it difficult to establish clear visual controls, there are two implication of this management principle in defining the value stream.

The first is that project teams should choose boundary objects that are appropriate for the level of complexity of the issues being discussed. Boundary object that reflect the appropriate level of complexity can capture certain information. If that information is missing or incorrect, then a problem is identified. This also requires that there be individuals involved with the activity that can effectively manage the boundary object. These considerations should be reflected in the value stream map by overlaying the people and objects to be used for different activities.

The second implication of this management principle is that it creates a need to be able to label certain problems. If a problem or potential problem is identified, then it forces the question of what type of problem is it. Project teams that strive to analyze and categorize problems in this way will end up with a valuable understanding of the common types of problems on projects and be better positioned to identify and address them earlier and more systematically in subsequent activities or projects.

6.3.6 Principle 6: Only Use Tested Technologies

Although this principle does not directly translate from manufacturing to information flow in construction projects, it also has some important implications. The management principle states that only reliable, thoroughly tested technology that serves the organization's people and processes should be used. Because each construction project is unique, the technologies, products, and construction processes will vary from project to project. However, although the information may be new, the process for integrating that information into the project can be a reliable and thoroughly tested process that has been developed and refined throughout many previous projects.

6.4 Enabling the Flow of Value

In addition to understanding the value stream, there needs to be an entity responsible for navigating the project team through the process. Construction projects do not take place in the relatively isolated environment of a manufacturing plant, so there are many factors that arise that introduce new, unexpected information into the process (e.g. weather, unforeseen conditions, materials shortages, approvals, commodity prices, etc.). Despite the best efforts of planning the value stream, there is always a need for someone involved with the project to be able to adjust the plan to address the reality of the situation. For the sake of this research, that entity is referred to as an "integrator." The following lean management principles help to outline the role of the integrator, which is more thoroughly outlined in section 5.5.

6.4.1 Principle 7: Build a Culture of Stopping to Fix Problems

Within the project team, it is the integrator's responsibility to build a culture of stopping to fix problems. This requires a mindset that recognizes that unaddressed problems will manifest themselves in other ways that will negatively affect the project more than the original problem. One outcome of setting goals for individual activities is that there are tangible, short-term deadlines that the team needs to meet. It is the integrator's responsibility to develop a sense of shared fate among the team so that challenges are seen as team issues rather than individual issues.

This is not limited to technical problems, but also includes social problems. The integrator needs to create a trusting environment were information, opinions, and concerns are shared openly and individuals are held accountable for their actions and responsibilities. In order to create this type of environment, the integrator needs to be able to pick up on subtle clues that suggest technical misunderstandings, personal conflict, or opportunistic behavior and address them before they become greater issues. It also requires that team members have enough trust in each other to bring up these issues if the integrator fails to foresee them.

6.4.2 Principle 8: Standardize Tasks

This management principle involves standardizing tasks to better facilitate continuous improvement and member empowerment. Because of the unique nature of every construction project, it is never possible to completely standardize all tasks. However, this does provide the impetus to develop formal processes that can help maintain quality, reduce ambiguity, and create environments that are more conducive to trust and learning. By using the same process over and over again, project team members learn what is expected and they can better prepare for future activities that improve the quality of the information that they contribute. Using the same process also has positive implications for building trust and learning among the team.

6.4.3 Principle 9: Develop Individuals Who "Get It"

As stated by Liker (2004), this management principle states that an organization should grow leaders who thoroughly understand the work, live the philosophy, and teach it to others. This principle translates into what Katzenbach and Smith (2003) call "deep commitment to one another's personal growth" in their description of high-performance teams. In order to implement this, integrators need to start with themselves and set an example of how individuals in the team should act and treat each other. Through their example and their actions, the integrator's behavior should empower others in the team to do the same. This begins with the integrator valuing the opinions of others, drawing links between the information that was shared by various individuals, and empowering each individual by asking them questions about the content areas that are their responsibility.

6.4.4 Principle 10: Develop Exceptional People

By developing exceptional people and teams who follow the project's philosophy (i.e. goals), projects become more than simply a short-term collaboration. One of the subcontractors in the field study phrased it well; "The ultimate goal is that everyone is here to make money, but we try to take it a step further and build relationship." Project goals provide a common metric by which every project team member's performance can be evaluated. Depending on how committed team members are to achieving the project goals and consequently making the project successful, the better chance they have of developing trust and lasting relationships with the other project team members. This is a point that an integrator should stress in order to help build commitment to the project, commitment to each other, and common understanding among team members.

6.4.5 Principle 11: Respect Your Extended Network

This management principle states that integrators need to respect their extended network or partners and suppliers by challenging them and helping them improve. Although some of these principles overlap with earlier principles, it also brings up the important point of considering individuals beyond the immediate project team. In construction particularly, "outside" individuals such as vendors, code officials, administrators, and consultants can provide valuable information. Although they may not be central members to the project team, it is important for integrators to be aware of their capabilities and incorporate them into parts of the process that would benefit from their involvement. In many cases, these outside individuals make up critical components of the process (e.g. code review or manufacturer's warranty review) so it is also important for integrators to understand what is important to these individuals and ask them for suggestions of how their involvement in the process could be made more efficient.

6.4.6 Principle 12: Understand the Situation Firsthand

In order for an integrator to effectively manage a process, they need to thoroughly understand the situation firsthand. As information is transferred from person to person, it loses some of its context. In addition to that, different individuals may pick up on different aspects of a situation. For these reasons, it is important for integrators to develop a firsthand understanding of a given issue. For technical issues, they need to be familiar enough with the specifics of the project and the general concepts to have substantive discussions with those who are specialists in that area and those that understand very little of the area. For social issues, integrators need to have an accurate understanding of each individual's existing frame of reference, disposition, and attitude toward others. Both the technical and social issues can be better understood with one-on-one interactions with various team members. Not only does this allow for more focused discussion and greater understanding, but is also builds trust between individuals and helps with the convergence of metal models and values.

6.4.7 Principle 13: Make Decisions Carefully, Implement Them Rapidly

This management principle states that decisions should be made slowly by consensus, that all options are considered, and that decisions be implemented rapidly. In many cases, individuals seem to care more that their opinion was considered than whether it was actually implemented. Part of an integrator's role is to solicit input from everyone and explain how that input relates to other issues. By linking information from one individual to that shared by others or the project in general, the integrator creates a common understanding and a collective solution to a problem. The artistry behind this is that the integrator does not let anyone develop a solution in isolation, but instead makes it a collaborative process. This way, no one person feels personally tied to a single solution.

The other component is that the decisions be implemented quickly. While the decision-making should wait until there has been a thorough and comprehensive process of developing potential solutions, delaying or drawing out the implementation process introduces opportunities for destructive conflict. While it is important that individuals clarify ambiguity related to the fundamental issues of project goals, approach, and roles before addressing an issue, prolonging the decision implementation process gives individuals the opportunity to change their minds and withdraw their support for the decision. This undermines the discipline of the team, shifts the focus back to the individual, and causes frustration amongst team members. As one of the field study participants commented regarding the negative affects of the team's inability to commit to a decision, "we can't kill anything on this project and as a result we're dying by a thousand cuts."

6.4.8 Principle 14: Become a Learning Organization

The final lean management principle is to become a learning organization. Both for the integrator's sake and the rest of the project team, it is important to learn through reflection and continuous improvement. In addition to adjusting the plan, a constant part of the integrator's role is to evaluate the effectiveness of past interactions and figure out how they could be improved. This not only helps the integrator do their job, but it also helps the other team members learn and develop additional trust in the integrator, especially if they are asked for their feedback. The more adept that integrators are at adjusting and improving their process the more effectively they can manage the information flow. However, modifications should be made early in a process and carefully so that the trust and expectations of other team members are not disturbed due to the change.

6.5 The Integrator's Role In Information Management

The term "integrator" is not new to the AEC industry. There have been numerous academic and professional efforts to promote better integration within project teams and "integrated design" and "integrated delivery" have become industry buzzwords. In recent years, the complexity of construction projects and the new information available to our industry has made effective integration even more important. These efforts are limited in the sense that they focus on the technical side of integration, e.g. making information available, the planning and timing of certain interactions between key project team members, etc. However, there has not been much of a focus on understanding the phenomena that actually enable project teams to effectively make use of that information. This research has formally illustrated what many in the industry already implicitly believe, that there is a major social component that enables effective information flow and integration. It is the acknowledgement and inclusion of this social aspect that makes this "integrator" role more comprehensive than those previously understood by our industry.

Because of the important role that the social factors of trust, commitment, learning, and common understanding play in enabling effective information flow, it is the primary role of the integrator to create an environment that enables positive iterations of the trust and learning cycles. In these cycles, once team members have had positive experiences with trust and learning, the subsequent convergence of mental models and values and increased in commitment and common understanding follow naturally. Therefore, the primary role of the integrator lies in creating an environment that facilitates the development of trust and learning among project team members.

To reiterate the definition of trust used earlier in this documents: *Trust* involves having positive expectations about another's future actions when an individual is vulnerable to those actions. For this reason, the main components of facilitating the development of trust reside in two critical responsibilities: 1) Valuing the contributions of the individual but only within the context of the team and project goals; and 2) Managing expectations by maintaining accountability, discipline, and fairness through establishing clear and consistent goals. In terms of learning, the critical responsibilities of the integrator are to: 1) understand the existing mental models of team members; 2) provide links between different mental models and to the project in general; and 3) use those links to other's mental models and links to the project to demonstrate the value of the information and stimulate additional interest and motivate further learning.

In order to create the proper team environment, integrators need to possess a certain suite of skills that are not necessarily in the traditional repertoire of construction management skills. These skills include: 1) having the appropriate technical knowledge; 2) high emotional intelligence; 3) expectation management; 4) strategic use of tools and techniques; and 5) planning and dynamic capabilities.

6.5.1 Appropriate Breadth and Depth of Technical Knowledge

An integrator needs to have the appropriate breadth and depth of knowledge for the scope that they are integrating. This involves having enough scientific, design, constructability, and performance knowledge to interact meaningfully with each member of the team regarding their area of focus. While the integrator needs to have a strong understand these areas in a general sense, they do not need to understand the specifics of the project. Integrators use their broad based knowledge to pull project-specific knowledge from other members of the design team. This empowers the other team members to better understand their scope and the project in general and reinforces the importance of their role in the project, but does not burden them with needing to prioritize their knowledge or translate that knowledge to be relevant to others.

One of the greatest intellectual tools available to an integrator is questioning. Asking good questions enables an integrator to pull the right information from various project team members at the right time. Questions allow an integrator to add needed information to the interaction without undermining another person's role. A good question has several characteristics: 1) it is not asked with the intent of embarrassing the responder; 2) it is specific enough that the integrator has a general idea of the type of answer that the responder will give; 3) it is phrased in such a way that it links the expected answer to information previously shared by another individual; 4) it is phrased so that it engages the responder by challenging them to think critically but also so that it doesn't lose the attention of others with less of an understanding; and 5) in the asking of the question, the integrator clarifies previously shared information that might have been ambiguous.

6.5.2 Emotional Intelligence

The second integration skill is having social awareness and emotional intelligence. Emotional intelligence is a person's ability to identify, assess, and manage their own emotions, the emotions of others, and group emotions. An integrator needs to be able to observe subtle signs of how team members are feeling and whether others understand the information being discussed. Based on these observations, the integrator needs to take steps to adjust or amend the current conversation and dynamic to create a more favorable situation. In addition to making observations during interactions, an integrator will also need to interact with individuals outside of group settings to gain a better understanding of their personal values, mental model, and goals and to discuss more delicate matters that are not appropriate for discussion in a group setting. This individual interaction also reinforces an individual's trust in the integrator and the notion that they are valued members of the team.

6.5.3 Expectation Management

The third skill required of an integrator is the ability to effectively manage expectations. Because trust comes from validation of expectations and higher-level learning relies on having a safe and trusting environment, it is critical that integrators are aware of the expectations that others have and can gage whether the reality of a situation has actually met those expectations. This requires that integrators be able to overcome their own biases and gain an objective understanding of the situation. Integrators can also gain a better understanding of the situation by having informal conversations with team members outside of meeting settings.

There are several techniques that can be used to help manage expectations. These include, techniques such as: 1) Using the same framework for repeated meetings; 2) Providing an overview of a process before it begins; and 3) Allowing a short period of time between in-depth discussions for individuals to absorb new information in an incremental, systematic process so that they can more effectively learn and absorb the information. Expectation management also allows an integrator to clearly layout goals, approaches, and individual responsibilities and reduces more value-based conflict that can compromise future interactions.

6.5.4 Strategic Use of Boundary Objects and Processes

An integrator also needs to be aware of how the use of various boundary objects and processes affect the facilitation of trust and learning so that they can be used strategically. The structure of boundary objects affects the richness of information that they can capture and the process for using that object and therefore can be used as a means to facilitate learning by: 1) pulling certain information from the team; 2) developing a common understanding; 3) reducing ambiguity; and 4) creating common explicit goals and approaches. In terms of building trust, boundary objects that quickly demonstrate their value by providing insight or an effective means of evaluating options quickly gain the trust of the users. Boundary objects that are commonly used establish expectations of what information is valuable and how it will be used. In cases where the boundary objects may be more complex, using a facilitator that can easily manage the tool so that others can focus on providing the necessary information rather than worrying about technical details.

Similarly, there are processes that can influence trust and learning. Explicitly asking each person for their input regarding important issues gives everyone, including more soft-spoken team members, the opportunity to share their thoughts and makes them feel like valued members of the team. Brainstorming is another technique that enables learning. The fast-paced nature of brainstorming allows ideas are shared and recorded but not evaluated immediately. As a result, team members are inspired by and build off of the ideas of others, but not develop personal attachment to any specific ideas because every idea is somehow a product of the ideas of the team. Another technique involves holding intense meetings with very explicit goals. These meetings can be full day meetings or a series of daylong meetings held in quick succession. The combination of having each person commit their entire day and the sense of shared fate motivates those present to work toward meeting the goals and find answers to questions rather than putting them off until the next meeting. Having a series of these meetings in quick succession, give individuals a chance to absorb the information and find answers to questions that emerged, but keep them from forgetting what was discussed and reverting back to their previous mental models. Finally, the use of breakout groups is a helpful tool for integrators because it allows the individuals in the breakout group to interact more closely and work on issues that are more relevant to their interests. In some cases, breakout groups emerged naturally in the course of discussion a complex topic. The larger groups would discuss all of their thoughts surrounding an issue. Then a smaller group of individuals would take those thoughts and develop several options and present it back to the group for feedback and modification. This resulted in everyone feeling as though his or her opinions were considered, but did not burden everyone with the task of developing solutions.

6.5.5 Planning and Dynamic Capabilities

Finally, an integrator needs to be able to develop detailed action plans, but also be able to quickly adapt their plan based on changing situations. Planning allows the integrator to develop an approach for realizing project goals, foresee potential conflicts or problems, and proactively develop alternatives. Using process mapping techniques, an integrator can map out the events that make up a process and overlay the people and tools that will be used to gain insight as to the potential for information flow and then modify or develop contingency plans for potentially problematic activities. Effective planning decreases the information load on the integrator and allows them to focus on the continuously changing and unpredictable nuances of the interactions. Without developing detailed plans and alternate plans, an integrator will not be able to guide interactions in positive directions or quickly respond to unforeseen issues. As a result, integrators also need to be flexible and be able to quickly adapt their plans to the reality of the situation while still working toward the project goals.

Chapter 7

Conclusion

This research began with the goal of finding means to better incorporating sustainability features into the design and construction of healthcare facilities. As a result of the complexity of these projects and the lack of knowledge that our industry has regarding information flow, the focus of this research shifted to understanding the critical factors regarding information flow effectiveness. The three-year in-depth field study of two healthcare projects yielded valuable insight regarding the characteristics of people and boundary objects that affect the potential for information flow. More importantly, this research uncovered key social and technical moderators that influence the effectiveness of information flow in project team interactions. These moderators were used to develop a model that links cycles of trust and learning. This model is then used to describe and analyze various interactions and understand why they were or were not effective. This model also provides valuable insight as to how principles of lean production management can be applied to improve information flow on complex projects. Together, all of these findings helped to reinforce the need for an integrator on complex projects and create a definition of what an integrator should be that is more comprehensive than any previous understanding of that role. Ultimately, it is the integrator's role to create a project environment that facilitates the building of trust and learning which establishes the basis for effective information.

7.1 Research Outcomes

There are two major outcomes of this research. The first is the development of the trust and learning interaction model. This model illustrates the important role that social factors play in enabling effective information flow. It also links together the four major moderators (i.e. trust, commitment, learning, and common understanding) of interactions in a way that can be used to analyze, evaluate, and improve the techniques being used to manage information flow (Figure 7-1). This model also provides a basic framework for further understanding the of information flow. This has significant implications for enabling future research in continuous process improvement to address complex information flow and helps to establish a basis for understanding the science behind the phenomenon of integration.

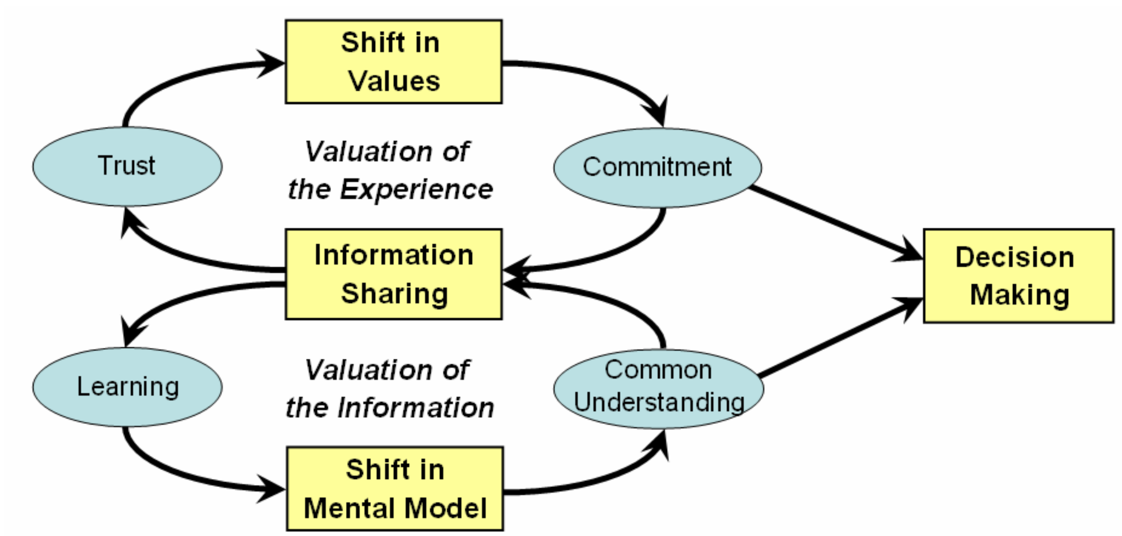

Figure 7-1: Interaction Model: Trust and Learning Cycles

The second major contribution is the development of a more comprehensive definition of the role of the integrator. This research has shown that integration relies on much more than simply bringing together diverse information. In order for that information to actually add value to the project, it has to be understood and accepted by the other project team members. Understanding and acceptance of new information depends on the convergence of the values and mental models of the various entities. This makes one of the most important responsibilities of the integrator the creation of a project environment that is conducive to the building of trust and learning. Using the conceptual model and examples from the field study, the findings outline a suite of specific skills and techniques with which an integrator should be adept; specifically, 1) having the appropriate technical knowledge; 2) high emotional intelligence; 3) expectation management; 4) strategic use of tools and techniques; and 5) planning and dynamic capabilities.

Even though this research began with an interest in better facilitating the greening of healthcare facilities, its implications stretch well beyond the focus of sustainability and healthcare facilities. The contributions of this research to the AEC research community includes:

- Creating a basis for understanding social and socio-technical factors affecting information flow. The vocabulary, categories, models, and relationships developed in this research provide a basis for future research to build upon, modify, or challenge.
- Using data collection and analysis methods that have not commonly been used in construction. These methods provide great opportunities to further the understanding of complex interactions and other significant social factors affecting the construction industry. The use of these methods also provides a conceptual and methodological link with other fields of study (i.e. organizational science and information science) to enable possible cross-pollination of ideas in the future.

In addition, there are some direct implications as well as broader impacts for the construction industry related to this research. These include:

- Describing the importance and necessary characteristics of the integrator, especially for complex projects.
- Outlining the potential that exists in using boundary objects and planning of interactions. By better understanding the characteristics of these entities, project teams can more strategically manage information flow.
- Establishing that information flow is a critical flow that needs to be formally addressed in the delivery process. As a result, existing processes and roles need to be modified to provide better information flow management.

7.2 Future Research

This research opens the door to many additional areas of research. One of the major challenges was trying to apply valuable social science, organizational science, and information science research to the construction industry. Because of the unique organizational environments created by construction projects, research from these other fields is not directly applicable. However, through developing a better understanding of the organizational characteristics of project teams, much of the mature research from the organizational sciences could be applied to the construction industry. The same can be done for the social and information sciences.

In addition, the trust/learning model can be used to analyze specific boundary objects or processes more closely. More detailed analysis can help to make this model more robust in terms of better understanding the links and interactions between moderators. This additional research can also be used to develop a greater understanding of how those tools can be used more effectively and improved.

Most of all, these methods could be applied to another field study to test these concepts further. A more structure content analysis could be conducted regarding the types and trends of information being shared throughout project delivery. Also, since these findings have been generalized from a single field study, there would be significant value in using subsequent studies to validate and further build upon this work.

The most promising aspect of this research, is that is sets the foundation for understanding the science behind integration. With our industry only become more complex and multi-disciplinary, integration will be the key to enabling construction project teams to realize their fullest potential. Our ability to effectively manage and incorporate new information into project is a critical. It is critical for enabling research and innovation to be incorporated into projects. It is critical for leveraging the valuable experiential knowledge that exists in the people that make up our industry.

Effective management of information is critical for another reason. Construction has always been a collaborative activity, because it is to too great an undertaking for any one person to tackle alone, so we develop specialties, learn how to do those tasks better, but need to work together with many other specialists to create the final product. Somehow in the integration of all these different specialties, project teams create amazing built environments, such as cancer institute or a children's hospital, that enable our society live longer, healthier, and more fulfilling lives. It is information combined with trust, commitment, and common understanding that allows the complex and complicated world of construction take a so many different components and create something that is so much greater than the sum of its parts.

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Publications

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