EXPLORING COMMUNICATION
IN MULTIDISCIPLINARY BUILDING DESIGN TEAMS

DISSERTATION

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ABSTRACT

Communication is a challenge in multidisciplinary building design teams. The multidisciplinary nature of the team, in which team members contribute knowledge and skills from within the boundaries of their disciplinary domain, combined with the fragmented building design process, makes exchanging information among disciplines difficult. Addressing this challenge is important because communication impacts project outcomes. While effective communication mitigates project risk, contributes to conflict resolution, and reduces project waste and errors, ineffective communication contributes to project failure.

Existing research on communication and teamwork provides us with two key insights: first, the presence of different disciplines – the functional diversity – on a team can lead to both positive and negative outcomes through different communication processes; then, communication in design includes three categories – communication as social behavior, as an information process, and the use of communication technology. However, this research comes from domains such as healthcare, manufacturing, and software design. As such, there are several gaps that limit our understanding of multidisciplinary building design communication:

a. As literature on multidisciplinary building design teams is sparse, we do not have sufficient documented information about multidisciplinary building design practice to the extent that we use the terms multidisciplinary and interdisciplinary interchangeably although they indicate different kinds of team functioning.
b. There are no approaches to studying communication in building design teams that account for the multidisciplinary nature of the team and the complexity of design communication. Identifying an approach to studying communication is a first step to improving team communication and project outcomes.
c. Though it is acknowledged that functional boundaries in a multidisciplinary team influence team functioning, the lack of literature on multidisciplinary building design teams and the lack of an approach to studying team communication means that we do not know how functional diversity affects team communication and outcomes.

My research contributes to our understanding of multidisciplinary building design team practice by developing a framework to explore multidisciplinary building design communication. Then, it applies the framework to three cases of multidisciplinary building design teams to explore the effects of functional diversity on building design team communication and outcomes.

The exploratory framework allows for the systematic description and analysis of multidisciplinary building design teams, their communication, and their outcomes. When applied to the three cases, multidisciplinary building design practice is explored along three lines of inquiry: What constitutes a multidisciplinary building design team? How do multidisciplinary building design teams exchange

information? And, what are multidisciplinary building design team outcomes? Data for the case studies are obtained from interviews of 32 industry experts spanning 13 disciplines across the three case studies. This data is analyzed using content analysis and a communication analysis approach that accounts for all three categories of communication.

Findings from the case studies do the following: they posit a relationship between functional diversity, communication, and outcomes that is dependent not only on team characteristics, but also on project characteristics and timing; they offer modifications to the exploratory framework that allow for a more accurate representation of building design practice; and provide strategies used by team members to deal with the challenges and complexities of multidisciplinary building design communication.

These contributions – the framework and the case study insights – provide building design researchers and practitioners with insights into building design teams, their communication, and their outcomes. They are intended to be a necessary first step towards improving building design team practice.

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1: INTRODUCTION

1.1: MOTIVATION

COMPLEXITY AND MULTIDISCIPLINARY TEAMS IN BUILDING DESIGN

Building design problems are complex. To understand their complexity, we must look at various descriptions of complex problems. For instance, complex problems have been described as ill-defined (Reitman, 1964), or as ill-structured (Simon, 1973). According to Reitman, ill-defined problems lack a complete description of their problem requirements and problem components (Lynch, Ashley, Pinkwart, & Aleven, 2009; Reitman, 1964). To solve such ill-defined problems, problem solvers re-characterize them by breaking them down into smaller, more manageable chunks. These smaller problems require input from many clients and decision makers with conflicting values. Ill-structured problems as defined by Simon, lack clear requirements and criteria for identifying when a solution is found, and gain structure by being decomposed into various component problems (Simon, 1973).

These descriptions of complex problems introduce three key characteristics that can be applied to building design, which is illustrated in Figure 1.1: First, complex problems usually have several goals that need to be achieved; second, solving complex problems requires their decomposition into smaller, more manageable component problems; and last, there are clients and decision makers to be considered who have often conflicting values.

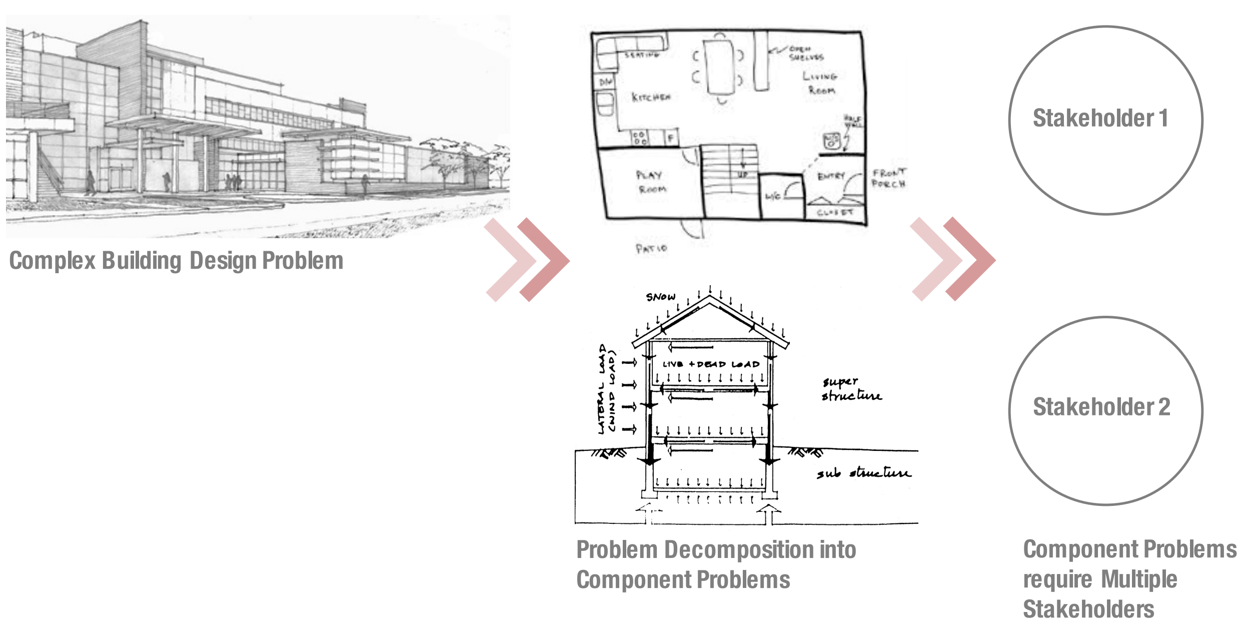


Figure 1.1 Complex building design problems are decomposed into component problems that require multiple stakeholders to solve (Lunz group, 2007; the house plans guide, 2004)

These characteristics readily apply to building design problems. First, there are usually multiple goals to be achieved such as those of sustainability, occupant comfort, indoor environmental quality, financial goals and so on. Second, building design problems tend to be decomposed into smaller problems such as spatial layout, site planning, the structural system, heating and cooling and so on. The third way these characteristics apply to building design is that, as smaller component problems usually require knowledge from different disciplinary and professional domains, multiple stakeholders with differing values are necessarily involved in finding solutions. That is, the clients, architects, engineers and designers are all involved in the project and all are responsible for making decisions on how to solve complex building design problems. This third characteristic of complexity means that multidisciplinary teams, rather than interdisciplinary or transdisciplinary teams, are needed in solving building design problems.

Solving complex building design problems requires knowledge from different domains and disciplines. Multidisciplinary teams are made up of team members from different disciplines and professions. Compared with other kinds of teams that comprise multiple disciplines, say interdisciplinary or transdisciplinary teams, multidisciplinary team members contribute to problem solving by providing knowledge and skills from their disciplinary domain while staying within the boundaries of these domains (Choi & Pak, 2006). This is important in building design as the different disciplines stay within their knowledge domains, that is, structural engineers provide solutions to structural design problems, mechanical and HVAC engineers deal with those specific problems and architects deal with architectural design problems.

Working in multidisciplinary teams has numerous benefits. Multidisciplinary building design teams can effectively use their combined skills resulting in creative solutions. Teams members are able to use the opportunities for informal learning that occur when the different disciplines work together to improve the standard and quality of team outcomes (Iliffe, 2008; Pfeiffer, 1981). Multi-disciplinary team members contribute to solution generation by providing different roles and perspectives that can complement each other, far beyond the scope of a single individual or profession.

There are, however, challenges to working in multidisciplinary teams. The major challenge faced by multidisciplinary team members is a breakdown of communication which may lead to conflict between team members and the poor integration of team processes. This breakdown of communication – which has impacts on building design – can be attributed to the functional diversity present in multidisciplinary teams and the fragmentation in the building industry.

FUNCTIONAL DIVERSITY, FRAGMENTATION AND MULTIDISCIPLINARY TEAM COMMUNICATION

A primary cause of the breakdown in communication is the functional diversity present in multidisciplinary teams (Bunderson & Sutcliffe, 2002; Cabrales, Medina, Lavado, & Cabrera, 2008). Functional diversity, or skill diversity is defined as the degree of variation in functional or professional units within the team (Bunderson & Sutcliffe, 2002). It is differentiated from demographic diversity, also known as social diversity, defined as "the degree of heterogeneity in a team with respect to demographic attributes such as age, gender, ethnicity" (Wamala, 2017). While exploring and understanding the effects of both aspects of diversity on teams is essential to improving team processes and outcomes in general (Yeager & Nafukho, 2012), exploring the effects of functional diversity is more critical to multidisciplinary teams.

Several factors contribute to the effects of functional diversity on communication in multidisciplinary teams including: the functional boundaries in the team; the language and information technology used by team members; and the physical and social proximity of team members. For instance, functional boundaries keep team members of similar professions together making it difficult to span these functional boundaries as the different disciplines in the multidisciplinary team are unable to communicate effectively with each other. Adding to the challenge of spanning the boundaries is the lack of a shared language among the different professions and lack of technology and tools to share information. Further, the proximity of team members, that is, whether they are co-located or work out of different offices, and the geographic distances between them can impact team communication and outcomes (Doyle, 2008; Madge & Khair, 2000).

These three factors are all linked together. Rather than standing alone, each factor contributes to the other factors that influence the team. For instance, it is impossible to separate these factors and talk about functional diversity, or the challenge of sharing information across functional boundaries without also addressing the lack of shared technology for different disciplines to exchange information, and considering the effects of the proximity of disciplines on team communication.

Specifically, in the building industry, a cause of communication breakdown is the issue of fragmentation and its effect on the building design process. The building design process has been described in several ways. Koskela came up with three conceptual models of the building design process (Koskela, 1992). She describes it as a conversion process where inputs are transformed to outputs, a flow process involving a flow of information and materials and, as a value generation process where design creates value for a consumer. (Ballard & Howell, 1998; Koskela, 1992).

The Flow Process Model of building design is relevant when considering fragmentation in the design process which makes exchanging information between the different professions even more difficult. This poor information exchange occurs due to the isolation of different professions from one another and the consequent development of silo culture in the team as illustrated in Figure 1.2.

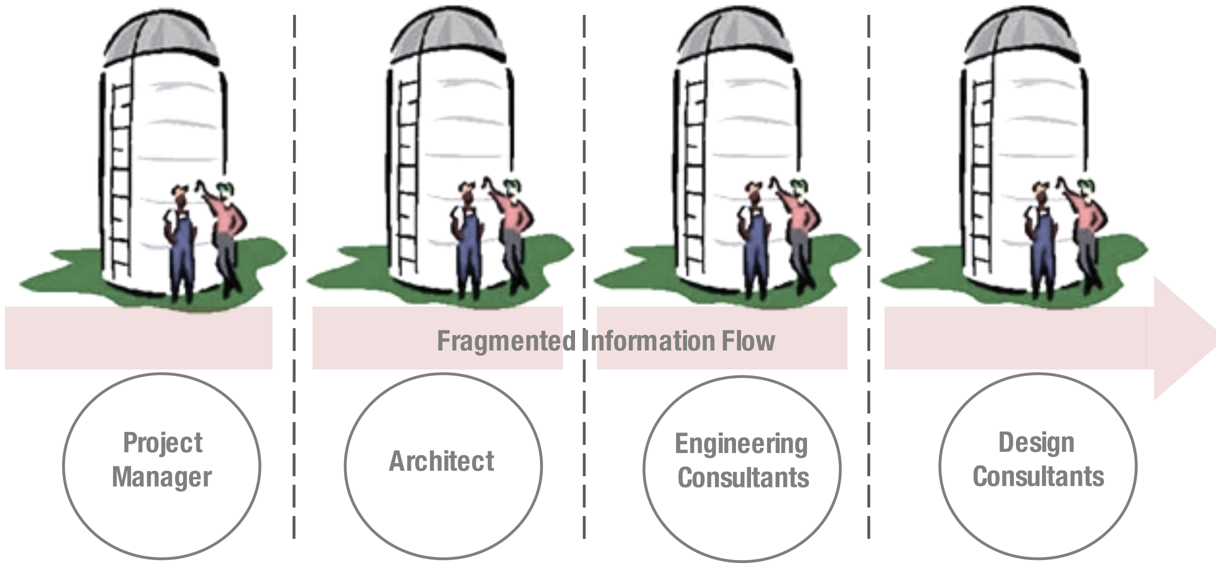


Figure 1.2 Fragmentation due to functional diversity leads to silo culture and poor team information transfer in the multidisciplinary building design team (Vilet, 2012)

Fragmentation is described as the "division that occurs from having multiple professions and specializations working on a building project. This division is a result the complexity of building projects" (Mohd Nawi, Lee, Noor, Azman, & Mohamad Kamar, 2014, p. 101). The traditional building design process is fragmented due to its linear and sequential nature and the division of responsibilities between involved stakeholders through the different stages, from Pre-Design, Schematic Design, Design Development, and Contract Documentation (AIA, 2006).

As team members are isolated from each other, information transfer between these stages and between the involved multidisciplinary stakeholders is often improperly managed (IPCC, 2007). This can lead to the development of silo culture in the multidisciplinary building design team. Silo culture occurs when there are boundaries within a team. Team members work within their silos, delineated by their functional boundaries, and are unable to communicate effectively across these boundaries (Bianca, 2012). That is, in a building design team, architects are only able to effectively communicate with other architects and not with other consultants on the team, negatively impacting team and design outcomes.

COMMUNICATION AND BUILDING DESIGN: WHY DO WE CARE?

Communication impacts project outcomes. Due to its dynamic and temporary nature and the complexity of the problems faced, building design provides a unique environment to study communication (Dainty, Moore, & Murray, 2007). Effective communication contributes to successful project outcomes and ineffective communication can lead to negative project outcomes. Communication has been shown to impact project outcomes in four ways:

Effective Communication Mitigates Project Risk

Owner Driven Changes	Accelerated Schedule	Design Errors	Design Omissions	Construction/ Coordination Issues	Contractor Delays	Unforeseen Circumstances
88	96	94	88	93	79	79

Communication Impact Factor

Figure 1.3 Effective communication between team members is the most impactful factor in mitigating the top causes of project risk. (McGraw-Hill, 2014)

In a 2014 survey of building owners, architects and contractors by McGraw Hill, seven risk factors were identified as the top causes of project uncertainty. These risk factors are: owner driven changes, an accelerated schedule, design errors, design omissions, coordination issues, contractor delays, and unforeseen conditions. The survey results showed that "improved early stage communication between team members was the most impactful factor in mitigating these identified risks" (McGraw-Hill, 2014, p. 44) as shown in Figure 1.3. Early stage communication, where team members meet at the beginning of the design process to familiarize themselves with the project and each other, as well as outline design goals is the highest factor to reducing risks across these seven categories.

Effective Communication Improves Conflict Resolution

Conflict occurs when there is a breakdown of communication between team members. While effective communication can reduce the instances of conflict on a project, it is more likely to influence the type of conflict that occurs and how that conflict is resolved which improves the building design process. While all conflict cannot be avoided, effective communication can ensure that constructive rather than destructive conflict occurs. Constructive conflict has a positive impact on teamwork by stimulating creative thinking and promoting healthy debate and discussion and leads to useful outcomes and improved decision making (Pinto & Pinto, 1990; Rolih, 2013). Constructive conflict is resolved with positive outcomes as "people change and grow personally from the conflict, the involvement of the individuals affected by the conflict is increased, and positive solutions are found" (Designing Buildings, 2016).

Effective Communication Reduces Project Waste and Errors

Effective communication in building design and construction teams has been shown to reduce instances of errors and rework on project teams. A breakdown of communication between team members prevents team members from sharing the information they need. Relevant information is likely to fall through cracks leading to more errors and rework on building design projects. Design errors are very costly. They can account for up to 7% of total project costs (Love & Lopez, 2012) and have been shown to be costly to rectify. In 2003, these costs would amount to £20 billion a year – about $26 billion – according to the British Standards Institute (BSI, 2003). Improvements to team communication can reduce the incidences of these errors, leading to improvements to design.

Ineffective Communication Contributes to Project Failure

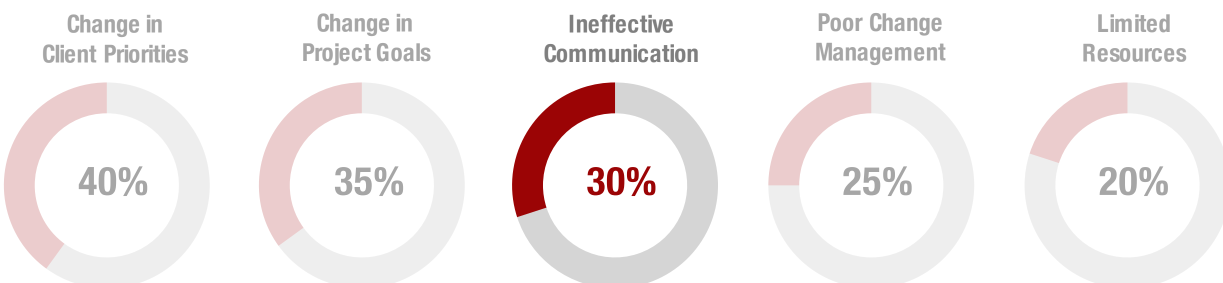


Figure 1.4 Ineffective communication is a primary contributor to project failure at least a third of the time (PMI, 2013)

Ineffective communication is a significant contributor to project failure. In its 2013 report on The Essential Role of Communications, the Project Management Institute (PMI) stated that “one out of five projects is unsuccessful due to ineffective communication” and, “ineffective communication is the primary contributor to project failure a third of the time and has a negative impact on project success half of the time” (PMI, 2013). Hoezen et al found that improvements in communication between the members of design and construction team could reduce construction project failure (Hoezen, Reymen, & Dewulf, 2006).

These four impacts show why we should care about communication in building design. As the breakdown of communication poses a challenge to multidisciplinary teams, it becomes even more important when considering multidisciplinary building design teams. The challenges of communicating effectively in multidisciplinary teams, combined with the potential impact of communication on project outcomes means it is necessary to study communication and outcomes in the context of the multidisciplinary building design team.

1.2: THE RESEARCH CASE

RESEARCH GAPS

Existing research on communication in multidisciplinary design teams has described stakeholder contributions to design, identified factors that influence team communication, and studied team member roles and communication patterns that impact design tasks. Lee described the different professions involved in a multidisciplinary building design practice and the ways in which their various contributions can influence design (Lee, 2015). Several researchers have studied the effects of the relationship between team members and the disciplinary diversity within the team on team member communication (Joshi & Roh, 2009; Knight et al., 1999; Pinto & Pinto, 1990; Stahl, Mäkelä, Zander, & Maznevski, 2010). Cross and Cross studied roles/relationships between team members and their relationship with successful task completion (Cross & Cross, 1995). However, there are several gaps in the knowledge on multidisciplinary building design teams.

Knowledge Gaps on Multidisciplinary Building Design Teams

a. The literature on multidisciplinary building design teams is sparse

Although there is a vast amount of literature on multidisciplinary teams in domains such as healthcare, manufacturing and software design, there is little empirical research on multidisciplinary teams in the building design domain. Research exists on architecture firms and their processes (Blau, 1987; Gutman, 1988), and on construction teams and their processes (Baiden, Price, & Dainty, 2006; Dainty et al., 2007; Foley & Macmillan, 2005). But, in the literature examined, there is little that focuses on the individuals involved in building design. Although parallels can be drawn from studies in other domains, these do not accurately capture the complexities of building design.

Consequently, we do not have sufficient documented information about multidisciplinary building design practice to the extent that we use the terms multidisciplinary and interdisciplinary interchangeably although they indicate different kinds of team functioning (Choi & Pak, 2006; Kasali & Nersessian, 2015). This inconsistent use of terminology clearly indicates that in building design domain, we still do not fully understand the ways in which multidisciplinary teams work.

b. We do not know how to study multidisciplinary building design team communication

Identifying an approach to studying communication is a first step to improving team communication and project outcomes. However, the literature is limited on how to study multidisciplinary building design team communication. The research on the benefits of studying communication have largely ignored approaches to studying communication in multidisciplinary building design teams. Only one study was found that outlined an approach to study and assess construction project team communication (Thomas, Tucker, & Kelly, 1999). This sparsity of research suggests that it is important to develop an approach to studying communication in multidisciplinary building design teams, particularly one that also accounts for the functional diversity in the team and the complexity of building design (Rajkumar, 2010).

c. We do not understand the effects of functional diversity on building design team communication and outcomes

The lack of research on multidisciplinary building design teams and approaches to studying multidisciplinary team communication impacts our understanding of how functional diversity in the team affects the team's communication and outcomes. Although it is acknowledged that the presence of functional boundaries in multidisciplinary teams influences team functioning, studies have not identified what the presence of functional boundaries and functional diversity does to team communication and outcomes (Hassall, 2009; Knight et al., 1999; Madge & Khair, 2000).

The few studies that do exist have concentrated on communication between the disciplines in construction teams particularly between the project team and project manager, and the project team and the owner (Baiden, Price, & Dainty, 2006; Hoezen et al., 2006; Wang & Huang, 2006). Very few studies have explicitly addressed communication between members – functionally diverse or otherwise – of the design team (Tunstall, 2006). Moreover, while it is assumed that team communication can influence its outcomes, even fewer studies have looked at the impacts of building design team communication on team outcomes, such as performance, functioning or decision making.

SCOPE AND SIGNIFICANCE

The research in this dissertation aims to address the gaps identified and outline an approach that explores communication and outcomes in multidisciplinary building design teams. Using this approach, this research provides descriptions of communication processes and outcomes in the context of the multidisciplinary design team members, and attempts to identify the effects of functional diversity on these communication processes and team outcomes.

The objectives of this work are:

Objectives

a. To focus explicitly on the workings of building design teams, clarifying the difference between multidisciplinary and interdisciplinary communication in the building design domain. The scope of this research includes the multiple disciplines involved in building design.

b. To provide an exploratory framework to studying building design team communication and outcomes that accounts for the multidisciplinary nature of the team and also the complexity of building design.

c. To use the above exploratory framework to analyze, describe, and document the relationship between the functional diversity of multidisciplinary building design teams, its communication, and its outcomes.

From the exploration of multidisciplinary design team communication and outcomes, this research provides suggestions and recommendations for building design practitioners and researchers. For practitioners, this research suggests approaches to manage the functional diversity in building design teams in ways that support effective communication and outcomes, while for researchers, this research suggests further areas that can be studied to deepen our understanding of multidisciplinary building design team practice.

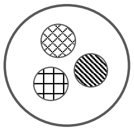
RESEARCH APPROACH

To achieve these goals, this research first develops a framework to explore multidisciplinary building design team communication and outcomes. This exploratory framework uses a dual-process model of diversity as a foundation to suggest a relationship between multidisciplinary building design teams, their communication and outcomes where functional diversity in the team leads to communication processes that in turn lead to negative and positive outcomes. The framework adds components from existing research to provide descriptions of the multidisciplinary team, the teams' communication across three categories – communication as social behavior, as an information process, and the use of communication technology – and the teams' outcomes, capturing the nuances of various project types and project teams.

Next, this research employs this framework to report on three cases of real-world multidisciplinary building design teams. The cases studied provide an accurate representation of real-life multidisciplinary building design teams with interviews as the primary method of data collection. The data obtained is analyzed using content analysis and a communication analysis method which combines aspects of several approaches to analyze team communication including Social Network Analysis (SNA), Communication Usage Diagrams (CUD), Value Flow Diagrams.

When applied to the specific cases, the framework offers insights into multidisciplinary building design team practice along the three lines of inquiry indicated in Table 1.1. The case findings do the following: they suggest a relationship between functional diversity, communication and outcomes; they offer modifications to the exploratory framework; and provide recommendations for multidisciplinary building design practice.

Table 1.1 Lines of inquiry and research gaps

Line of Inquiry	Description	Research Gaps	Questions
Inquiry 1: 	Multidisciplinary Building Design Teams	There is very little empirical research on multidisciplinary building design teams Multidisciplinary and Interdisciplinary are used interchangeably	What/Who constitutes a multidisciplinary building design team?
Inquiry 2: 	Multidisciplinary Building Design Team Communication	Communication processes in building design teams have not been studied The effects of functional diversity have not been documented	How do multidisciplinary building design teams exchange information? How does the presence of functional boundaries influence team communication?
Inquiry 3: 	Multidisciplinary Building Design Team Outcomes	The impact of communication processes on outcomes in building design teams have not been studied The effects of functional diversity have not been documented	What are multidisciplinary building design team outcomes? How does the functional diversity – communication relationship influence team outcomes?

Lines of Inquiry 1: Multidisciplinary Building Design Teams

Question: What constitutes a multidisciplinary building design team?

This line of inquiry explores multidisciplinary teams in building design and the professions and disciplines involved in these teams. It describes the practice of the multidisciplinary building design team, its' features, composition and hierarchy within it, thereby attempting to gain a sense of what it is multidisciplinary building design teams do. Functional diversity, its meaning, significance and effects on multidisciplinary building design teams are also explored along this line of inquiry.

Line of Inquiry 2: Multidisciplinary Building Design Team Communication

Question: How do multidisciplinary building design teams exchange information? Does the presence of functional boundaries and functional diversity in the team influence this information exchange among disciplines?

This line of inquiry focuses on communication in the multidisciplinary building design team. Theories of communication provide a definition of communication as information exchange between team members. Along this line of inquiry, an approach to studying team communication is developed which allows the description and visualization of multidisciplinary building design team communication, focusing on the flow of information between the disciplines on the team.

Line of Inquiry 3: Multidisciplinary Building Design Team Outcomes

Question: What are multidisciplinary building design team outcomes?

This line of inquiry explores building design team outcomes. It identifies these outcomes, and describes the effects of the team's functional diversity and information exchange processes on the team's outcome measures.

From the analyses of obtained data, in addition to the exploratory framework, the following are developed: the individual case reports describing the findings from each case study given in Appendix D, the cross-case report in Chapter 4, and the synthesis of the case study findings, their implications, and the recommendations of the research in Chapter 5.

The results presented using the exploratory framework developed in this dissertation are specific to the cases studied. The dissertation does not aim to provide a global account of communication in all building design teams, and the results obtained are not intended to be generalized to all building design teams. Rather, this research offers this robust framework for describing and analyzing team communication, and uses this framework to provide insights into multidisciplinary building design team practice through the specific examples presented in the case studies.

CHAPTER OVERVIEW

This section provides an overview of the organization of this dissertation:

Chapter 1: Introduction

The current chapter provides an introduction to the research in this dissertation, outlining the rationale behind exploring communication and outcomes in multidisciplinary teams. The gaps identified from existing research are discussed highlighting the need for further research that contributes to this area. The scope of the work along the three lines of inquiry guiding the research are introduced.

Chapter 2: Research Background

The second chapter reviews existing literature from different fields along each of the lines of inquiry. The meaning of multidisciplinary and its relevance to design teams is described. Theories of functional diversity are analyzed to identify the framework used to investigate communication and outcomes in design teams. This chapter also considers the current methods and approaches to analyze building design team communication, and identifies outcomes that can be applied to building design teams.

Chapter 3: Research Design and Methods

This chapter introduces the exploratory framework offered by this research including the lines of inquiry and their research questions, and the design of the cases studies of multidisciplinary building design teams that use this framework. This description of the case study design includes the rationale and procedures for data collection and analysis: interviews, document review, content analysis, and communication analysis.

Chapter 4: Case Study Findings

Chapter Four presents the findings from the cases studied in this research. Guided by the exploratory framework and its lines of inquiry, the findings provide descriptions of the multidisciplinary team, the teams' communication across three categories – communication as social behavior, as an information process, and the use of communication technology – and the teams' outcomes.

Chapter 5: Discussion

Chapter Five reexamines and synthesizes the case study findings to identifies the commonalities and patterns that offer answers to the research questions outlined in Chapter 3. This synthesis is used to: suggest a relationship between functional diversity, communication and outcomes in building design teams; modify the exploratory framework; and offer recommendations for multidisciplinary building design practice, as the implications of the case findings.

Chapter 6: Conclusion

The final chapter summarizes the work done in this research and outlines its contributions, limitations and future research directions.

2: RESEARCH BACKGROUND

2.1: MULTIDISCIPLINARY TEAMS IN BUILDING DESIGN

THE PRACTICE OF BUILDING DESIGN

Practice has been described as a formalized type of behavior where there is an interdependent relationship between several elements, such as the people who make up the practice, the knowledge required for the practice, and the attributes required to sustain the practice. (Shove, Pantzar, & Watson, 2012). To understand and improve practice, we must first be able to describe and analyze it and its' elements, in the different forms in which they may occur (Valkenburg & Dorst, 1998).

Blau in her sociological exploration of architecture firms identifies three forms of building design practice: building design as a process, building design as an organization, and building design as a business in a market economy (Blau, 1987). Each form of practice, shown in Figure 2.1, addresses the complexity of building design problems in different ways and provides its own descriptive guide to building design through its unique elements.

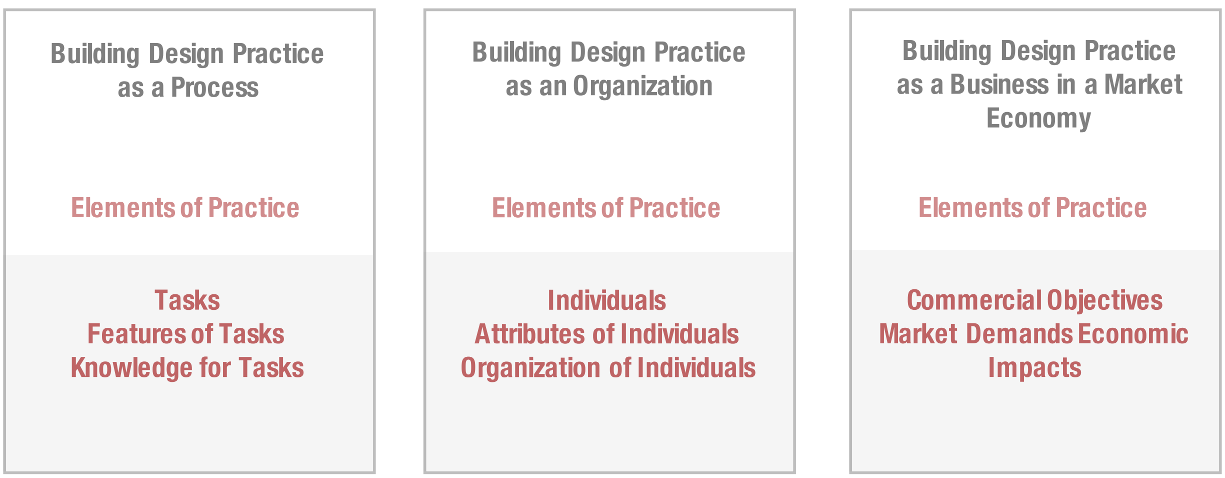


Figure 2.1 The three forms of building design practice (Blau, 1987)

The process form of practice emphasizes the tasks performed during building design. As discussed in Section 1.1 (*Complexity and Multidisciplinary Teams in Building Design*, p. 2), building design involves achieving multiple goals by performing a set of related and dependent tasks. Furthermore, there is a significant amount of variation both in the characteristics and features of these tasks, as well as the ways in which the tasks can be organized. While the process form provides significant insights, it does not account for the individuals involved in building design.

The organizational form of practice is concerned not only with the tasks of building design, but also with the individuals who perform these tasks. These individuals – who come from different disciplinary and professional domains – are often arranged into structures to support achieving building design goals. Understanding building design as an organization provides a big-picture description of building design beyond just the tasks performed.

However, there is an even bigger picture view of building design practice, namely, that of a business in a market economy. This form of practice considers that building design does not occur in a vacuum but is part of and subject to economic fluctuations. Building design is a business with commercial objectives that guide the activities that occur.

Research on building design practice has primarily focused on understanding building design as a process. There are multiple accounts that outline the phases and steps required for building design (AIA, 2006, 2017; BUILD LLC, 2008; Designing Buildings, 2017). Studies have identified what tasks occur in the different stages of the building design process, the inputs and outputs of the tasks, and how the tasks connect with each other. Other studies have focused on the activities required for the different tasks involved in the design process.

However, research has largely ignored the other two forms of practice, building design as an organization, and building design as a business in a market economy. The research within this dissertation is concerned with the second, organizational form of practice: building design as a practice that occurs in a multidisciplinary team. Few accounts have included descriptions of the building design team that identify the different professions on the team (Designing Buildings, 2017; Lee, 2015). These accounts do not include descriptions of the individuals making up the team, their knowledge, competencies and relationships.

A complete understanding of the multidisciplinary building design team as an organization involves accurately describing, and analyzing the individuals, skills and interactions present in the team. But first, it is important to fully understand what teams are, the meaning of multidisciplinary and the significance the multidisciplinary team in the building design context.

BUILDING DESIGN TEAMS, OR BUILDING DESIGN WORK GROUPS?

It is widely accepted that teams offer many advantages. For instance, organizations use teams to improve their efficiency in performing complex tasks and problems that need to be completed within a short time-period (Hassall, 2009). Another example: utilizing teams is a well-stated strategy for improving productivity. Approximately 78% of US organizations reporting their use of teams to perform groups of tasks that were originally performed by individuals (Bishop & Mahajan, 2005). This shift to the use of teams is a result of the nature of work tasks and the demands of a globalized work environment. Teams perform tasks beyond the capabilities of a single individual by combining the skills of individuals to come up with rapid, creative, flexible and adaptive solutions (Kozlowski & Bell, 2003).

Despite the agreement on the advantages of using teams, there is there is disagreement on what constitutes a team. Approaches to defining teams fall into two categories. The first category uses the terms teams and work groups interchangeably. This category does not differentiate between these two terms and attributes this to professional practice where managers and team members do not make a distinction between working in a group and working in a team (Fisher & Hunter, 1997). The second category makes a distinction between teams and work groups stating that all teams are work groups but not all work groups are teams (Hinds, 2015).

Distinguishing between teams and work groups provides an accurate representation of the practice of building design. Katzenbach and Smith define work groups as "a group for which there is no significant incremental performance requirement or opportunity that would require it to become a team. The members interact primarily to share information, best pegiractices, or perspectives and to make decisions to help each individual perform within his or her area of responsibility" (Katzenbach & Smith, 1993). They define teams as "a small number of people with complementary skills who are equally committed to a common purpose, goals, and working approach for which they hold themselves mutually accountable" (Katzenbach & Smith, 1993).

The difference between the two is that team members have shared responsibility, shared objectives and a common outcome whereas group members may not. That is, a team forms a group where members share a common goal to be achieved. A simple example that illustrates this is the difference between a football team and a knitting group. In a knitting group, members come together for their love of knitting. They have their individual skill levels and work on individual projects at their own pace. In a football team, though team members play different roles and at different positions, all team members are committed to the goal of winning games. Figure 2.2 highlights this difference between teams and groups. In building design, team members are committed to a common goal of successfully designing a building even though they have different disciplinary roles on the team.

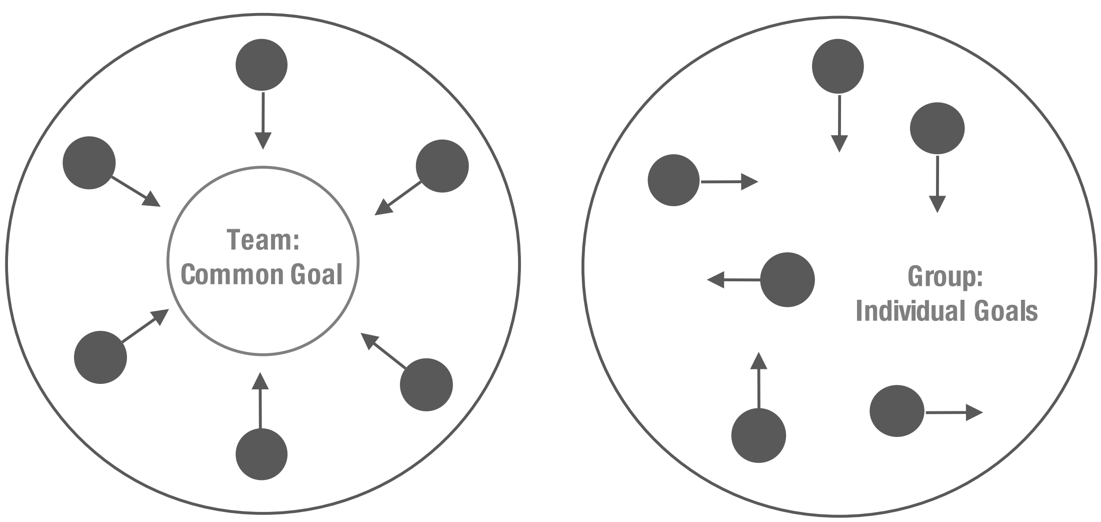


Figure 2.2 Team members work towards a common goal, while group members work on individual goals (Kozlowski & Bell, 2003)

Research that describes and analyzes teams and teamwork suggests that it is necessary to obtain deep insights into what the team does, how the team does it and interrelations between team members.

These insights can be obtained by identifying and describing four critical characteristics of teams: team context, multilevel team influences, team workflows, and team dynamics (Kozlowski & Bell, 2003).

Critical Characteristics of Teams

a. Team context

Team context describes the environment and climate of a team and exists on two levels: proximal and distal. Proximal context includes the immediate environment of the team and can be described as the internal team environment. Distal context includes the broader external environment the team exists in (Bradbury & Kamey, 2010). Descriptions of multidisciplinary building design team contexts include rich descriptions from the perspectives of the different disciplinary team members, the relationships between them, and the larger organizations of which team members are a part.

b. Multilevel team influences

Team context creates influences at different levels; these must be accounted for when studying teams. Multilevel influences include individual level characteristics, team level characteristics and the external characteristics that can affect how teams work (Cyert, March, & others, 1963). In a building design team, identifying these influences involves identifying the specific attributes at the individual, team, and external level, that influence team functioning and design outcomes.

c. Team workflows

Team workflows identify what teams do, how they convert inputs to outputs and the structure within which team members carry out their responsibilities. Building design teams often have a structure or hierarchy that can be identified through team member roles and the activities they perform. This structure influences the interactions and links between team members, team processes and team effectiveness (Lichtenstein, Alexander, Jinnett, & Ullman, 1997).

d. Team dynamics

Team dynamics reflect an understanding that teams constantly change over time. This characteristic is largely ignored in research, however, it is essential to pay attention to it as time has impacts on team learning and development (Kozlowski & Bell, 2003). Building design projects often have a short duration with team members who have been put together for specific purposes, and therefore, it is easy to overlook the impacts of time. Identifying and describing changes that may occur contributes to the depth of information on team development and team functioning in building design.

These critical characteristics contribute to an analytic framework for studying the multidisciplinary building design team. Research on multidisciplinary teams has become more prominent due to their use in several fields such as healthcare and education. In building design however, the term 'multidisciplinary' is still not well-understood.

MULTIDISCIPLINARY TEAMS VERSUS INTERDISCIPLINARY TEAMS

Teams comprising members from multiple disciplines are required in order to solve real world, complex problems, as such problems often include issues from more than one discipline. However, the boundaries between disciplines impose an artificial division of knowledge (Choi & Pak, 2006). Building design problems, for instance, require knowledge from disciplines of architecture, engineering, planning, development and finance. These disciplines bring different skills and perspectives to solving the problem in a coordinated manner.

The way in which these skills from multiple disciplines are combined depends on the disciplinary types present within a team. Theoretical explorations have identified six disciplinary types that occur in teams ranging from single disciplinary teams – where all team members come from the same discipline – to transdisciplinary teams – where individuals come away from their disciplines and assume roles outside their specific discipline (Garner, 1994; Jantsch, 1947).

Research in the areas of design, building design and architecture has focused on the terms interdisciplinary and multidisciplinary. These two disciplinary terms indicate specific types of team functioning. Unfortunately, these terms are used interchangeably in the literature without accounting for the differences that the terms engender. Table 2.1 highlights the differences between the two terms.

Table 2.1 Multidisciplinary teams versus interdisciplinary teams (Choi & Pak, 2006).

	Multidisciplinary Teams	Interdisciplinary Teams
Disciplines	Involves working with several disciplines Involves more than two disciplines	Involves working between several disciplines Involves reciprocity between two (or more) disciplines
Workflow	Team members work in parallel or sequentially on different aspects of a problem	Team members work jointly on all aspects of the problem
Tasks	Tasks depend on individual disciplines	Tasks are shared regardless of disciplines
Roles	Team members have separate but related roles and maintain disciplinary roles	Team members have common roles
Boundaries	Disciplinary boundaries are maintained	Disciplinary boundaries are blurred
Methods	Separate methods	Common methods
Knowledge	Complementary knowledge is used to address problems and tasks through an additive process	New knowledge and perspectives are created through an integrative process
Outcomes	The outcome is the sum of individual parts	The outcome is more than the sum of individual parts

Multidisciplinary teams are made of several separate disciplines working to achieve a common goal. Each discipline has their specific concepts, approaches and methods that are not shared or integrated with those of other disciplines. Team members bring a variety of knowledge from different disciplines, but work within individual disciplinary boundaries, while sharing information with each other. Knowledge is combined in an additive rather than integrative manner where the approaches and perspectives of different disciplines are combined without being changed (Bernard-Bonnin, Stachenko, Bonin, Charette, & Rousseau, 1995; Choi & Pak, 2006; Derry, Schunn, & Gernsbacher, 2014; Garner, 1994; NSERC, 2016)

By definition, building design teams are multidisciplinary. Multidisciplinary building design teams are made up of several disciplinary stakeholders, architects, engineers, interior designers, urban planners and so on who work in parallel on different aspects of the building design problem with each discipline staying within their disciplinary boundary. In other words, architects do not solve the engineering problems, urban planners do not solve the interior designers' problems and so on. Each discipline has different approaches to solving their aspects of the problem, for instance, engineers attempt to find an optimal engineering design solution while architects attempt to find the design solution that best satisfies the client requirements (Simon, 1988).

When building design teams are called interdisciplinary, it suggests that the team works in a continuously integrated manner. This provides an inaccurate representation of building design teams. Interdisciplinary teams share ideas and fully integrate their different concepts, knowledge and methods, unifying links between them and forming a well-resolved whole solution. Each disciplines contribution is well interwoven that individual contributions cannot be identified. Team members use frequent, collaborative exchanges to develop new knowledge beyond what is already known (Bernard-Bonnin et al., 1995; Choi & Pak, 2006; Garner, 1994; Grossman, 1979; NSERC, 2016).

This distinction between multidisciplinary and interdisciplinary is important when studying building design teams. Although it is common knowledge that working in building design teams is challenging, specific problems and challenges are often unidentified (Lee, 2001). Identifying the right problems faced by teams depends on applying the accurate theoretical lens and terminology. Accounting for the differences between these two terms, and applying the right one provides a clear description of building design teams without oversimplifying or misrepresenting how building design teams function.

Working in multidisciplinary teams poses a different set of challenges than working in interdisciplinary teams. These challenges primarily occur because multidisciplinary team members work within their individual disciplinary boundaries. Team members of one discipline can solve their individual problems without completely comprehending what other disciplines do. Overall, a lot of effort is required to coordinate between disciplines. This is not the case in interdisciplinary teams where frequent and collaborative exchanges are the norm and team members work together on most aspects of problem solving. An additional challenge stems from individual disciplines tending to have their individual language and jargon. Multidisciplinary teams are thus concerned with translating jargon and languages between disciplines which would not normally be an issue in an interdisciplinary team where team members have a shared language.

Building designers are becoming increasingly aware of the challenges of the multidisciplinary nature of their teams. The AIA found that architecture firms are increasingly consisting of multiple disciplines, offering more than one specialization in-house. In their 2016 survey of firm profiles, there was a decrease in architecture firms that describe themselves as single-disciplinary from about 60% to 50% from 2005 to 2015. Also, within this time, there was a corresponding increase in architecture firms that self-describe as multidisciplinary from 25% to 40%. This increase was most prominent in larger firms with 85% of larger architecture firms classifying themselves as multidisciplinary (AIA, 2016). This increase in multidisciplinary firms is illustrated in Figure 2.3.

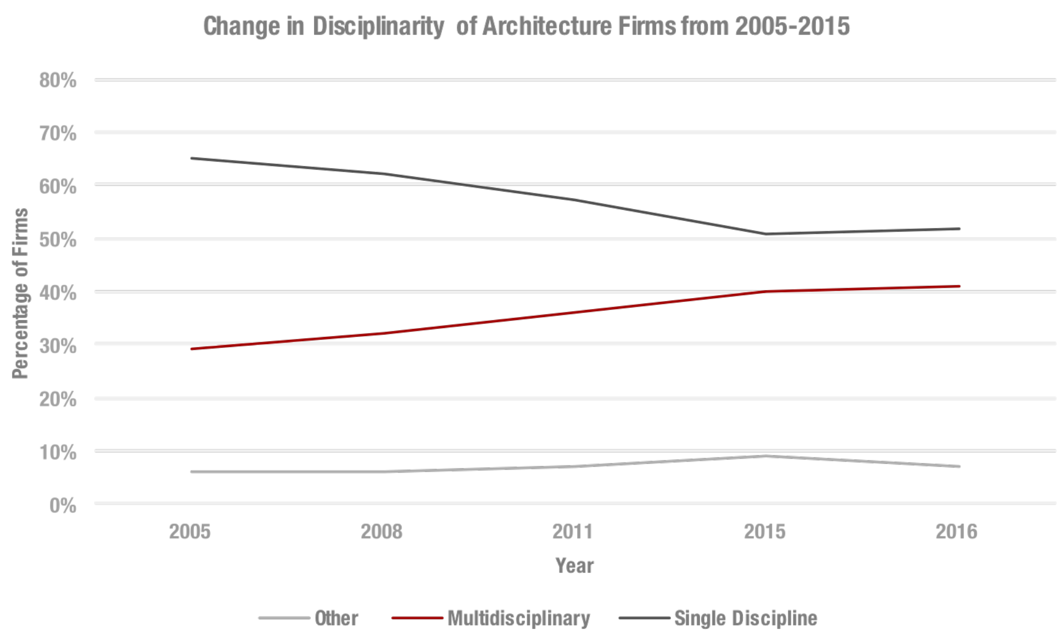


Figure 2.3 Increase in multidisciplinary architecture firms from 2005-2015 (AIA, 2016)

Several factors contribute to this increase in self-described multidisciplinary firms: an increase in the size and complexity of projects firms handle, and an increase in profits made by architecture firms (AIA, 2016). However, this increase in multidisciplinary architecture firms also suggests an awareness of the benefits of multidisciplinary teams where team members can provide complementary knowledge and perspectives beyond the scope of a single individual or profession.

One manifestation of this increased awareness of the potential benefits of multidisciplinary design teams is Integrated Project Delivery (IPD). IPD is a project delivery approach that emphasizes collaborative design practices using an integrated design process, shared goals, open communication and a multidisciplinary project team.

Integrated project delivery requires the early involvement of stakeholders to collaboratively solve problems and make decisions. The stakeholders do so because of mutual trust and respect established in the process and through the shared risks and shared rewards approach (AIA California, 2008; Thomsen, Darrington, Dunne, & Lichtig, 2009). IPD focuses on open, direct and honest communication between stakeholders. This open communication promotes a culture that emphasizes conflict resolution and minimizes blame assignment (AIA, 2006). Studies have shown that there has been an increase in the use of integrated project delivery on projects, as well as a reported increase in the stakeholder awareness of the benefits of integrated project delivery.

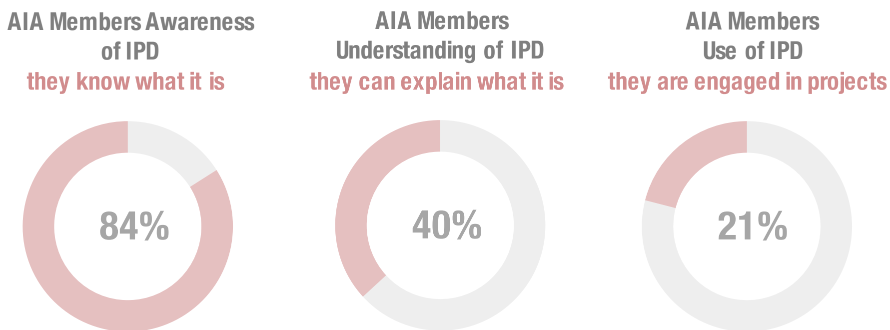


Figure 2.4 The awareness, understanding and use of IPD (AIA 2013)

Although there is an increase in multidisciplinary building design teams, and an awareness of the benefits of having multidisciplinary design teams, there is insufficient information on how these teams function. Understanding what multidisciplinary building design teams do involves paying attention to the diversity, specifically, the functional diversity in the team.

2.2: FUNCTIONAL DIVERSITY IN MULTIDISCIPLINARY TEAMS

DIVERSITY IN TEAMS

Research on diversity in teams shows that, not surprisingly, diversity influences team processes and team outcomes. Such research introduces the input-process-outcome model of team effectiveness. The model states that team outcomes occur as a function of team inputs and the process, where an input characteristic – in this case, diversity – influences processes or patterns of behavior, which in turn, influence outcomes achieved by the team (Bunderson & Sutcliffe, 2002).

Figure 2.5 Team inputs influence team processes which in turn influence team outcomes (Bunderson & Sutcliffe, 2002)

The input-process-outcome model has been used by several prominent theories to explain the effects of diversity in teams. These theories show that diversity in teams leads to different outcomes, both positive and negative. However, the theories use different aspects of diversity as inputs (size, specialization, boundaries), and different processes (structure, team member behavior, information sharing), to explain team outcomes. The theories include: structuralist approach, organizational complexity, organizational information processing theory, similarity attraction principle, theory of embedded intergroup relations, and social identity theory. An overview of the theories, shown in Table 2.2, has two implications for the study of multidisciplinary building design teams: there are multiple aspects of diversity, and diversity can lead to both positive and negative team outcomes.

Table 2.2 Overview of theories on diversity using the input-process-outcome (IPO) model

	Structuralist Approach	Organization Complexity	Information Processing	Similarity Attraction	Social Identity Theory	Embedded Intergroup
Input	Diversity: Defined as size	Complexity: Defined as variation in structure	Diversity: Defined as variation in units	Diversity: Defined as dissimilarity in units	Diversity: Defined as variation in identity groups	Diversity: Defined as subgroup boundaries
Process	Structure	Team member behavior: omissions, errors, filtering	Information behavior, Information chunking	Attraction	Categorization processes	Boundary permeability between subgroups
Description	Diversity (size) influences team structure	Complexity affects team member behavior	Diversity influences the amount of information available to the team	Similar individuals are attracted to each other. Diversity increases dissimilarity	Diversity triggers categorization processes in identity groups within teams	Diversity in subgroups leads to more boundaries in the team.
Outcome	More diversity = More structure = Good outcomes	More diversity = More errors and omissions = Poor outcomes	More diversity = More information = Good outcomes	More diversity = More dissimilarity = Poor outcomes	More diversity = More categorization = Poor outcomes	Permeable subgroup boundary = Good outcomes
Relationship Posed	+	-	+	-	-	

Structuralist Approach

The structuralist approach focuses on the relationship between the variation in an organization's structure and the outcomes of that organization. This approach holds that an organization's form or structure is a function of its complexity: complex organizations are more likely to perform better than less complex ones. Studies on the structuralist approach have used the size of an organization as the primary variable for determining its structure, with research looking at the effects of organizational size on its internal environment, functioning and outcomes (Blau &

McKinley, 1979; Kimberly, 1976). Figure 2.6 shows the IPO model of the structuralist approach.

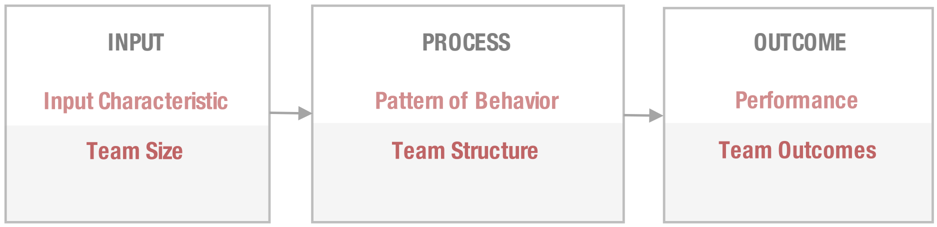


Figure 2.6 The model of the structuralist approach

This approach suggests that in a building design team, the complexity or size of the team affects its structure and performance: larger teams would have more structure and outperform smaller teams. Critics have suggested that other aspects and determinants of structure, rather than size, need to be understood in order to provide a clearer picture on the structure - performance relationship (Blau & McKinley, 1979; Kimberly, 1976).

Organizational Complexity

Organizational complexity, shown in Figure 2.7, suggests that the variation in, and structure of an organization influences team member behavior, which then impacts team performance. Complexity, in this case, is defined as the amount of differentiation present within the units and elements that make up a group or team. Usually, in organizations, it is the number of different specializations present within the organization.

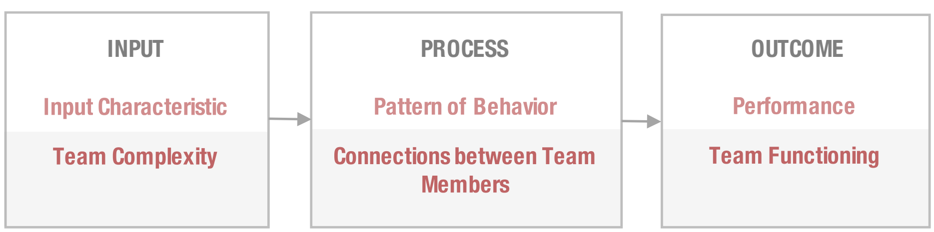


Figure 2.7 The model of the organizational complexity theory

The presence of these different specializations places constraints on the ability to form interconnections between the units and elements within the group, necessary for a highly effective team. Team members make assumptions to simplify their working situations. Dooley states that "team members make omissions, tolerate errors, filter, abstract and chunk information to deal with complexity" (Dooley, 2002). Connections are made easily between similar units and elements within the team compared with dissimilar units leading to fewer omissions, error tolerance and higher performance (Blau & McKinley, 1979; Dooley, 2002). In the multidisciplinary building design team, complexity is the number of different disciplines in the team. Organizational complexity theory suggests that in a building design team with a high number of disciplines, team members find ways to deal with and adapt to the complexity of the team. In dealing with the complexity of the team, team members will tolerate more errors leading to low team functioning and performance.

Organizational Information Processing Theory

Organizational information processing theory also addresses the ways team members deal with complexity on the team, but focuses on information behavior, rather than overall behavior. The theory, shown in Figure 2.8, explains the effects of variation in the team on information behavior and team performance where information behavior represents the ways in which the team obtains and adapts the information they require to perform their tasks.

Figure 2.8 The model of the organizational information processing theory

Regarding the theory, Stahl et al state that the "diversity in a team or in an organization brings different contributions to the team or organization, covering broader territory of information and tapping into more diverse networks" (Stahl et al., 2010). The richness of information provided by having a diverse team leads to a large knowledge base for the team which contributes to creative and innovative results, and an effective problem solving process (Blau & McKinley, 1979; Stahl et al., 2010; Weick, 1995). When applied to building design teams, organizational information processing theory suggests that diversity in multidisciplinary building design teams will lead to a rich knowledge base for team members to tap into, leading to creative and innovative outcomes. On the other hand, the similarity-attraction principle (see next section) suggests the opposite: that diversity leads to negative team outcomes.

Similarity-Attraction Principle

The similarity-attraction principle, shown in Figure 2.9, states that people are attracted to those like themselves and prefer to work with other individuals they find similar in terms of values and beliefs (Stahl et al., 2010). Individuals' agreement on these values and beliefs reinforces attraction and positive attitudes between similar units, leading to a positive effect on team integration. On the other hand, the lack of attraction to dissimilar individuals in a diverse team has negative effects on integration (Lichtenstein et al., 1997).

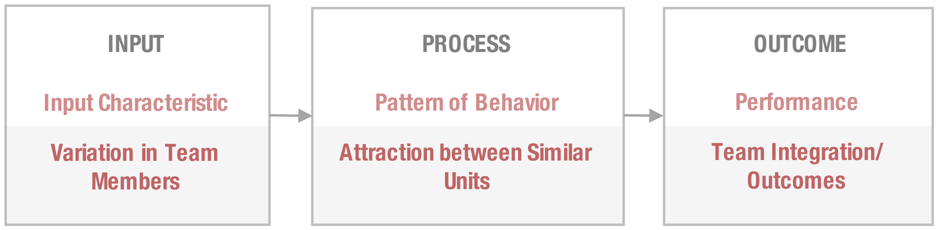


Figure 2.9 The model of the similarity-attraction principle

The similarity-attraction principle suggests that diversity will make disciplines stick to their individual groups. In a multidisciplinary building design team, disciplines will be unwilling or unable to work with other disciplines on the team, negatively affecting team integration and performance.

Social Identity Theory

The negative relationship between diversity and team outcomes in the similarity-attraction principle is supported by social identity theory. Social identity is described as the self-identification or self-categorization individuals place to situate themselves within a team or a group. People categorize themselves into groups based on similar social identities and exclude themselves from other groups based on dissimilar social identities. As in the similarity-attraction principle, the belief in shared values between members of the same identity groups promotes favorable behaviors between team members that leads to high performance (Stahl et al., 2010; Tajfel, 1974). Figure 2.10 illustrates Tajfel's Social Identification and Categorization Theory, which states that individuals belong to a group based on their perceptions of how they fit within the group and their perceptions of similarity between group members.

Figure 2.10 The model of the social identity theory

Social categorization poses a challenge in multidisciplinary building design team. In the multidisciplinary team, different disciplines need to work together. Categorization processes due to the diversity in multidisciplinary teams can potentially lead to disciplinary or identity silos (discussed in Section 1.1 *Functional*

Diversity, Fragmentation, and Multidisciplinary Building Communication, p. 3) and low team performance.

Theory of Embedded Intergroup Relations

Alderfer's theory of embedded intergroup relations takes a different approach to categorization due to diversity by focusing on the permeability of boundaries within a team. The theory states that teams are a part of a larger social structure. Team members belong to groups within the larger social structure that are external to the team. These external groups can influence team member interaction within the team. The influence of the external groups depends on the permeability of the team boundary. A permeable boundary will allow members to maintain stronger ties with their external groups than with the team, negatively affecting team integration. A 'rigid' boundary, on the other hand, will preserve strong ties within the team, positively affecting team integration (Alderfer & Smith, 1982; Lichtenstein et al., 1997).

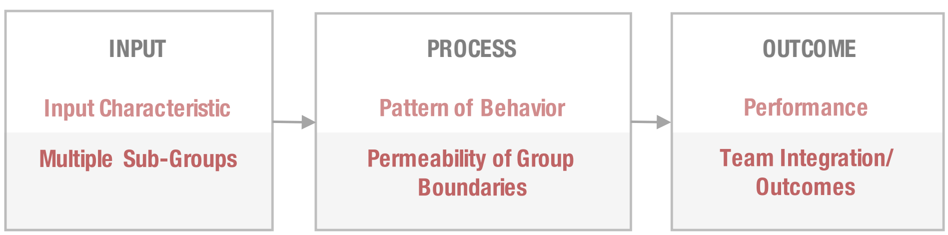


Figure 2.11 The model of the theory of embedded intergroup relations

In a multidisciplinary building design team, the individual disciplines serve as the external groups within the larger social structure. Aldefer's theory suggests that a rigid team boundary will promote integration between the multidisciplinary team members, minimizing external influence from the individual disciplines.

The overview shows that, first, these theories use different approaches to define and operationalize diversity. The structuralist approach makes use of size, organizational complexity and the organizational information processing theory use variation between units, while the theory of embedded intergroup relations uses the boundaries within a larger social structure. As diversity serves as the input in the input-process-outcome model, it is necessary to clearly define and operationalize the diversity in multidisciplinary building design teams.

Second, the theories show competing results. Certain theories suggest that diversity in teams has a positive influence on team outcomes, decision making, conflict resolution, creativity and innovation (Joshi & Roh, 2009; Keller, 2001; Knight et al., 1999; Kozlowski & Bell, 2003; Randel & Jaussi, 2003), others suggest that diversity in teams has a negative influence on team outcomes (Joshi & Roh, 2009; Kozlowski & Bell, 2003). These competing results mean that in an input-process-outcome model, where diversity is the input, two possible outcomes may occur. This suggests that while the input-process-outcome model provides a useful framework, it does not sufficiently capture the effects of diversity on multidisciplinary building design team outcomes.

The two findings from the overview can be addressed by identifying the ways to define and measure diversity – the functional diversity – in the multidisciplinary team, and by introducing the dual-process model of diversity.

MEASURING FUNCTIONAL DIVERSITY IN TEAMS

The multidisciplinary nature of building design teams makes them functionally diverse. Functional diversity has been defined as the variation in functional units, skills and abilities within a team. This definition has been conceptualized in four ways which suggest different measures for functional diversity: dominant functional diversity, functional background diversity, functional assignment diversity, and interpersonal functional diversity (Bunderson & Sutcliffe, 2002; Knight et al., 1999).

Table 2.3 The four conceptualizations of functional diversity (Bunderson & Sutcliffe, 2002)

	Dominant Functional Diversity	Functional Background Diversity	Interpersonal Functional Diversity	Functional Assignment Diversity
Definition	Variation in dominant/longest career area	Variation in complete functional backgrounds	Variation in the extent of specialization of team members in all functional areas	Variation in team member roles and responsibilities
Measurement	Measured by asking team members which discipline they have worked the longest	Measured by reviewing the complete work histories and professional backgrounds of team members	Measured by asking team members if they are narrow or broad specialists in all areas in their background	Measured by asking team members which tasks they performed on the team
Strength	Easy to measure Most commonly used conceptualization of functional diversity	Fully accounts for team members complete professional background	Fully accounts for the extent of team member complete professional expertise	Easy to measure Closely aligned with the organizational chart and hierarchy of the team
Limitation	Does not account for the full extent of team member experience	Very intrusive data collection process Difficult to measure	Very intrusive data collection process Difficult to measure	Does not account for team member backgrounds or professional experience

Dominant Functional Diversity

Dominant functional diversity is defined as the variation in the areas or disciplines where team members spent the longest part of their careers. Measuring dominant functional diversity involves determining the disciplines or functional areas that team members have spent the greater part of their careers in. In a multidisciplinary building design team, dominant functional diversity can be measured by asking team members to identify the discipline in which they have worked the longest, thereby forming a list of all the disciplines on the team.

This approach to functional diversity has both limitations and strengths. The limitation of the dominant functional diversity is that it does not address the full extent of team member functional experience. For instance, a team member who has been a project manager for most of their career could also have prior experience as an architect. However, in the broader body of research on diversity from different fields, the dominant functional diversity is most commonly used. The research within this dissertation uses this conceptualization to situate this research within the larger body of work. The approach also presents methodological strengths as it is the least intrusive approach to studying team functional diversity (Bantel, 1993; Knight et al., 1999).

Functional Background Diversity

Functional background diversity is defined as the variation in the complete functional backgrounds of team members. This approach is operationalized by reviewing work histories or backgrounds of team members, taking note of educational background and other functional areas the team members may have worked in. This approach to functional diversity assumes that each functional area in a team members background is independent from prior ones and that there is no overlap in the knowledge that can be gained from this approach.

In a multidisciplinary building design team, this approach involves collecting the complete professional histories of all team members and determining the amount of variation in their histories. This highlights the limitation of this approach, where it is necessary to obtain complete work histories from all team members, making it ill-suited to large teams (Sutcliffe, 1994).

Interpersonal Functional Diversity

Interpersonal functional diversity focuses on the extent of specialization of team members within a specific functional area. It extends on the functional background diversity approach by not only asking what areas team members work in, but also capturing their proficiency in those functional areas. It asks if team members are narrow functional specialists, with expertise and knowledge from a few relevant functional areas or if they are broad functional specialists with knowledge from multiple functional areas.

Interpersonal functional diversity attempts to thoroughly cover all aspects of team members' backgrounds. In a building design team, team members can be knowledgeable about multiple disciplines, for instance, a team member may be familiar with the architecture and structural engineering disciplines. This approach would involve determining the range of expertise of the specific team member. This again highlights the limitation of this approach. Though it provides the most nuanced approach to functional diversity, it is the least feasible approach (Bunderson & Sutcliffe, 2002).

Functional Assignment Diversity

Functional assignment diversity moves away from looking at team member backgrounds. Instead, it addresses the variation in the assigned tasks of team members and the roles they play on the team. It is most closely aligned with the organizational chart and hierarchy in the team. Building design team members often perform roles that are separate from their discipline, for instance certain team members can act as design team leaders, or interns on projects. The limitation of this approach is that it leaves out all aspects of team members background and only focuses on the functional areas covered by their current tasks (Ancona & Caldwell, 1992).

These conceptualizations of functional diversity focus on different aspects of functional diversity in building design teams. Dominant functional diversity focuses on the disciplines in the team, functional background diversity requires the complete professional histories of all team members, interpersonal functional diversity requires the extent of team member specialization in all disciplines they are familiar with, and functional assignment diversity uses the roles performed by team members (Bunderson & Sutcliffe, 2002).

Although each approach can be applied to building design teams, and that it would be interesting to see how the different approaches influence the input-process-outcome model, the research within this dissertation is restricted to dominant functional diversity. Using dominant functional diversity as the input for the input-process model helps situate this research within the larger body of work on team diversity. However, it is still necessary to address the issue of competing outcomes from studies of team diversity discussed earlier.

THE DUAL PROCESS MODEL OF DIVERSITY

The research within this dissertation uses the dual process model, shown in Figure 2.12, to unite the competing results from diversity studies.

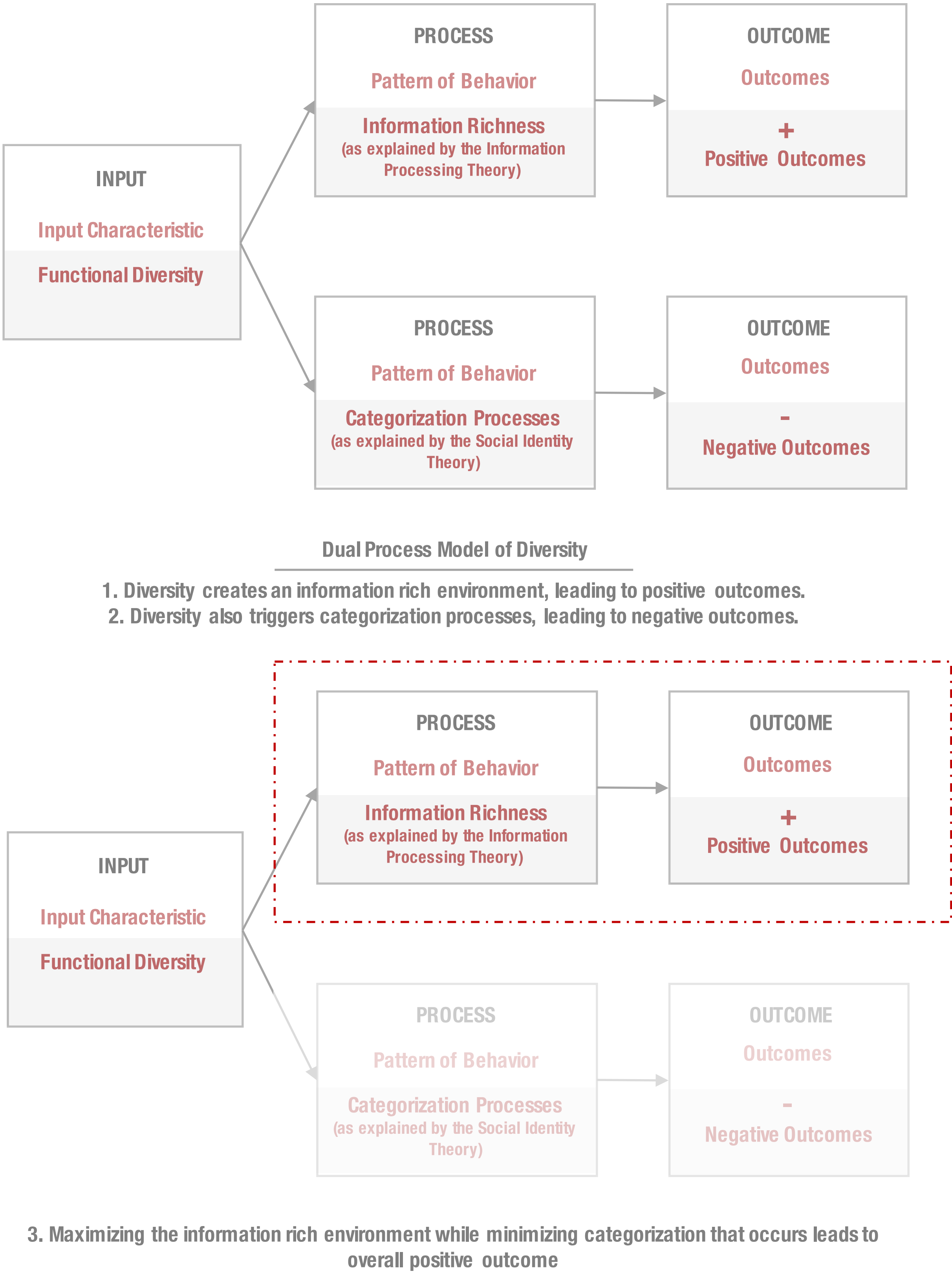


Figure 2.12 The dual process model of diversity illustrating that diversity can lead to both positive and negative outcomes in teams (Srikanth, Harvey, & Peterson, 2016)

Dual process models describe two different processes that can occur when observing a phenomenon (Lizardo et al., 2016). Following the input-process-output model of team effectiveness, the dual-process model of diversity suggests that rather than having either positive or negative effects, diversity can have both positive and negative effects, depending on the processes involved. Positive outcomes are obtained due to the increase in the information available from having multiple perspectives present in the team and negative outcomes are obtained due to increase in conflict that may occur from social categorization processes of team members (Srikanth et al., 2016)

The two processes of the model can be explained using some of the theories described earlier. Positive outcomes, can be explained by the organizational information processing theory where diversity leads to a high performing team. High team performance is achieved through more information availability and a greater knowledge base for the team to tap into. Negative outcomes can be explained by the similarity-attraction principle and social identity theory where categorization due to diversity leads to a low performing team. Low team performance occurs when team members stick to their identity groups and are less likely to interact with different identity groups within the team (Tajfel, 1974; Weick, 1995)

The model also suggests that negative outcomes in teams can be reduced. This can occur either by eliminating the categorization processes that lead to negative outcomes, or amplifying the information rich environment of the team. While this seems theoretically sound, critics argue that in practice, it is difficult to eliminate the categorization that occurs (Srikanth et al., 2016). Eliminating categorization may be impossible in a multidisciplinary team where team members work within their individual disciplinary boundaries, rather teams may utilize strategies that minimize the effects of categorization.

The dual process model of diversity underlies the framework for this research inquiry into multidisciplinary building design teams, the teams' communication, and its outcomes. Frameworks provide structure and guide the specific research questions along the lines of inquiry. The dual process model is useful when studying building design teams as the effects of functional diversity on team processes and outcomes have not been studied. Though critics have argued that the model does not consider the long-term effects of learning on team processes, this limitation makes it suitable for studying building design teams as building design teams are usually short-term teams put together for specific project purposes.

The model, as a part of the framework for this research, raises specific questions about the multidisciplinary building design team: Are multidisciplinary teams taking advantage of their information-rich environment? Do categorization processes occur and are there strategies in place to minimize them? And do these affect multidisciplinary team outcomes? Answering these questions requires a study of building design team processes and outcomes. The next part of this research background address communication as it is a critical building design team process as discussed in Section 1.1 (*Communication and Building Design: Why Do We Care*, p. 4) and looks at the ways to define and evaluate team communication.

2.3 COMMUNICATION IN MULTIDISCIPLINARY TEAMS

COMMUNICATION AND BUILDING DESIGN TEAMS

Communication poses a challenge to building design teams. As discussed in Section 1.1 (*Communication and Building Design: Why Do We Care*, p. 4), ineffective team communication contributes to waste and rework on building projects, increased project risk and uncertainty, conflict, and project failure (BSI, 2003; Designing Buildings, 2016; Love & Lopez, 2012; McGraw-Hill, 2014; PMI, 2013). The multidisciplinary nature of building design teams poses additional challenges to communication. The presence of members from multiple disciplines who work within their individual disciplinary boundaries adversely affects team communication, as team members are without a shared language to exchange information (Choi & Pak, 2006).

Surprisingly, literature on communication in building design teams is limited. This paucity of knowledge on building design teams means that we do not know the approaches multidisciplinary teams use to exchange information, and why these approaches break down. Obtaining sufficient insight into communication is necessary to understand, and also diagnose the practices of multidisciplinary building design teams.

Studies of communication fall under the general umbrella of communication theory. Communication theory addresses the processes involved in human interaction (as opposed to human-technology interaction). From this area, several scholars have described communication in different ways. These descriptions suggest that communication involves interaction and information exchange between units that can respond to stimuli (Dance, 1970; Hoben, 1954; Hoezen et al., 2006; Mead, 1964; Ruesch, 1957; Sondel, 1956; Stevens, 1950).

Although these descriptions provide an idea of communication, there are models that provide formalized definitions of communication as an information transmission process. Of these three are important models: Shannon and Weaver's linear model – the first communication model, Schramm's interactive model, and Barnlund's transactional model (Alder, Rodman, & Kramer, 1991; Foulger, 2004). Each model attempts to build upon the previous model by adding a new component to the information transmission definition.

Shannon and Weaver's model defines communication as an information transfer process and uses a set of basic components to describe the process. In this model, information is generated at a source, then sent to a receiver at a destination (Foulger, 2004; Shannon, 1949). The flow of information occurs in a linear process, that is, from source to receiver. When this definition of communication is applied to building design teams, the model suggests that some team members generate information while others receive information, and there is a linear transfer from sources to receivers.

Schramm's model keeps intact the sender and receiver component of Shannon and Weaver's linear model, and builds on it by including feedback to form the interactive model. In addition to the linear flow between the sender and receiver, there is also room for feedback from the receiver, back to the sender, for instance through questions and knowledge sharing (Schramm, 1954). Based on this model's definition of communication, there is a bi-directional flow of information between building design team members.

Critics of the interactive model state that it leaves out the timing of information flow where both the source and receiver can send information simultaneously. The transactional model, developed by Barnlund, addresses this timing issue by defining communication as a continuous process of interdependent information exchanges where each unit acts as a communicator (Barnlund, 1970). From this definition, in a multidisciplinary building design team, each member sends and receives information with room for feedback between them. Using Barnlund's model, shown in Figure 2.13, building design communication can be viewed as the dynamic transmission and exchange of information.

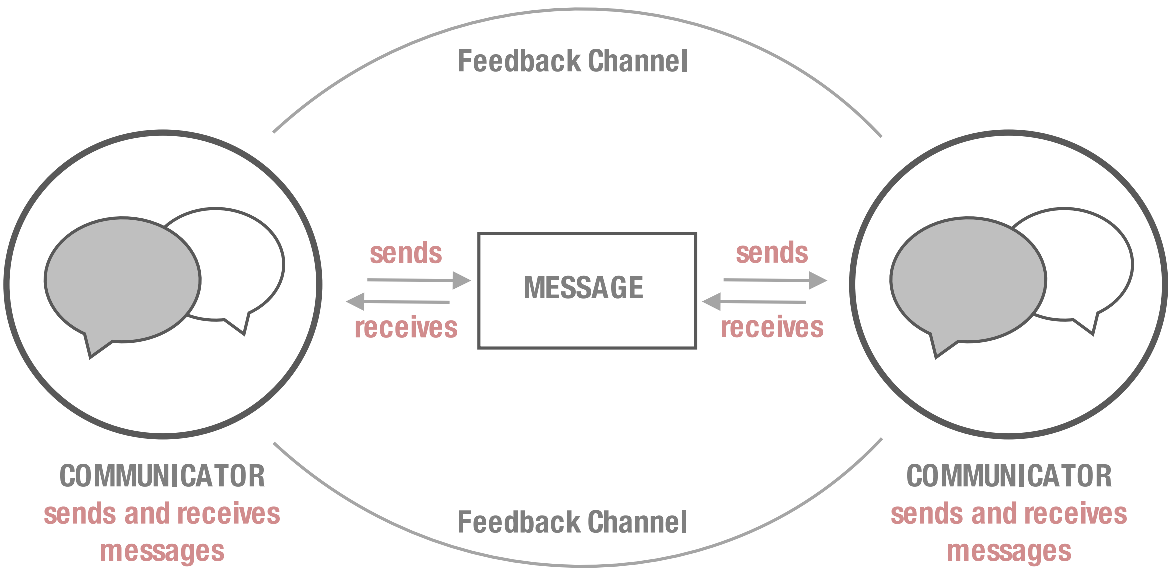


Figure 2.13 Barnlund's transactional model of communication

However, Barlund's model still does not fully represent building design communication. In building design teams, communication is so much more than dynamic information exchange. Communication includes patterns and activities, knowledge construction, and generative and elaborative acts that influence performance (Dong, 2005; Hassall, 2009; Stempfle & Badke-Schaub, 2002).

More recently, studies of communication that focus on design teams have adopted a more holistic approach to communication, offering three categories: as social behavior, as an information process, and as a technology interface (Norouzi, Shabak, Embi, & Khan, 2015). These three forms of communication have direct application to multidisciplinary building design teams wherein team members develop social relationships, engage in information sharing and make use of different technology. Describing the three forms of design team communication and the ways in which researchers have studied them provides a useful guide for the inquiry into multidisciplinary building design team communication.

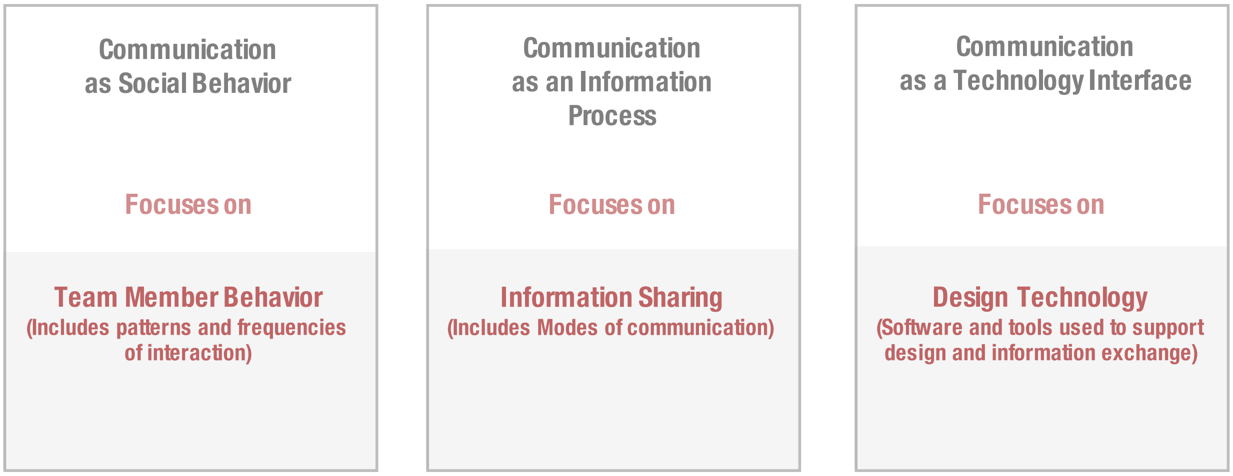


Figure 2.14 The three categories of design communication: communication as social behavior, as an information process and as a technology interface (Norouzi et al., 2015)

Communication occurs as social behavior between team members when team members engage in interactions and behaviors that "facilitate the achievement of goals" (Norouzi et al., 2015, p. 637). In studying team communication as a social behavior, researchers have looked at patterns of team member interactions where these patterns have been shown to be indicative of team success and team effectiveness (Ancona & Caldwell, 1992; Hassall, 2009). Researchers have also studied team member proximity – which contributes to the effects of functional diversity as discussed in Section 1.1 (*Functional Diversity, Fragmentation, and Multidisciplinary Building Communication*, p. 3) – and 'communicative acts' such as generation and elaboration (Hassall, 2009; Stempfle & Badke-Schaub, 2002).

As an information process, communication involves developing a shared understanding between team members through obtaining and sharing information. Research on communication as an information process has focused on the forms of information used in design communication, and the modes of communication team members use. Team members use and develop multiple types of design information, such as technical language, analogies and examples, gestures, graphics, objects and artifacts. (Williams & Cowdroy, 2002). In sharing such design information, team members make use of various modes of communication. Research suggests that team members show a preference for interpersonal, synchronous exchange of information (Dainty et al., 2007; den Otter & Emmitt, 2008; Gorse & Emmitt, 2007).

As a technology interface, communication links the different computer-mediated tools and technologies used to support design (Norouzi et al., 2015). Research on communication as a technology interface has addressed issues of interoperability between these different tools (Lee, Akin, Akinci, Garrett, & Bushby, 2009). However, tools do not function on their own; they are used by designers to perform their tasks. The technology touchpoint, where communication links individuals and their computer mediated tools is important when studying the team communication as it expands the technology interface category to include the interaction between the team and their tools. Research on communication technology has attempted to ensure that team members use the right tools for the right tasks, based on task requirements (Lee, 2011).

These three categories are useful when describing design communication, but in multidisciplinary design teams, the effects of multiple disciplines should be accounted for. Research suggests that team members have unique communication profiles and that consistently use the same strategies to exchange and share information, even when given new tools and technology (den Otter & Emmitt, 2008; Williams & Cowdroy, 2002). As the individual disciplines perform specific tasks and requirements, it follows that each discipline has specific social behaviors, information processes, and communication technology.

Identifying the unique disciplinary communication profiles contributes to framing the approach, inquiry, and research questions in this dissertation. The dual process model discussed in Section 2.2 (*The Dual Process Model of Diversity*, p. 28) suggests that diversity has two distinct effects on team processes, as a result definitions of communication in the building design context help identify the communication-specific research questions for this dissertation. The questions address the patterns and frequency of communication, use of communication technologies, and team information behavior.

Answering these questions involves identifying approaches to analyzing team communication, discussed in the following section, which address all three categories of communication.

ANALYZING TEAM COMMUNICATION

Several approaches aim to describe and assess team communication. These approaches have been used to understand and identify problems with team communication, and determine procedures for effective communication. While each approach can be applied to at least one of the three categories of communication identified earlier, none of the approaches address all three communication categories (Stanton, Salmon, & Rafferty, 2013).

Table 2.4 presents an overview of five approaches to evaluating team communication. The overview includes the category of communication addressed by each approach, the time required for learning and applying the approach, the data collection methods, the advantages and disadvantages of each approach.

Table 2.4 Approaches to evaluating team communication

	Communication Usage Diagrams	Social Network Analysis	Behavior Observation Scales	Performance Assessment of Comm. & Team.	Communication Project Assess. Tool
Approach	Tracks communication elements (agents, technology, reasons) involved in performing defined tasks communication	Collects data from team members to develop an association matrix. The network diagram is developed from this matrix	Assesses defined aspects of team communication. The assessment is conducted by an appropriate observer	Assesses the presence of a set of communication behaviors on a Likert scale	Assesses team communication in project management, engineering, and construction project groups
Related Methods/ Tools	The CUD requires video recordings, audio recordings, and a diagramming software package	Observations, interviews, and questionnaires are used to obtain the relational data required for SNA	A Likert scale is required to obtain the data for the BOS	Observations and rating scales (Likert Scales) are used in the PACT	Questionnaires and Surveys provide the data required for COMPASS
Output	Visual output: The output table	Visual output: Network maps and visualizations (Sociograms)	Rating Scale	Communication Scoresheet	Communication Effectiveness Score
Category of Comm.	Communication technology Communication as information process	Communication as social behavior Communication as information process	Communication as social behavior Communication as information process	Communication as social behavior Communication as information process	Communication as social behavior Communication as information process
Advantage	The approach provides a complete description of the tasks performed. It analyses the communication technology used in performing various tasks	The most important relationships and roles within the team are identified. A map of communication and interaction is developed	This approach is general and can be applies to any observable team communication behavior .	Tool is already developed and in use. Extensive documentation exists on the use of the tool.	Tool is already developed and in use. Extensive documentation exists on the use of the tool.
Disadvantage	Difficult to construct for large, complex tasks Errors in, and the time spent on the tasks are unaccounted for	Difficult to construct for large, complex tasks Requires responses from about 80% of team members	There is a limit to what can accurately be observed.	The tool only assesses overall team communication.	The tool only assesses overall project team communication. Available documentation must be purchased from the CII
Takeaway	Shows information flows Accounts for teams spanning multiple locations	Shows interactions and information flows Can identify patterns	Easily adaptable	Assesses the absence or presence of behaviors	Addresses communication effectiveness

The overview shows that while all the approaches address the information process category of communication, only some of the approaches address the other two categories. The Communication Usage Diagram (CUD) is the only approach that addresses the tools and technology of communication while the other four approaches address the social behavior category of communication. Rather than using one approach, this research combines aspects of multiple approaches to capture all three categories of communication, rather than just one or two.

Communication Usage Diagram (CUD)

Communication Usage Diagrams (CUD), as illustrated in Figure 2.15, are used to describe communication between team members across several locations. Descriptions of communication tasks between team members are obtained along with the different technologies used to facilitate communication. Observational methods and interviews are the primary means of collecting the data required to develop the CUD.

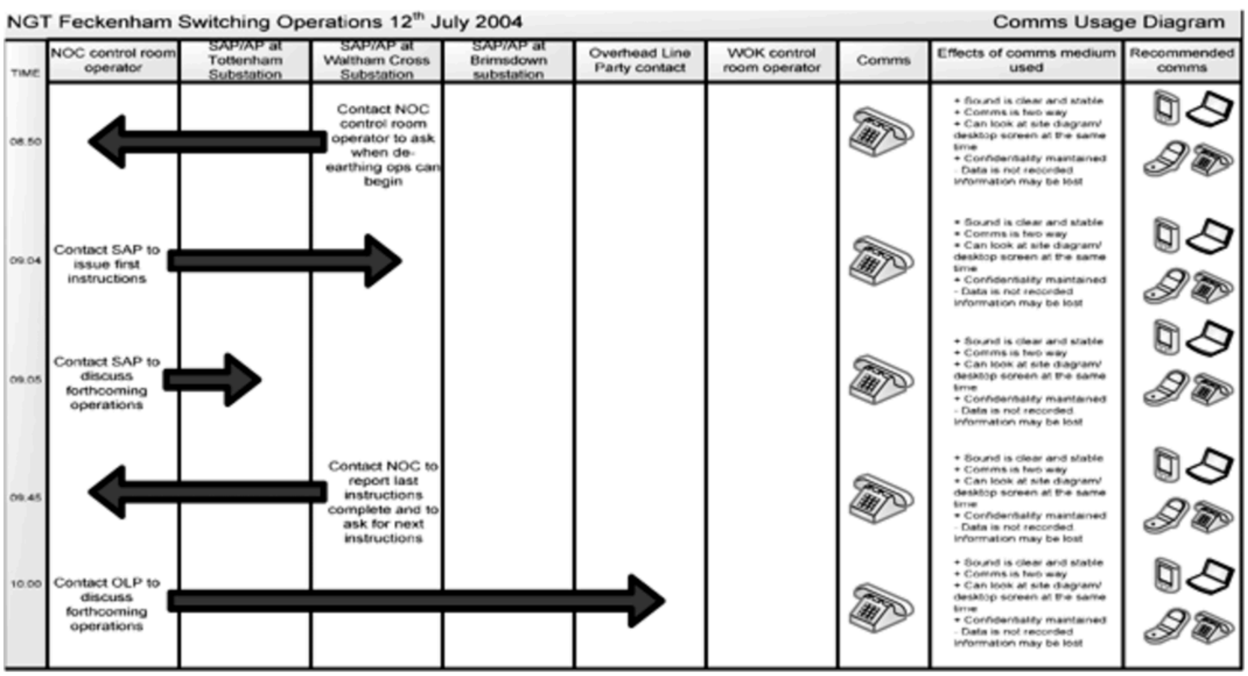


Figure 2.15 Communication usage diagram for an energy distribution task (Stanton et al., 2013)

An output table, that forms the basis for the CUD is developed. The table shows the step by step flow of information from a specific team member to others. The main advantages of this approach are its ease and simplicity of use and interpretation. Flaws in communication can be easily identified through missing flows from different individuals. However, the CUD approach is best suited to small tasks and teams spanning different locations (Stanton et al., 2013; Watts & Monk, 1998).

Social Network Analysis (SNA)

Social Network Analysis (SNA) is a method used to study the relationships and interaction between members of a team. This method views the team as a network and the team members as units within the network. Results are displayed graphically and show the whole system of team members as well as the links between members, representing the interactions between them.

The network map, as shown in Figure 2.16, can be further analyzed to identify features such as the frequency of interactions between team members, the centrality of individual team members, the density of the network and distance between individual team members.

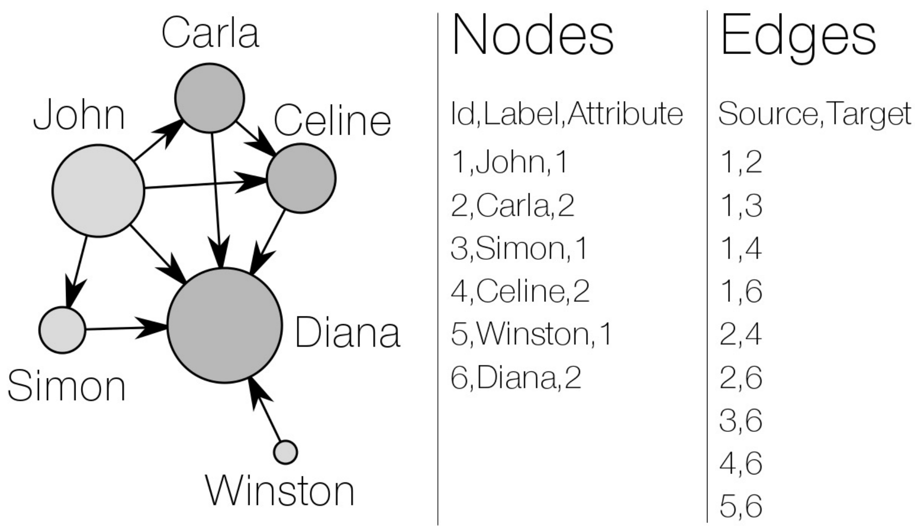


Figure 2.16 Simple social network graph showing nodes and actors (Grandjean, 2013)

Observational methods such as interviews and questionnaires are the primary methods of data collection for SNA. Once the necessary data is obtained, a matrix showing communication flows between team members is developed and used to form the network map. Unlike the CUD, SNA is not primarily concerned with the technologies used to facilitate communication between team members. Rather, patterns, frequencies and densities of communication can be determined from the network maps. SNA however becomes very difficult and complex for large teams requiring extensive and thorough data collection capabilities (Scott, 2012; Stanton et al., 2013)

Behavior Observation Scales (BOS)

Behavior Observation Scales (BOS) shown in Figure 2.17 assess various team characteristics. The BOS uses a rating scale developed specific to the analysis being performed including team communication as a team characteristic. Raters can use this rating scale to evaluate the communication features of the team rather than of team members as individual units and the communication between them.

Observational data collection methods are used with the BOS. After rating scale is developed, raters use observational methods to assess communication. The rating scale can be used to assess multiple teams and provide a comparison of the different communication approaches of different teams.

Title: Communication

Definition: Communication involves sending and receiving signals that describe team goals, team resources and constraints, and individual team member tasks. The purpose of communication is to clarify expectations, so that each team member understands what is expected of him or her. Communication is practised by all team members.

Example Behaviours

____ Team leader establishes a positive work environment by soliciting team members' input

____ Team leader listens non-evaluatively

____ Team leader identifies bottom-line safety conditions

____ Team leader establishes contingency plans (in case bottom line is exceeded)

____ Team members verbally indicate their understanding of the bottom-line conditions

____ Team members verbally indicate their understanding of the contingency plans

____ Team members provide consistent verbal and non-verbal signals

____ Team members respond to queries in a timely manner

Figure 2.17 Communication checklist for a behavior observation scale (Stanton et al., 2013)

Scale development needs to be rigorous to ensure that the right communication features are being measured. Subjectivity in the use of the rating scales by the raters can negatively affect the reliability of the results. The main advantage of the BOS is that it can be adapted to any aspect of communication as required (Stanton et al., 2013).

Performance Assessment of Communication and Teamwork (PACT)

The Performance Assessment of Communication and Teamwork (PACT) tool, shown in Figure 2.18, was developed by the Agency for Healthcare Research and Quality (AHRQ) to improve communication between professionals in healthcare delivery teams.

Like BOS, behaviors representing effective team communication are evaluated on a Likert scale. These behaviors are grouped into five categories of "team structure that identifies roles and responsibilities, leadership that addresses resource use, situation monitoring, mutual support addressing conflict resolution and communication regarding the distribution of information" (UW Macy, 2011).

Coder: ______________________
Date: ________________________
Simulation: ☐ 1st ☐ 2nd ☐ 3rd

Session: ☐ AM ☐ PM

Scenario Type: ☐ Asthma ☐ Pediatric ☐ CHF ☐ SVT ☐ OB ☐ ________

Performance Assessment for Communication and Teamwork (PACT) – Long Form for experienced observers

Please score the team performance by circle the anchors in the scale.

Frequency scale:
Present (P -The behaviors is present.
Absent (A)-The behavior is absent.
Not Applicable (NA)-There was no opportunity for the team to demonstrate such behavior.

Quality scale:
Poor (P)-The team performed poorly.
Need Improvement (NI)-The team performed okay but there is still space for growth.
Satisfactory (S)-The team performance met expectation but the quality can be better.
Excellent (E)-The team performed well.
Not Applicable (NA)-The team did not demonstrate such behavior or there was not enough information to judge the quality of the behavior.

Additional comments:
____
____
____
____
____
____
____

Behavioral Markers	Frequency			Quality				
Team Structure								
1. Team members recognize a leader.	P	A	NA	P	NI	S	E	NA
2. Team members refer to established protocols and checklists for the procedure/intervention.	P	A	NA	P	NI	S	E	NA
Leadership								
3. The team leader conducts briefs, huddles, and/or debriefs.	P	A	NA	P	NI	S	E	NA
4. The team leader empowers team members to speak freely and ask questions.	P	A	NA	P	NI	S	E	NA
Situation Monitoring								
5. The team applies the STEP process when monitoring the situation. STEP-Status of the Patient, Team Members, Environment, Progress Towards Goal	P	A	NA	P	NI	S	E	NA
6. The patient/family is included in communication.	P	A	NA	P	NI	S	E	NA
Mutual Support								
7. Team members ask each other for assistance prior to or during periods of task overload.	P	A	NA	P	NI	S	E	NA
8. Team members use the Two-Challenge rule or CUS to resolve conflict.	P	A	NA	P	NI	S	E	NA
Communication								
9. Team members verbalize their activities aloud when they are actively involved with the patient.	P	A	NA	P	NI	S	E	NA
10. Team members repeat back or paraphrase instructions and clarifications to indicate that they heard them correctly.	P	A	NA	P	NI	S	E	NA
11. Team member A hands off the patient's case to team member B, and team member B assumes responsibility for the patient.	P	A	NA	P	NI	S	E	NA
12. The team demonstrates efficient communication skills, including patient Situation, Background, Assessment, and Recommendation (SBAR).	P	A	NA	P	NI	S	E	NA
13. Team members demonstrate closed-loop communication such as check-backs.	P	A	NA	P	NI	S	E	NA

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Figure 2.18 Experienced observer form for the PACT-expert tool (UW Macy, 2011)

Raters evaluate overall team behaviors in these different categories. The tool, though developed for healthcare teams can be adapted to other kinds of teams. Using the tool, the rater assesses if the behaviors are absent or present, the frequency of behaviors and the quality of observed behavior. Two versions of the tool exist depending on the experience of the rater, PACT-novice for newer raters and PACT-expert for more experienced raters who are familiar with the behaviors to be evaluated. Though easy to use, the tool only assesses overall team communication behaviors and cannot be used to evaluate communication between individual team members.

Communication Project Assessment Tool (COMPASS)

Effective communication is a challenge for most multidisciplinary teams. The Communication Project Assessment Tool (COMPASS), shown in Figure 2.19, was developed as an assessment tool for critical communications in multidisciplinary teams. The tool was developed by the Construction Industry Institute (CII) as part of recommendations to improve building construction project team communication.

Category (1)	Description (2)	Weight (4)
Accuracy	The accuracy of information received as indicated by the frequency of conflicting instructions, poor communications, and lack of coordination.	2.1
Procedures	The existence, use and effectiveness of formally defined procedures outline scope, methods, etc.	1.9
Barriers	The presence of barriers (interpersonal, accessibility, logistic or other) interfering with communications between supervisors or other groups.	1.8
Understanding	An understanding of information expectations with supervisors and other groups.	1.6
Timeliness	The timeliness of information received, including design and schedule changes.	1.4
Completeness	The amount of relevant information received.	1.2

Figure 2.19 Critical communication categories on COMPASS (Thomas, Tucker, & Kelly, 1999)

Questionnaires and surveys of construction team members are used to determine a measure of communication effectiveness. The communication effectiveness score is intended to identify and diagnose problems with design and construction team communication. The communication effectiveness score is based on six critical categories: the accuracy of information provided; the existence and use of formally defined procedures; the presence of communication barriers; team member understanding of expectations; timeliness in receiving information and; the completeness of information received (Thomas et al., 1999).

The approaches show different outputs: visual outputs and a communication score. SNA and CUD provide visual outputs to show the flow of information between team members. On the other hand, PACT gives a communication scoresheet, while COMPASS gives a communication efficiency score. The approaches also address different categories of communication. While all approaches address the information process category, CUD is the only approach that addresses communication technology. All others – SNA, BOS, PACT, and COMPASS – address communication as social behavior.

THE COMMUNICATION ANALYSIS APPROACH

Aspects of the two visual approaches, CUD and SNA, are used to evaluate multidisciplinary building design team communication as shown in Figure 2.20. This combined approach allows for the study of team level interaction and information processes, while paying attention to the patterns of communication between the different disciplines in the team and the technology used to perform tasks. The visual approaches are used rather than the score approaches as the research in this dissertation does not aim to assess or grade communication, but to provide descriptions of team communication as social behavior, an information process, and the use of communication technology.

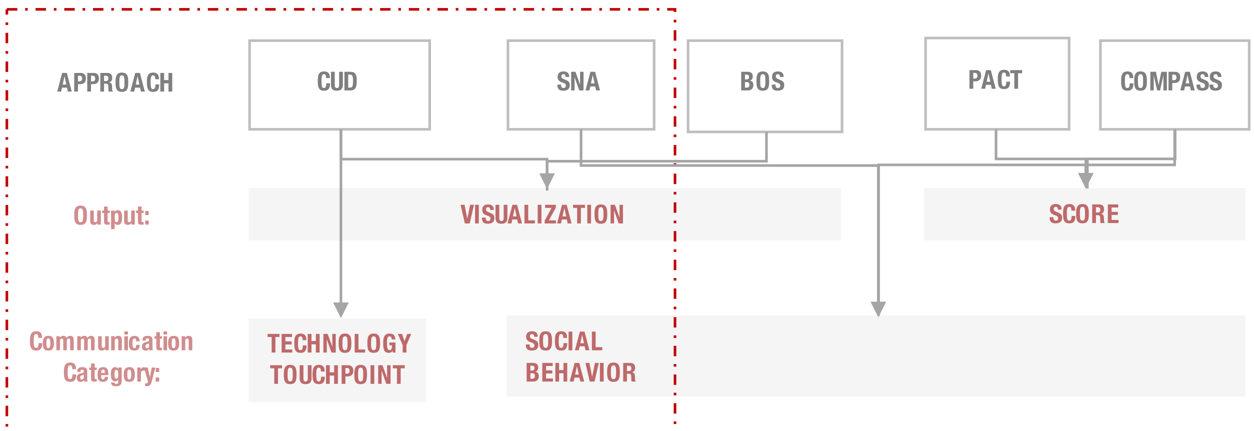

Figure 2.20 Combination of different approaches to form the communication evaluation approach used in this research

Aspects of the CUD used include descriptions of the tools used by disciplines to facilitate building design tasks, while aspects of SNA used include network maps which visualize the information connections between the disciplines on the team. However, as mentioned earlier, SNA is a powerful tool capable of much more than simply network visualization. A wide range of network metrics beyond the scope of this research, such as the centrality, density, tie strength, and closure of the network, can be obtained using the SNA approach.

To only capture the network visualization and qualitative aspects of SNA, Value Flow Diagrams – an approach from service design – used to illustrate the dependencies and value creation between individuals in a service process are used instead (Pantyukhin, 2014). When applied to the study of multidisciplinary building design team communication, this approach visualizes the information flow and dependencies between the disciplines on the team similar to SNA.

This research also deals with effective communication. Identifying effective team communication involves studying team outcomes. Team outcomes vary by the kind of team and the tasks they perform. The last section of this research background addresses building design team outcomes.

2.4: OUTCOMES OF BUILDING DESIGN TEAMS

MEASURING TEAM OUTCOMES

Measuring team outcomes presents several difficulties. First, team outcomes vary by the kind of team, and the tasks they perform. That is, the outcomes for a building design team will be different from the outcomes for a manufacturing team, or a healthcare team. In addition, team outcomes are often multidimensional, with many aspects. Rather than just having one measure for team outcomes, such as the delivery time for a building design team's tasks, there are usually multiple measures that can be applied to capture the range of team outcomes (Keller, 2001; Lemieux-Charles & McGuire, 2006).

Regardless of these difficulties, researchers have been able to measure outcomes by monitoring and recording progress of tasks towards achieving an established goal (US GAO, 2005). By providing a reasonable, valid and reliable comparison of progress against the goal, outcome measures provide useful feedback to teams. For instance, in building design teams, comparing expected task completion time to the actual completion time can provide teams with useful feedback. This feedback can serve as an assessment tool to help teams detect significant changes to task or project progress, allowing team members make necessary adjustments, and develop skills as required (Barr, 2012; Brannick, Salas, Prince, & others, 1997).

Measuring outcomes requires an awareness of two factors: the level at which measurement will occur, and the approach to measurement. Outcomes can be measured at the team level or the individual level, either subjectively or objectively. Individual-level outcomes use team members as the unit of analysis, while team-level outcomes use the team as the unit of analysis.

Individual-level outcome measures evaluate the quality of an individuals' output and productivity, and the contribution of that individual to overall outcomes. Examples of outcomes that can be measured at the individual level include individual accuracy, individual errors, individual safety record, timeliness of the individual, and ideas generated by the individual (Cannon-Bowers & Salas, 1997; OPM, 1998). These outcome measures are suited to groups where individuals work on their own goals, without the need for a common goal.

In contrast, measuring outcomes at the team level is better suited to building design teams since team members work towards a common goal, as established in Section 2.1 (*Building Design Teams, or Building Design Work Groups?* p. 15). Team-level outcome measures evaluate how well the team delivers on its overall goals. Examples of outcome measures at the team level include the accomplishment of goals, overall team accuracy, team error propagation, client or customer satisfaction with the team product, the number of completed cases, the cycle time for the team's work process (Cannon-Bowers & Salas, 1997; OPM, 1998).

Both the team and individual levels of measurement can occur either objectively or subjectively. Objective approaches involve obtaining quantifiable, unbiased measurements of team outcomes.

The challenge of the objective approach is that it can usually depend on the availability of and access to the required information i.e. it can be difficult accessing accuracy, error, or timeliness information. Subjective approaches do not face this challenge as they focus on the more 'attitudinal aspects' of measuring team outcomes. Subjective approaches to measuring team outcomes usually involves team self-assessments of various team outcomes (Cohen & Bailey, 1997).

There are strengths and weaknesses to either approaches. The objective approach provides unbiased assessments of team outcomes while the subjective approach introduces some bias in the outcome measurements. However, with the objective approach, it can be very difficult to access the information required for measurement. The subjective approach does not have this access problem as it emphasizes the self-assessment of team outcomes. This self-assessment can provide more in-depth information, as team members are more aware of the team's critical characteristics, its context, influences and dynamics.

It is necessary to be aware of the approaches to, and levels of measurement before measuring team outcomes. The research in this dissertation focuses on team-level outcomes using the subjective rather than the objective approach. However, the approach to use depends on the specific team outcome being measured.

BUILDING DESIGN TEAM OUTCOMES

Identifying which team outcome to measure depends on several factors including: the purpose of the measurement, behavior to be measured, and the expense of measurement (Brannick et al., 1997). The expense of measurement determines the feasibility of measuring an outcome. The purpose of, and behavior to be measured determines which outcomes are selected, as outcomes for one type of team may not apply to other types of teams. For instance, while the numbers of publications or number of citations is a useful research team outcome, it would not be useful when considering building design teams.

Possible building design team outcomes include: client satisfaction, design quality, innovation, delivery time, cost, and errors (Iezzoni, 1997; Teixeira, Koufteros, & Peng, 2012). These outcomes come from two areas: literature on outcomes in manufacturing, healthcare and design that can be applied to building design teams, and the 2014 McGraw Hill survey of building owners, architects, and contractors that identified performance evaluation criteria for building design teams (McGraw-Hill, 2014).

An overview of the identified building design team outcomes is presented in Table 2.5. The table shows that some outcomes are best measured with objective approaches (cost, delivery time), while others are best measured using the subjective approach (innovation, design quality).

Table 2.5 Overview of identified building design team outcomes

	Client Satisfaction	Design Quality	Innovation	Delivery Time	Cost	Errors & Rework
Purpose	Addresses how well the design team met the client's expectations	Addresses the 'goodness' of design	Addresses the presence of novel design features	Addresses the time it takes to complete the project	Addresses how much it costs to complete the project	Addresses the number of errors and rework on the project
Application	This outcome can be applied to building design teams	This outcome can be applied to building design teams	This outcome can be applied to building design teams	This outcome is usually used for construction teams but can be adapted to building design teams	This outcome is usually used for construction teams but can be adapted to building design teams	This outcome is usually used for construction teams but can be adapted to building design teams
Approach	Subjective approach to measurement – relies on client perceptions	Subjective approach to measurement Objective measurement is difficult ad quality is hard to define	Both the subjective and objective approaches can be used – perceptions of innovation, and counts of innovation	This outcome can be objectively measured	This outcome can be objectively measured	This outcome can be objectively measured
Feasibility/ Cost	Relatively easy to measure There may be problems accessing design team clients	This outcome is difficult to measure due to the subjectivity in defining quality	Difficult to measure as it can be hard identifying what an innovative feature is	Relatively easy to measure	Can be difficult to isolate to design teams only	Relatively easy to measure

The client satisfaction outcome addresses how well the team meets their clients' requirements and expectations. Measuring client satisfaction is useful for marketing as it gives an indication of how likely a client is to reuse a team's services. The client satisfaction outcome is measured subjectively using surveys to obtain the required feedback (Larsen, Attkisson, Hargreaves, & Nguyen, 1979).

Assessing how well a design team meets their clients' expectations contributes to the design quality outcome. Design quality addresses the goodness of the design. While there have been numerous attempts to understand and define quality in building design, Joseph Juran's approach, adopted by the automotive, manufacturing and pharmaceutical industries, links quality to customer satisfaction and a lack of failure (Juran, 1986). When applied to building design teams, the design quality outcome assesses how well clients' expectations were met without errors and unnecessary rework.

Design quality is difficult to define, thus difficult to measure partly due to the subjective nature of the outcome – quality depends on the project and its requirements. This difficulty is echoed in the innovation outcome. Innovation refers to new or novel products. Innovation in building design, which refers to the presence of novel or unique design features is difficult to measure as novelty is bound by location and time. For instance, a feature that is novel in Pittsburgh may be used commonly elsewhere.

Outcomes that can be measured objectively include delivery time, cost and errors. The delivery time outcome is related to the project schedule and addresses how long it takes the project to be completed. The cost outcome is related to the budget and addresses how under or over budget the project is, and the errors outcome addresses the amount of changes and rework related to design on the project (Lopez, Love, Edwards, & Davis, 2010; Love & Lopez, 2012). These objective outcomes are typically associated with the performance of design and construction teams – perhaps because there are physical outcomes of the construction process – but can be applied design teams alone.

However, the outcomes, taken individually do not account for the multidimensional nature of building design. Accounting for multiple outcomes, rather than using a single outcome is useful as it captures a range of team activities, and tells a more complete story of how well a team is doing (Kua, 2013). An example of multidimensional measurement is the Team Development Survey (TDS) which measures a range of team outcomes from coordination to customer satisfaction (Hallam & Campbell, 1997).

The research in this dissertation explores the presence of this range of outcomes using the dual process model as a part of the framework. The model states that both positive and negative outcomes can occur at the same time due to diversity on the team and points to the need to identify the outcomes of multidisciplinary building design teams. The research in this dissertation explores the outcomes used by team members to understand the effects of the functional diversity on building design team processes and outcomes.

2.5: SUMMARY

Building design teams are multidisciplinary and studying them involves understanding not only the elements of the team but also the effects of functional diversity on team processes and team outcomes. As functional diversity and diversity in general have been shown to cause varying processes which lead to both positive and negative team outcomes, the dual process model of diversity is used as a part of the guiding framework for this research.

The dual process model attributes positive outcomes to improved information behavior due to the presence of diverse knowledge sources, and negative outcomes to self-categorization resulting from the presence of different identity groups. The model's ability to account for both outcomes is useful when studying building design team processes and outcomes, and highlights the importance of team processes that lead to diverging outcomes.

As a process, communication is critical to building design. Communication in design is much more than information exchange, it is social behavior, an information process, and includes the use of communication tools and technology. This research uses these three categories as a guide to explore building design team communication, understand the effects of functional diversity on team communication, and identify the communication processes teams use to achieve positive outcomes. A communication analysis approach that combines aspects of Communication Usage Diagrams (CUD), Social Network Analysis (SNA), and Value Flow Diagrams is offered to account for these three communication categories.

This dissertation also identifies several common outcomes used to evaluate design teams and explores this range of potential building design team outcomes to identify the positive and negative outcomes resulting from the functional diversity of building design teams.

3: RESEARCH DESIGN AND METHODS

3.1: THE STUDY DESIGN

THE EXPLORATORY FRAMEWORK, LINES OF INQUIRY AND RESEARCH QUESTIONS

It was established in the preceding two chapters that communication in building design teams is important as it impacts project outcomes, although it can be difficult to achieve effectively. This difficulty is compounded by the functional diversity of the team – the presence of different disciplines – which can hinder communication and lead to both positive and negative outcomes.

Existing research, however, does not provide us with an approach to study building design team communication and outcomes. As a result, we have no descriptions of the effects of functional diversity on building design communication and outcomes. The research within this dissertation does two things to address these gaps: it offers an exploratory framework to systematically describe and analyze multidisciplinary building design team communication and outcomes; and it applies this framework to cases of multidisciplinary building design teams.

This framework, introduced in Figure 3.1, uses the dual-process model described in Section 2.2 (*The Dual-Process Model of Diversity*, p. 28) as a foundation to suggest a relationship between functional diversity, communication and outcomes in multidisciplinary building design teams.

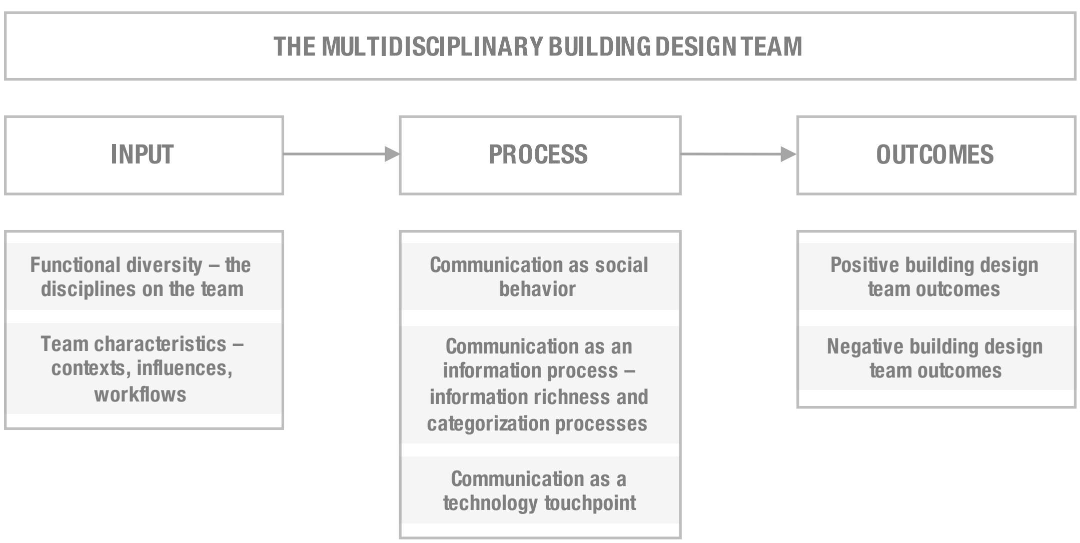

Figure 3.1 The exploratory framework to describe and analyze multidisciplinary building design team communication and outcomes

However, the dual process model only captures the information process category of communication. To provide a robust approach for studying the subject area, additional components are included to the inputs and processes of the exploratory framework.

The framework establishes that as inputs, we should not only explore functional diversity, defined for this research as the disciplines on the multidisciplinary building design team, rather than their roles can also influence team communication (Awomolo, Jabbariarfaei, Singh, & Akin, 2017). We should also explore the team contexts, influencing factors and workflows, described in Section 2.1 (*Critical Characteristics of Teams*, p. 16). Similarly, as processes, rather than just explore the one category of communication in the dual process model, we should explore all three categories of design team communication including: communication as social behavior, as an information process, and the use of communication technology as in Section 2.3 (*Communication and Building Design Teams*, p. 32).

Three lines of inquiry presented in Table 3.1, each with their own questions emerge from this framework: What constitutes a multidisciplinary building design team? How do multidisciplinary building design teams communicate? And how does this communication affect team outcomes?

Table 3.1 Lines of inquiry and research questions

Line of Inquiry	Description	Research Questions
Inquiry 1:	Multidisciplinary Building Design Teams	1. What disciplines comprise the multidisciplinary building design team? 2. How are these disciplines organized? 3. What factors influence the team, its formation, organization, and tasks?
Inquiry 2:	Multidisciplinary Building Design Team Communication	1. What modes and tools of communication do team members use to exchange design information? 2. Do these forms, modes, and tools vary by disciplines on the team? 3. Do team members take advantage of the information rich environment due to functional diversity? 4. Do categorization processes, also attributed to functional diversity, influence team communication?
Inquiry 3:	Multidisciplinary Building Design Team Outcomes	1. What do team members identify as positive and negative team outcomes? 2. What outcomes can be attributed to an information rich environment? 3. What outcomes can be attributed to categorization processes? 4. What factors and processes lead to positive, or negative team outcomes?

The first line of inquiry explores multidisciplinary building design teams in order to identify the key individuals and features that contribute to the functional diversity of the team. Identifying the disciplines that make up the multidisciplinary building design team, their tasks and organization is necessary to describing the team and its critical characteristics as discussed in Section 2.1 (*Critical Characteristics of Teams*, p. 16). The descriptions obtained provide the context for the second and third lines of inquiry.

The second line of inquiry explores communication as social behavior, an information process and the use of communication technology in multidisciplinary building design teams. This line of inquiry is guided by the dual process model to suggest that, owing to the functional diversity present in the team, the information process category of communication either occurs in an information rich environment, or is impacted by categorization processes. Identifying the modes, patterns, and tools of information exchange provides rich descriptions of building design team communication and contributes to our understanding of the functional diversity – communication relationship.

The third line of inquiry explores the outcomes of multidisciplinary building design teams described in Section 2.4 (*Building Design Team Outcomes*, p. 43). As the dual process model predicts distinct outcomes resulting from two different team communication processes, identifying building team outcomes – both positive and negative – provides information on the ways in which communication contributes to the outcomes obtained (as per the dual process model).

THE PRACTICE-BASED, CASE STUDY APPROACH

This research applies the exploratory framework described in the preceding section using a practice-based case study approach. Case study research – best applied to instances where there is a need to understand complex social behaviors – can provide rich, qualitative descriptions to explore and improve a practice (Yin, 2013). When applied to building design teams, this approach provides an in-depth, empirical inquiry, into the exploratory (how?) and the explanatory (why?) questions posed in Table 3.1.

There are strengths and limitations to this research approach. The emphasis on real-life teams means that the insights obtained from the research are applicable to actual building design practice. However, due to the contextual nature of the approach, it is unlikely (and not the intent) that the findings and results from the research are generalizable to all building design teams. The main strength of this approach which accounts for its lack of generalizability, is that the descriptions of the cases contribute to the knowledge base on building design teams and can be transferred to similar contexts (Bloomberg & Volpe, 2008; Merriam & Tisdell, 2015; Yin, 2013).

This research uses multiple case study design, which has the distinct advantage over single case study design of providing stronger results through cross-case analysis, allowing the results obtained be grounded in varied evidence from several cases. Validity – the appropriateness of the study methods and procedures – and reliability – the replicability of the study – are addressed using the strategies outlined in Table 3.2.

Table 3.2 Strategies for validity and reliability in case study design (Yin, 2013)

	Description	Strategies
Validity	Concerned with the appropriateness of the design *Does the study measure what it intends to measure?*	Use multiple sources of evidence Have key informants review the results obtained
Reliability	Concerned with the processes in the study design *Does the study produce consistent results?*	Use a case study protocol Use a case study database

The research within this dissertation employs two strategies to achieve valid results: multiple sources to ensure that the right data is collected, and have key team members review the results from the case studies. In applying this to multidisciplinary building design teams, descriptions of the team are obtained and reviewed by several team members.

Strategies to achieve reliable results include using a case study protocol and a case study database. The case study protocol outlines and documents the steps involved in conducting the case study while the case study database stores and organizes all the material collected in conducting the case study. The case study protocol is described in the following section.

3.2: THE CASE STUDY PROTOCOL

The case study protocol shown in Figure 3.2 outlines the steps in conducting the case study. This protocol was developed using Yin's case study guide (Yin, 2013).

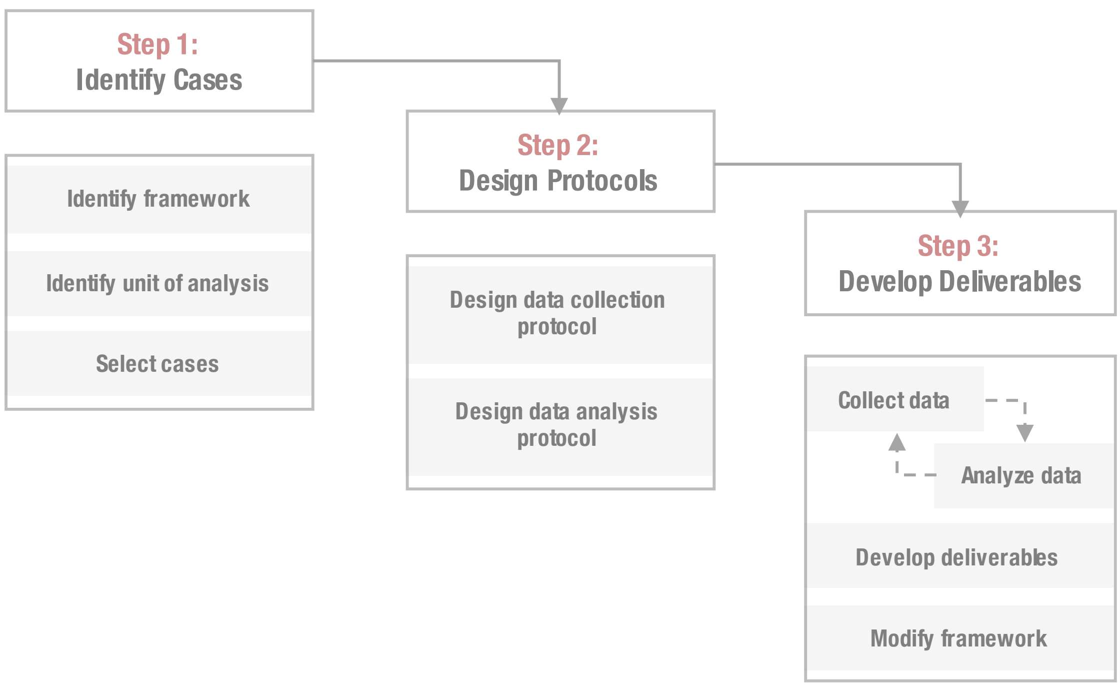

Figure 3.2 The case study protocol (Adapted from Yin, 2013)

The steps in are:

Step 1: Identifying several multidisciplinary building design teams as case studies

Step 2: Designing and documenting the data collection and analysis procedures

Step 3: Developing three deliverables: individual case reports, the cross-case report, and the case study synthesis, research implications and recommendations.

STEP 1: IDENTIFY CASES

Identifying the multidisciplinary building design teams as cases first involves identifying the framework for this research and the unit of analysis, then the teams to participate in the study as shown in Table 3.3.

Table 3.3 Step 1: select cases

Step		Description	Strategies
1: Identify Cases	Identify framework	A framework from existing research and theory is identified to guide the case studies	The exploratory framework
	Identify unit of analysis	Multidisciplinary building design teams who have been involved in a building design project rather than individuals are the unit of analysis	
	Select cases	Cases are identified to maximize the information obtained on multidisciplinary building design teams	Purposive, Non-Probability sampling

Identify Framework

The exploratory framework, described in Section 3.1 *(The Exploratory Framework, Lines of Inquiry, and Research Questions*, p. 47), suggests that functional diversity leads to both positive and negative outcomes through distinct processes, making it useful when studying multidisciplinary building design team communication and outcomes.

Identify Unit of Analysis

Multidisciplinary building design teams in Architecture, Engineering and Construction (AEC) firms are used as the unit of analysis. Specifically, teams who have recently been involved in a building project, from predesign to design development, are used. Information collected from individuals on the team is aggregated so that as discussed in Section 2.4 (*Measuring Team Outcomes*, p. 42) the team, rather than its individual members and disciplines, remains the unit of analysis.

Select Cases

A case is a specific, bounded entity selected to maximize what can be learned about the research subject (Yin, 2013). Based on the description of a case, multidisciplinary building design teams that have recently been involved in the design of a project and can provide the most information on their communication and outcomes are used.

The research within this dissertation uses purposive, non-probability sampling to select cases for the study. Purposive sampling emphasizes the characteristics of the cases studied. Cases are selected to obtain maximum knowledge on building design team practices. As such, they neither need to be randomly selected nor be statistically representative of all building design teams.

Potential cases of multidisciplinary building design teams are identified from (AEC) firms in Pittsburgh, Pennsylvania, using the member firm directory and architect finder features of the AIA Pittsburgh website. AEC firms are contacted with an introduction and brief description to the study. All introductory materials are included in Appendix A. Firms who respond and are interested in participating are identified as potential cases.

After receiving interest from the firms about participating in the study, specific criteria are applied to select teams as cases:

<u>Criterion 1:</u> The teams must be made of multiple disciplines.

<u>Criterion 2:</u> The team must have worked on a mid-size project – greater than 5000 sq. ft. but less than 100,000 sq. ft. (AIA, 2016) – in the Pittsburgh area for feasible data collection. Smaller projects will yield insufficient information for conclusions to be drawn, while large projects will be difficult to thoroughly study.

<u>Criterion 3:</u> The project should be recent – within the last year – as a completed pre-design, schematic design, or be in design development stage to allow team members to recall and, as much as possible, accurately report on their experiences.

STEP 2: DESIGN PROTOCOLS

Designing the protocols involves designing the data collection and data analysis protocols, shown in Table 3.4. Data will be obtained and analyzed from each case study through qualitative methods.

Table 3.4 Step 2: design protocols

Step		Description	Strategies
2: Design Protocols	Design data collection protocols	Interviews and Document Review are the data collection methods	Described below
	Design data analysis protocols	Content analysis and Communication analysis are the data analysis methods	Described below

Interviews and document reviews are the methods of data collection. Interviews provide direct information from team members about their experiences (including detailed descriptions of their activities) to address most of the research questions posed earlier. Document reviews provide further evidence on the findings from the interviews, and also provide data on strategies and recommendations for multidisciplinary building design practice (Merriam & Tisdell, 2015).

Content and communication analyses are the methods of data analysis. Content analysis identifies recurring themes and categories present in the data collected (Merriam & Tisdell, 2015), while communication analysis, introduced in Section 2.3 (*The Communication Analysis Approach*, p. 41), combines the Communication Usage Diagrams (CUD) and Value Flow Diagrams approaches to analyze all three categories of communication – communication as social behavior, as an information process, and the use of communication technology.

The data collection and analysis methods are shown in Figure 3.3.

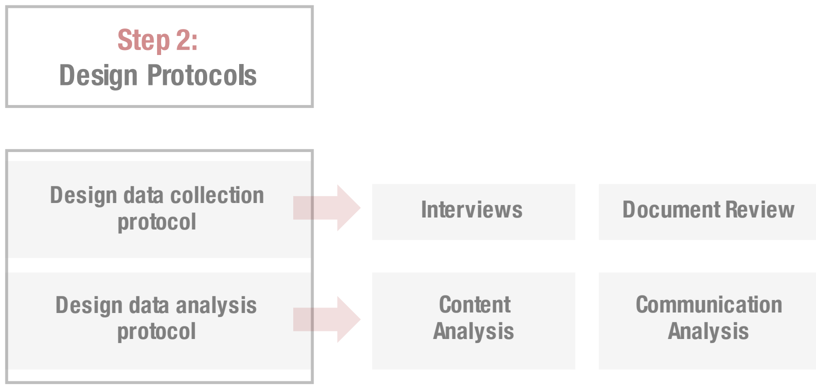

Figure 3.3 Data collection and data analysis methods

Design Data Collection Protocols

The interview and observation procedures are:

Interviews

This research uses semi-structured interviews that combine aspects of the structured and unstructured approach. In the semi-structured interview, a list of questions is prepared beforehand, and the interview is conducted as a conversation between the researcher and the participant, with the prepared questions as a guide. The interview guide, included in Appendix B, organizes the questions asked.

Semi-structured interviews are more engaging than structured interviews as they proceed as a dialogue between the researcher and the participant being interviewed. Due to the conversational approach, information on contexts and the rationale behind findings can be explored in depth. (FAO, 2008).

There are limitations when conducting semi-structured interviews. The interview questions must be well-designed to avoid leading participants to a specific or a preferred response. The researcher must develop interviewing skills and be able to ask non-directed questions, probe for additional responses, and listen for specific information cues (Cohen & Crabtree, 2006). In, addition, as responses obtained may need to be recorded and transcribed for analysis, the confidentiality of participants needs to be ensured.

Regardless of these limitations, semi-structured interviews provide reliable qualitative data with the use of an interview guide that provides the structure lacking in unstructured interviews, without the rigidity of structured interviews. Individual perspectives and opinions can be captured, even on more sensitive topics, and multiple perspectives can be combined to obtain a complete picture of the research subject.

The semi-structured interview procedure, developed using Alvesson's guide to semi-structured interviews (Alvesson, 2003), is outlined in Figure 3.4. The procedure consists of six steps: identify the interview technique, develop the interview guide, test the interview questions, recruit interview participants, conduct the interview, and transcribe the interview.

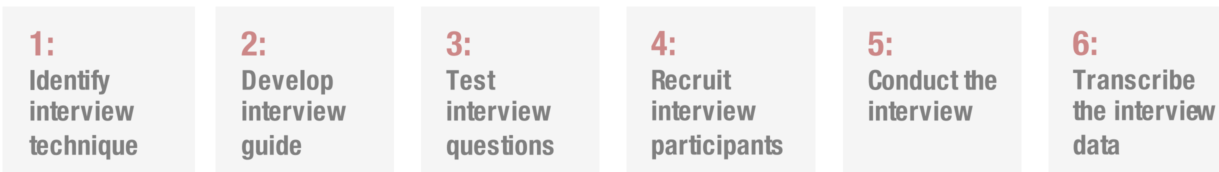

Figure 3.4 The semi-structured interview guide (Alvesson, 2003)

1. *Identify the Interview Technique*

This research uses synchronous rather than asynchronous interviews. While asynchronous interviews – through questionnaires or email – can save time and costs, synchronous interviews allow for direct interaction between the researcher and the participant. This direct interaction provides the researcher with opportunities to explore and clarify responses made by participants. In this research, interviews synchronous with time and space – face-to-face interviews – are preferred to those synchronous with only time – telephone or video interviews.

2. *Develop the Interview Guide*

The interview guide provides the researcher with a set of relevant questions for participants. Questions elicit what the participants know, rather than directly asking why things occur, and allow the interview to proceed as natural conversation (Alvesson, 2003).

The questions in the interview guide are connected to the research questions outlined in Table 3.1. The guide, included in Appendix B, uses different types of questions including introductory questions that build rapport with the participant *"Tell me a bit about yourself"* and initiate the discussion on a topic *"Tell me about the project"*. Responses are followed up with probing questions that ask for more information about a previous response *"So you mentioned 'x', could you give me a specific example about that?"*, and direct questions that ask about a specific topic *"How were you specifically involved on the project?"* (Kvale, 2007).

3. Test the Interview Questions

Pilot testing establishes that appropriate terminology is used in the interview questions. The pilot test identifies potential issues with the question intent and framing to ensure that the different groups of study participants understand and interpret the questions the same way. The pilot test of an earlier version of the interview questions was conducted in October 2016. Feedback from this test was used to develop the interview guide in Appendix B.

4. Recruit Interview Participants

The first point of contact is identified from publicly available information on the selected cases. Once approval to participate in the research study is obtained, the point of contact sends out a memo to key team members from the different disciplines on the building design team, informing them of the details of the study. The introductory materials and memo are included in Appendix A.

5. Conduct the Interview

Consent to participate is obtained from the firms through the initial point of contact and the individual participants per CMU Institutional Review Board requirements. The invitation letters to participants and consent forms are included in Appendix A.

In conducting an interview, the researcher introduces the research study, provides the participant with information on its intent, and the purpose of data collection. Questions are posed using the interview guide and interviews are conducted by synchronous means – in-person or over the phone.

Interviews are recorded using the iPhone Voice Recorder application, QuickTime player, and field notes. Excerpts from the interview data, including data transcripts and field notes are included in Appendix B.

6. Transcribe the Interview Data

Audio recordings of the interview data are transcribed in preparation for data analysis using the transcription service, TranscriptionPuppy. The audio files are submitted to the service and for a fee, the transcripts of the interviews are returned in a Microsoft Word file.

<u>Document Review</u>

This research uses the review of relevant documents to further support the research findings from the interview data, and provide recommendations for multidisciplinary building design practice (Sauro, 2015). Document review is particularly useful in collecting data on questions that ask, 'what' and 'how many' and in obtaining background information which may not be discussed in interviews (CDC, 2009). This approach also provides a fresh perspective on the research subject and is very useful when research subjects are unable or unwilling to speak on a topic.

However, the quality of document review depends on the search and collection of relevant documents by the researcher. This search can be difficult as relevant documents may be inaccessible to the researcher and consent often needs to be obtained for access. Also, as documents can be accidentally or deliberately altered, they may not always accurately represent the research subject (Merriam & Tisdell, 2015; Yin, 2013).

Even with these limitations, the review of documentation provides strong background and contextual information, and is an inexpensive approach that does not require direct engagement with participants. The document review procedure, consisting of four steps – identify relevant documents, secure access to relevant documents, compile relevant documents, and summarize information from documents – is shown in Figure 3.5.

Figure 3.5 The document review procedure (CDC, 2009)

1. Identify Relevant Documents

The relevant documents types required for the research are identified through a literature search. This preliminary search determines what type of documents are available and the kinds of data that can be obtained.

2. Secure Access to Relevant Documents

Documents may require specific permissions for access, as well as a secure storage location in instances where they contain sensitive information (CDC, 2009). While the use of documents with sensitive information in this research is limited, required permissions are obtained before accessing relevant documents and the documents obtained are stored in a secure location.

3. Compile Relevant Documents

Once documents are accessed, the conditions under which the documents were developed are determined to ensure data validity. The documents are assessed for missing or misrepresented information, which also affects the validity of data obtained. If needed, additional supporting documents are also obtained.

4. *Summarize Information from Documents*

The information in the documents obtained is summarized in preparation for analysis. Superficial examination by skimming followed by a thorough examination of the documents is used to develop summaries of the documents obtained.

Design Data Analysis Protocols

The content and communication analyses procedures are:

<u>Content Analysis</u>

Content Analysis provides a systematic means of describing and analyzing written messages. It provides a broad description of the research subject and is usually applied to qualitative data. Content analysis either focuses on manifest data such as transcripts that only include what has actually been said, or latent data which includes non-verbal communication such as facial expressions (Elo & Kyngäs, 2008).

This research uses manifest data from the interview transcripts, and the interview field notes for content analysis. This allows the researcher focus on the actual verbal content of the interviews. While leaving out the more nuanced information may make focusing on the manifest data seem simplistic, this approach provides evidence for the findings and prevents the risk of over interpretation of non-verbal content by the researcher.

The content analysis procedure is based on Elo and Kyngäs's process and outlined in Figure 3.6. The procedure consists of four steps: prepare the data, identify themes in the data, organize and categorize the identified themes, and report on the data. The steps are described below.

Figure 3.6 The content analysis procedure (Elo & Kyngäs, 2008)

1. *Prepare the Data*

Preparing the interview data involves reviewing the transcripts to check for errors and inconsistencies between the transcripts and the recorded interviews. Once the transcripts are reviewed, they are organized according to case. The interview field notes are matched to their corresponding transcripts and also organized according to case. An excerpt from the prepared interview data is included in Appendix C.

2. Identify Themes in the Data

The prepared transcripts and field notes are reviewed to identify themes present in the data through codification. Preliminary codes are developed based on the interview guide discussed earlier. The transcripts and field notes are coded and sub-codes are identified under the primary codes. The codification process is an iterative one as codes are continually reviewed and modified until a stable set is developed.

3. Organize and Categorize Themes

After the transcripts and field notes are coded, the codes are grouped into categories based on similarities. The final codes and their categories are included in Table 4.1. This organization and categorization of codes and the coded data occurs for the individual cases and then between the cases studied. From these groupings, themes begin to emerge that can be used to answer the research questions posed in Table 3.1.

4. Report on the Data

A detailed report of the themes identified from the interview data is developed. The report includes descriptions of the content categories and subcategories found. A report is developed for each case studied which forms the first research deliverable – the individual case reports included in Appendix D (the guide for developing the individual case reports is included in Appendix C). The individual reports are compared to form the second research deliverable – the cross-case comparison in Chapter 4.

Communication Analysis

The communication analysis approach combines the technology description aspects of the Communication Usage Diagrams (CUD) with the visual display of information dependencies of Value Flow Diagrams (and Social Network Analysis) described in Section 2.3 (*The Communication Analysis Approach*, p. 41). The approach is applied specifically to the communication portions of the interview transcripts and field notes, on completion of content analysis.

This combined communication analysis approach produces visual outputs in the form of a communication map, as well as a description of the technologies used to facilitate team communication, covering the three categories of communication: as an information process, as a social behavior, and communication technology, also described in Section 2.3 (*Communication and Building Design Teams*, p. 32).

The approach is flexible enough to be applied to different building design project team configurations and can highlight the strengths and flaws of team communication. However, like most qualitative analysis methods, the approach is highly subjective and becomes complicated with very large teams.

The communication analysis procedure is shown in Figure 3.7. The procedure consists of five steps: identify team stakeholders, define team associations, visualize the flow of information, identify communication technology, and prepare communication report.

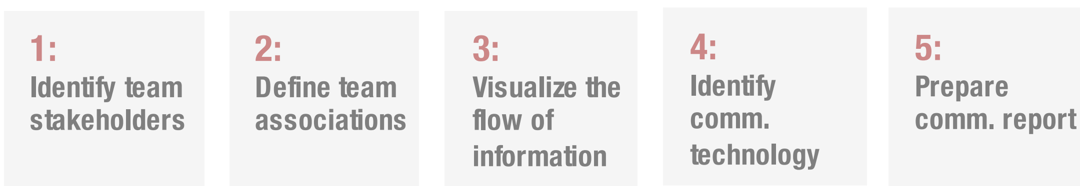

Figure 3.7 The communication analysis process

1. *Identify Team Stakeholders*

Typically, stakeholders are individuals involved in the building design project including team members, owners, regulatory agencies and so on. However, in this research defines stakeholders as the different disciplines involved in the multidisciplinary building design team. In addition, within each discipline, there are specific members who perform certain roles related to information exchange. Therefore, in identifying the team stakeholders, the specific roles and tasks performed by the disciplines, as well as the roles and tasks performed by members within disciplines are identified from the coded transcript data.

2. *Define Team Associations*

Associations show the relationships between the stakeholders in a team. When applied to the communication analysis approach, associations – described as information relationships – are identified from the interview data and used to define the information exchange relationships between the disciplines on the multidisciplinary building design team. The associations show the types and extent of interaction between the different design disciplines on the team and form the basis for the value flow diagrams.

3. *Visualize the Flow of Information*

The stakeholders identified and associations defined provide the data to map the flow of design information between the different disciplines on the multidisciplinary building design team. The diagrams produced use directed arrows to link the different disciplines on the multidisciplinary building design team, showing the flow of information between the different disciplines. The development of a value flow diagram is shown in Appendix C.

4. Identify Communication Technology

The different tools used to facilitate the exchange of design information between team members are identified from the coded transcript data. Description of the tools, their benefits and limitations for the different tasks performed by the disciplines are identified and further discussed in Chapter 5.

5. Prepare the Communication Report

Similar to the reporting step of the content analysis procedure, the communication report provides descriptions and interpretations of the findings from the communication analysis and contributes to the case study reports outlined earlier (*The Case Study Protocol*, p. 50).

STEP 3: DEVELOP DELIVERABLES

Developing the case study deliverables involves collecting and analyzing data, writing the reports, developing the research implications that include modifying the exploratory framework based on the findings from the data collected as shown in Table 3.5.

Table 3.5 Step 3: develop deliverables

Step		Description	Reports
3: Develop Deliverables	Collect and analyze data	Data is collected and analyzed using the procedures described in step 2.	
	Develop deliverables	The individuals case reports and cross case reports are developed from interview data using the case report guide.	Individual Case Report (Appendix D) Cross-Case Report (Chapter 4)
		The synthesis of the case study findings, and the implications and recommendations of this research are developed using both the interview and document review data	Discussion (Chapter 5)
	Modify framework	The exploratory framework is modified based on findings from the cross-case report	

Collect and Analyze Data

Data is analyzed as it is collected, rather than waiting for all the data to be obtained before starting the analysis. The data collection and analysis is shown in Figure 3.8.

Figure 3.8 Data collection and analysis

As described earlier, team members are interviewed and the interviews are documented with recordings and field notes. The interview transcripts and field notes are analyzed using content analysis and communication analysis. From this analysis, reports – both the individual and the cross-case reports – are developed. The reports contain implications and potential recommendations for multidisciplinary design team practice. Relevant documents are obtained to provide supporting evidence for the recommendations. These documents are analyzed using content analysis to further develop the implications and recommendations of this research.

Develop Deliverables: Case Reports, Implications and Recommendations

The case study deliverables are developed: the individual case reports, the cross-case report, and the research implications and recommendations report. The individual case reports in Appendix D detail the findings from each case, while the cross-case report in Chapter 4 provides a comparison of the findings from all the cases. A discussion of the implications and recommendations of the research – the exploratory framework and the case studies – in Chapter 5 forms the final deliverable of this research.

Modify Framework

The findings discussed in the case reports and their synthesis are used to expand the exploratory framework. This modification is discussed in the research implications and recommendations presented in Chapter 5.

3.3: SUMMARY

An exploratory framework is developed to study building design team communication and outcomes and applied using the practice-based case study approach. The cases aim to accurately represent real-life multidisciplinary building design teams, their communication and outcomes.

Teams are selected from AEC firms in the Pittsburgh area that have gone through the design stages – pre-design to design development – of a building project. Interviews and observations are used to collect data from team members from each discipline on the building design team. The data collected is analyzed using content analysis and communication analysis. From the analyses of obtained data, three reports are developed: the individual case reports describing the findings from each case study included in Appendix D, the cross-case report in Chapter 4, comparing the findings across each case report, and the case study synthesis along with the implications and recommendations of this research in Chapter 5.

4: CASE STUDY FINDINGS

4.1: CASE DESCRIPTION

METHODS OVERVIEW

Three cases of multidisciplinary building design teams were studied using the exploratory framework outlined in Section 3.1 *(The Exploratory Framework, Lines of Inquiry, and Research Questions*, p. 47). The cases, each comprising a multidisciplinary building design team, were identified based on the interest expressed by AEC firms contacted about participating in the study.

Getting the cases to participate in the study was difficult. Initially, twenty potential cases were contacted for the study, seventeen in Pittsburgh, and one each in Minnesota, North Carolina and the UK. From the twenty potential cases only three were able to fully participate. The other potential cases were either unwilling to or unable to participate for several reasons: lack of time to participate, projects and teams that were too small to obtain useful results, and projects that were not proceeding as planned.

Data for the case studies was collected at different project stages as shown in Figure 4.1. Data for Cases 1 and 3 was collected on completion of the design development stage of the project, while data for Case 2 was collected on completion of the schematic design stage, prior to the start of design development.

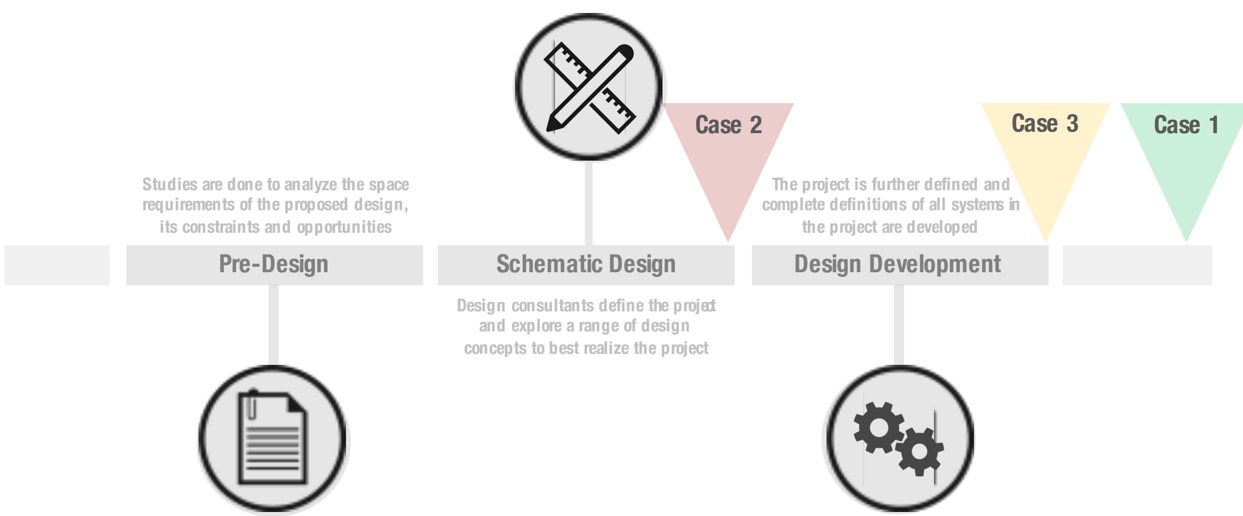

Figure 4.1 Design stage at which data was collected for the three cases

Data was collected using in-depth interviews. In total, 32 team members across all the cases were interviewed. Ten team members were interviewed for Case 1 and Case 2 while twelve team members were interviewed for Case 3. The interviews were conducted in-person or over the phone, depending on the interviewees' preference. In Case 1, six team members were interviewed in-person and the remaining four were interviewed were over the phone. In Case 2, five team members were interviewed in person and the remaining five interviews were over the phone, while in Case 3, two team members interviewed in person while the remaining ten were interviewed were over the phone.

The interview data was coded according the coding protocol developed from the review of existing literature presented in Chapter 2, and the research questions outlined in Table 3.1. Table 4.1 provides the definition of the codes and examples from the transcribed data.

Table 4.1 Coding Protocol

Codes	Sub-Code	Definition	Example
Project	Description	General information about the project, specific project features that differentiate it from others	*"That would be typically be how a project of this type would be put together"*
	Challenges	Project issues and concerns that could not be controlled or accounted for.	*"We actually switched contractors which was very, very, disruptive to the process"*
Team	Location	The location of the different disciplines with respect to each other and the project	*"We want to be close to our architectural clients, which is why we are located…"*
	Involvement	Design stage when the different disciplines were involved on the project	*"Well in this instance we were involved fairly early... so you know very different stages of the project..."*
	Tasks	The specific tasks and roles performed by the different design disciplines on the team	*"Sure, you know our responsibility is to design the structure..."*
	Relationships	Prior working relationships and personal relationships between team members and the different disciplines	*"Yes, so I've worked on this team with on multiple projects"*
	Organization	Descriptions of the team structure and hierarchy	*"So, we had myself, who could sort of manage and be in parts of different things,"*
Communication	Design information	The kinds of information team members exchanged with each other	*"So architecturally we would release CAD backgrounds, a description of what they should be looking for"*
	Social behavior	Patterns of information exchange, descriptions of interactions between team members	*"There's a trust factor that's developed. I think there's a, there's a frankness and an honesty."*
	Information process	Modes of information exchange	*"There were milestones that the design team would have to meet on a weekly or monthly basis"*
	Technology	Tools and software that facilitated the exchange of design information	*"When you're able to take a model, and spin it and see how the structure interacts with the architecture..."*
	Recommendations	Descriptions of approaches to ensure and improve effectible communication between disciplines	*"quite often the model... is not... their model isn't to the point where I can figure things out. they say now… oh you needed a dimension,"*
Outcomes	Positive	Outcomes showed the team was effective	*"So, along those lines we have gotten feedback that the clients are very pleased with our efforts…"*
	Improvements	Outcomes that indicated the possibility of improvement for the team	*"So, it certainly hasn't been as perfect as a delivery package as I would generally want to see"*

The coding protocol comprises 4 main codes – project, team, communication, and outcomes – which have sub-codes associated with them. An excerpt from the coded data is included in Appendix C.

All the interview transcripts from the three cases were coded using this protocol. The coded data was analyzed by identifying the themes that emerged, first within each case, then across the three cases studied. These themes are presented in Section 4.2 (p. 68). At the outset, it is necessary to discuss key case characteristics that influenced the results presented.

CASE CHARACTERISTICS

Three main characteristics that describe each case and provide contextual information for the results are presented in Table 4.2: the team disciplines, project description, and challenges. While these characteristics were important at the time of this report, it is possible that these characteristics may have changed as the projects progressed.

Table 4.2 Summary of case description

Case Characteristics		Case 1	Case 2	Case 3
Team Disciplines	**No. of Disciplines**	6	10	10
	Disciplines	project managers, architects, landscape architects, civil engineers, structural engineers, MEP engineers	project managers, construction managers, architects, landscape architects, civil engineers, structural engineers, MEP engineers, lighting, acoustic, and AV designers	project & construction managers, architects, landscape architects, civil engineers, structural engineers, MEP engineers, transport engineer, sustainability consultant, commissioning agent
Project Description	**Project Type**	Mixed use redevelopment – residential and commercial	Institutional building	Institutional building
	Project Size	–	36.000 square feet	40,000 square feet
	Project Location	Pittsburgh, PA	Pittsburgh, PA	Pittsburgh, PA
	Delivery Method	Design-Bid-Build	CM at risk	CM at risk
Challenges	**Project Challenges**	Change in the project manager, the need to reduce the project budget	Change in the project scope and budget, owner made of several groups	Project profile, geographic separation of team members, change in the project manager, aggressive design schedule, owner made of several groups
	Design Challenges	–	The maker space, connections to existing buildings	New space types, transit connections

Disciplines Involved in the Cases

All the cases were made of members from at least six disciplines as shown in Figure 4.2. Each team comprised architects, landscape architects, project managers, civil engineers, structural engineers, and mechanical/electrical/plumbing (MEP) engineers.

While the team in Case 1 only comprised these disciplines, the teams in Cases 2 and 3 had additional disciplines to reflect the complexities of their individual projects. In addition to the six disciplines outlined earlier, the team in Case 2 also included construction managers, lighting designers, acoustic designers and audio-visual designers, and the team in Case 3 included construction managers, transportation engineers, sustainability consultants, and the commissioning agent.

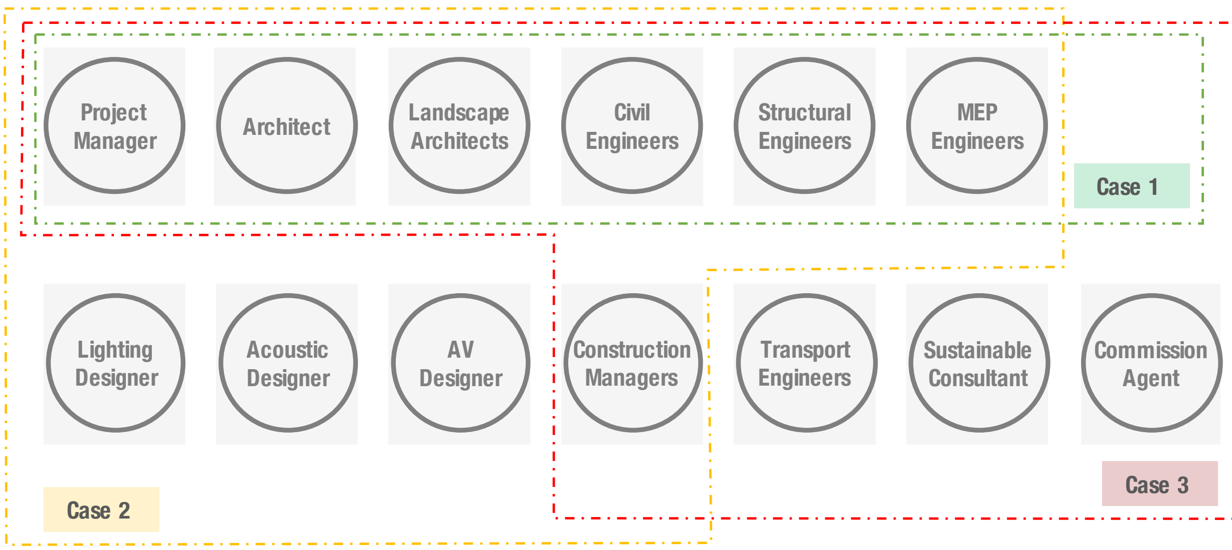

Figure 4.2 The disciplines involved in the three cases

Furthermore, while in Cases 1 and 2 the disciplines were housed within a specific firm, in Case 3, two disciplines were represented by two firms each. The architecture discipline had one firm as the design architects and another as the architects of record, and the civil engineering discipline had one firm as the site civil and another as the geotechnical engineers.

Project Type, Size and Location

The teams in all three cases worked on projects in Pittsburgh, PA. However, there were differences in the project types, sizes, and delivery approach.

Figure 4.3 Map of Pittsburgh showing the location of the three cases

The team in Case 1 worked on the phase one development of a large, approximately 12.75 acre, campus-style, mixed-use redevelopment expected to consist of 650 residential units and 20,000 sq. ft. of commercial space across multiple buildings (Henry, 2016; Schooley, 2015).

The project in Case 1 followed a traditional Design-Bid-Build project delivery approach. As expected, in the case with the traditional approach, the owner held contracts with the architects for the design team and the contractors for the construction team.

The teams in Case 2 and 3 both worked on institutional buildings. The building in Case 2 is 36,000sq ft., containing classrooms, collaborative work spaces, simulation spaces, office and conferencing spaces. The building in Case 3 is 40,000sq. ft., containing administrative spaces, collaborative work spaces, simulation spaces, office and conferencing spaces.

The projects in Case 2 and 3 followed a CM at Risk project delivery approach. In the CM at Risk approach, the construction manager provided the owner with a guaranteed maximum price (GMP) contract and as such was involved with in the project from the start of design.

<u>Challenges</u>

The teams in each case faced project challenges and design challenges. Project challenges were the issues which were either external to, or beyond the control of the team such as a change in the project manager, while design challenges which were a result of the project type and project complexity. The challenges provide the rationale for some of the findings presented in Section 4.2 below.

The team in Case 1 faced some project challenges: a change in the project manager in the middle of design development, and the need to reduce the project budget. These challenges were caused by changes in the vision and goals for the project, and led to a compressed time frame to develop the project delivery package. Also, challenges posed by the projects' size and scope, meant the project was to be completed in four phases. Each phase included master planning to provide a framework for the development of the residential and commercial buildings, circulation, streets and relationships within it (Philipsen, 2015).

The team in Case 2 faced both project and design challenges. In Case 2, the project challenges included changes to the project scope and budget, and the large group owner who was made of several end user groups with distinct requirements. Design challenges posed were the design of the makerspace, and connections to existing buildings. The makerspace – a large multi-story workshop/collaboration space – in particular presented several design challenges as it was a relatively new type of space, with previously undefined requirements.

Along the same lines, the team in Case 3 also faced both project and design challenges. Project challenges were due to the high-profile nature the project, the location of the architect who was the design lead, and again the large group owner comprising many interested stakeholder groups. The project profile and scope meant there were significant master planning and neighborhood implications in addition to a change in the project manager, and an aggressive design schedule. As in Case 2, design challenges were the relatively new types of spaces – for instance the robot garden – with previously undefined requirements.

These three characteristics introduce the cases and provide some context and framing for the findings presented below.

4.2: FINDINGS ALONG THE THREE LINES OF INQUIRY

The findings from this research are presented in three sections, along each line of inquiry discussed in Section 3.1 *(The Exploratory Framework, Lines of Inquiry, and Research Questions*, p. 48): the multidisciplinary building design team, the teams' communication, and the teams' outcomes. Even though most of the findings are commonsense, they provide supporting evidence for, and to some extent, unpack our intuitive expectations of multidisciplinary building design practice. For ease of explanation, the findings are numbered and referenced as 'Finding X'.

THE MULTIDISCIPLINARY BUILDING DESIGN TEAM

The first line of inquiry explores multidisciplinary teams in building design. Along this line of inquiry, the team practices, composition and hierarchy are studied. Two findings emerge along this line of inquiry: the teams' contracts reflect its organization, and all disciplines prefer to be involved as early as the predesign stage of building design.

1: A team's organization reflects its' contracts which are modified by project and team characteristics

The contracts between disciplines establish the chain of command – who works for and reports to who – on the building design team. Therefore, it makes sense to expect that contracts between disciplines detail the hierarchy or organization of the team.

Finding 1 confirms this commonsense intuition that the organization of a multidisciplinary building design team reflects the contracts between the disciplines. While evidence can be found in all three cases, the organization of the team in Case 1, shown in Figure 4.4, illustrates this finding.

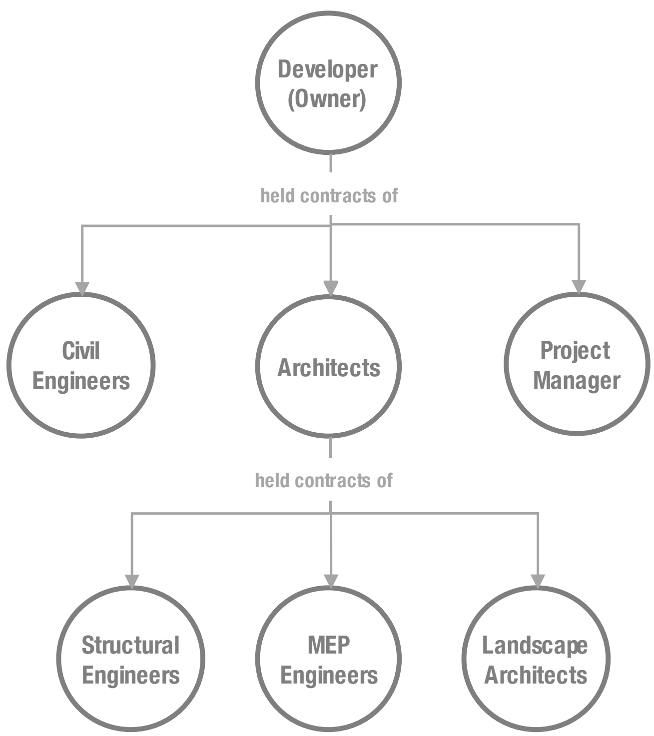

Figure 4.4 Organization of the team based on the contracts in Case 1

In Case 1, the owner/developer held the contracts of the civil engineers, project managers and architects. The architects in turn held the contracts of the structural engineers, MEP engineers, and landscape architects.

Thus, it is possible to infer that in multidisciplinary building design teams, the contracts among disciplines is the team organization and defines the hierarchy between disciplines.

However, a team's contracts can be modified by project and team characteristics. In the cases studied, there were four modifying characteristics shown in Figure 4.5: the project delivery approach, the role of the project manager on the team, preexisting social and professional relationships between the team members, and the location and geographic proximity of the disciplines to each other.

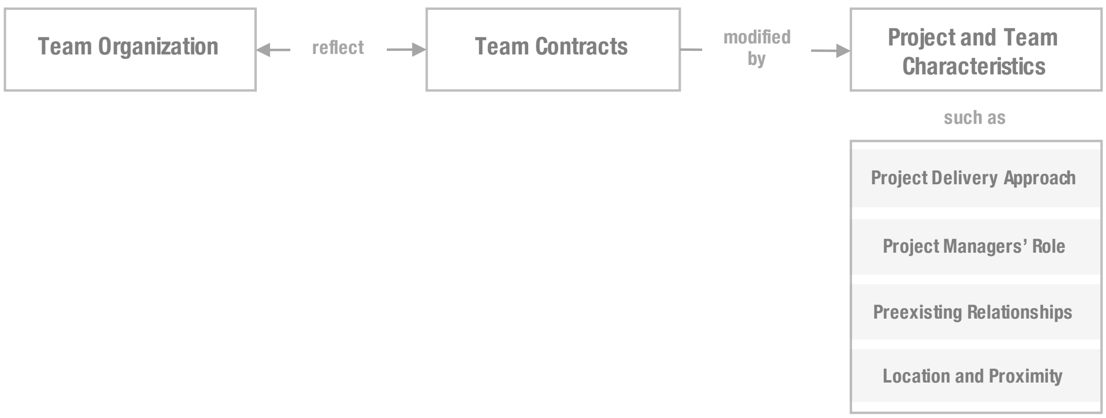

Figure 4.5 Team organization reflect team contracts which can be modified by project and team characteristics

<u>The Project Delivery Approach</u>

The two different project delivery approaches – the Design-Bid-Build approach, and the CM at Risk approach – resulted in different contractual structures. Finding 1 suggests that the project delivery approach may modify the team contracts, therefore its organization.

Comparing the organization of Case 2 (CM at Risk) in Figure 4.6 against that of Case 1 in Figure 4.4 (Design-Bid-Build) provides the evidence for this.

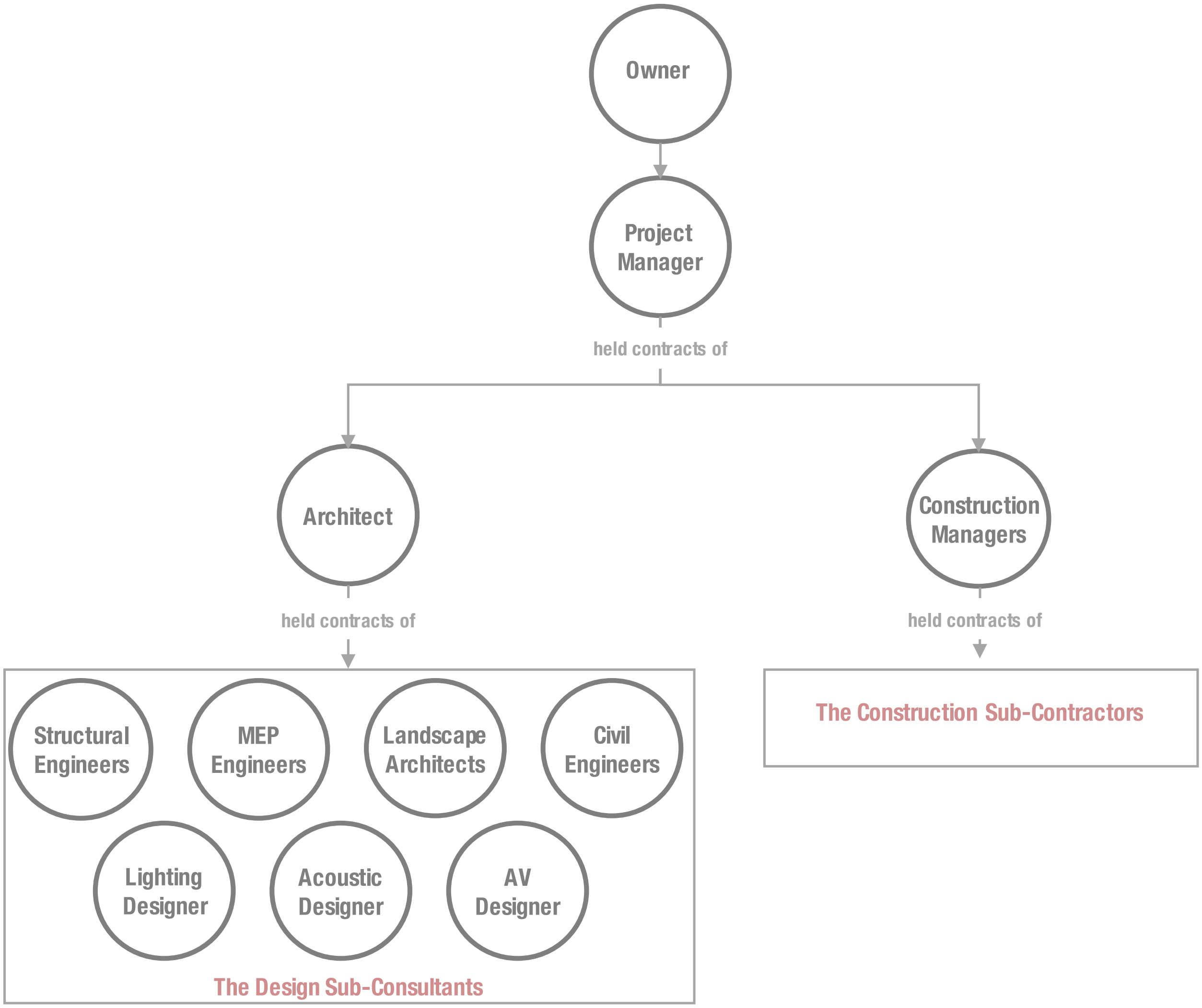

Figure 4.6 Organization of the team in Case 2

The obvious difference in organization was the involvement of the construction managers in Case 2 but not in Case 1. The construction managers were present in the design stages of Case 2 (the CM at Risk case) to ensure that the building design remained within the owners' budget, and the guaranteed maximum price (GMP) for construction.

The presence of the construction manager meant the project manager was central to the design team in Case 2, rather than the architect in Case 1. As the project managers held the contracts of the construction managers (and their sub-contractors) and the architects (and their sub-consultants), the project managers position became central to the team.

Comparing the cases shows that project managers are a central figure in the organization of teams that use the CM at Risk project delivery approach, while architects are central to the organization of teams that use the Design-Bid-Build approach. Therefore, we can imply that the project delivery approach may modify team organization by influencing the position and centrality of the disciplines on the team.

It follows then that the specific role of the project managers on the team and its effects on team contracts and organization also need to be considered.

The Role of the Project Manager

The project managers in Cases 2 and 3 played a more significant role, resulting in a different contractual structure when compared with those in Case 1. Finding 1 suggests that the specific role and tasks performed by the project managers may modify the team contracts, therefore its' organization as shown in Figure 4.8.

The project managers in Cases 2 and 3, as the direct representatives of the owners, were responsible for facilitating the project. As facilitators, they identified the project goals, selected the project architects and construction managers, and indirectly held the contracts of the entire project team.

To identify the project goals, the project managers performed a wide range of tasks. As reported in Case 2, they met with several end user groups to come up with specific requirements for the project, developed the initial project program, and validated the budget:

"We did discuss possible program, square footages, footprint, all those types of things, and then we also validated the budget. And for that, after the architect had some very quick schematics, we worked with another construction company which has done projects on site. So, they came in, we gave them the scope and they vetted the scope with the gift agreement. And from there, we were like, "Okay, this can happen, but we are limited to 25,000 square feet…"

This quote shows the range of tasks performed by the project managers to develop the project goals and emphasizes the importance of their role in Case 2. In this role, they were also responsible for communicating the project goals to potential architects and construction managers.

To select the specific firms as the project architects and construction managers, the project managers held workshops where potential firms were invited to meet with the owners and end user groups. As reported by the project managers in Case 2, at these workshops, discussions were held with potential firms to provide them with information regarding the project goals and scope, and get a sense of the firms' approach to address the project:

"We just had a workshop and in that workshop, I did some slides and I showed with the program – what we were anticipating the program to be. There were parts to those workshops. One was infrastructure. The other one was the master plan, so they understood the owner's master plan and then the third one was the program which I sat in and I explained the program and the scope for each of those firms. We had slides and from there we asked for the proposals."

Basically, by providing the potential firms with an explanation of the project and assessing the firms' responses to the project, the project managers were able to select the specific firms on the team. The project managers also held the contracts of the architects (and the design team) and the construction managers (and the construction team).

This finding implies that the role of the project manager can influence the team organization. Specifically, in teams where project managers are facilitators, it is expected that they occupy a central position in the team. Comparing the organization of the team in Case 2 in Figure 4.7 where the project managers were facilitators, with the team in Case 1 in Figure 4.4 where they were the owner-developer's representative, illustrates the difference in the centrality of the project managers.

It is worth mentioning that in addition to modifying the team organization, the project managers' role as facilitators can lead to improvements in team effectiveness and outcomes. Facilitation allows team members work together to learn from and be mutually accountable to each other (Patrick, 2016). These benefits are achieved as team members are able to sit together, share ideas and ask questions to develop a mutual understanding of what they do, before beginning their design tasks.

While facilitation and the role of the project managers was beneficial to building design, it is also necessary to note that facilitation itself is not well-defined and can mean different things. Facilitation in the cases referred to establishing clear goals and managing disciplinary expectations, but it can also refer to working with individuals to resolve conflict or make changes to an organization (Anderson, 2016). Thus, prior to making recommendations on project managers as facilitators, it is necessary to further explore and clearly identify what facilitation means in the multidisciplinary building design context.

<u>Preexisting Social and Professional Relationships</u>

In all three cases, there were preexisting social and professional relationships between the disciplines on the teams which contributed to firm selection and promoted positive team working environments. This finding suggests that preexisting relationships may directly modify team contracts through connections between disciplines, and may indirectly modify the team organization through the specific firms on the team, shown in Figure 4.7.

Figure 4.7 Preexisting relationships between disciplines directly and indirectly modify team organization

The preexisting relationships between disciplines established contracts where there would typically be no contracts as illustrated by the relationship between the civil engineers and the owner-developer in Case 1. The civil engineers reported that they had a preexisting professional relationship with the owner-developer from working with them on a prior project:

"Actually, in this case, we knew the developer before the project. You know we worked with this developer in their other, in some of their other regions, like in Indianapolis suburbs particularly. So, when they were coming to Pittsburgh to look, some of our people introduced them to us and actually did some help with… sort of with the ground work…"

There was direct link between the civil engineers and the owner-developer owing to this prior relationship, where the owners held the contracts of the civil engineers. Without this relationship, the civil engineers would have been contracted to the architects (see Figure 4.4).

The preexisting relationships between disciplines also determined the specific firms selected as the design sub-consultants. For instance, the civil engineers in Case 1 were aware that their prior relationship with the owner-developer contributed to them working on the project.

Case 2 provides another example of this finding where the project managers reported that in selecting the consultants to participate in their workshops, they only invited firms they had recently worked with or received proposals from:

"Some projects start out with like RFQs, Request for Qualifications. We send them out to those architectural firms and then they will send them back to us with their qualifications. This particular project though, we didn't go through the RFQs. We went to five architectural firms that we've done work with recently or we've seen proposals from them recently."

The quote shows that in this case, the project managers had a clear preference for working with firms with whom they had preexisting relationships with.

The main benefit of preexisting social and professional relationships was that they contributed to positive working relationships across disciplines. For instance, the architects in Case 1 reported that they had previously worked with the structural, civil and MEP engineers and had positive relationships with them:

"So, I had a lot of familiarity with the structural engineer, and the civil engineer. The firm had just…we are just wrapping up a project with the mechanical engineers. There are a lot of good working vibes and a positive working environment. The landscape architects, I haven't worked with them personally but my firm has, maybe 15 to 20 times, and I know them personally, you know from the industry"

In other words, there was a positive working environment owing to the professional relationships between the disciplines, and even close social relationships between individual team members.

The positive environment from preexisting relationships meant that disciplines could anticipate what each other would need even before the start of design, making them accountable to each other and leading to positive team outcomes. This could also address the communication challenges – potential issues of categorization and information silos – of multidisciplinary building design teams.

Existing research on familiarity and trust processes in teams supports these findings and suggest that the familiarity between team members promotes interpersonal attraction. Stronger interpersonal attraction leads to better team performance in several areas including the quality of their output, team satisfaction and cohesion (Harrison, Mohammed, McGrath, Florey, & Vanderstoep, 2003; Jehn & Shah, 1997; Nooteboom & Six, 2003).

Therefore, it makes sense that there would be a preference to work with familiar firms, since teams with familiar or recurring members outperform teams with unfamiliar members. This implies that trust and familiarity through preexisting relationships are necessary for positive multidisciplinary building design team functioning and outcomes.

However, there is one caveat with the benefits of relationships among disciplines and firms. It is possible to continually work with firms and disciplines to take advantage of the trust processes while overlooking others who may better suited to the project (by experience or capability). While this was not discussed in these cases, it is important to be aware of as relying on preexisting relationships may not be suited for all building design scenarios.

Location and Geographic Proximity

The preexisting relationships between the disciplines in all the cases was in part due to the location of the disciplines. This suggests that by contributing to the development of preexisting relationships, the location and geographic proximity of the disciplines indirectly modifies team contracts, therefore its' organization.

With the exception of Case 3, all the disciplines were located in the Pittsburgh area. The civil engineers in Case 1 described Pittsburgh as having a close-knit building design community:

"You know Pittsburgh is this big small town and the civil engineering community, or the design…development community is…Very close-knit. Yeah. Everybody knows each other. You're in a room with a bunch of people which you've known for a long time. You know how they function a little better and just more comfortable, more relaxed, and lot easier to have a dialogue with somebody which you have history with."

In this close-knit building design community, design firms and consultants regularly work together on similar projects, and develop social and professional relationships.

Having disciplines in a close-knit community where they can be co-located is ideal for multidisciplinary building design as positive social and professional relationships are likely to form. Research supports this finding where in their analysis of 145 software design teams, Hoegl and Prosperpio found that the degree of team member physical proximity is significantly related to the quality of teamwork as close physical proximity facilitated social relationships and coordination between team members (Hoegl & Proserpio, 2004).

However, in Case 3, all disciplines were not located in Pittsburgh. Team members reported that this did not adversely affect design and only required increased coordination efforts between the disciplines.

In Case 3, the design architects – the design lead discipline – were located in New York. From the findings in Cases 1 and 2, one would expect that having the lead discipline in a different location could adversely impact the team. Indeed, research on geographically dispersed teams suggests that when teams have distinct co-located subgroups comprising members in the same location (that is, subgroup A in one location and subgroup B in another location), fault lines occur between the subgroups which leads to more conflict and less trust. This research also suggests that negative effects are worse in two sub-group teams with one fault line, than in three or more sub-group teams (Lau & Murnighan, 2005; Polzer, Crisp, Jarvenpaa, & Kim, 2006).

However, the location of the design architects as separate from the other design consultants did not negatively influence the team outcomes. As reported by the site civil engineers in Case 3, *"I think it would've helped to have them here. But that's really for the ease of access to them and convenience. I don't think it created any undue stress or issues as a result of it…"*. While this difference in location was not ideal, it did not impact the disciplines perceptions of the team functioning or its outcomes.

Research supports this finding from Case 3 and suggests that while geographic dispersion is not ideal, it does not necessarily present an issue for teams. Team members are able to combine their experiences by relying on the 'situated knowledge' of the sub-group more familiar with local practices (Sole & Edmondson, 2002). Along these line, team members in Case 3 specifically pointed to the close geographic proximity of most disciplines to the site as factor that address potential challenges of geographic dispersion. This proximity meant that they could were familiar with regional practices and requirements, and could anticipate expectations beforehand.

Based on these findings and as research expresses neither strong positive or negative impacts of location and geographic dispersion on teams, it is difficult to infer that the proximity of the different disciplines directly impacts multidisciplinary team practice. Rather, due to the nature and constraints on building design teams, this finding implies that co-location is ideal and contributes to preexisting relationships, and dispersion, while not ideal, is best dealt with familiarity to the project location and site.

As consultants cannot always be in the same location as each other or their projects, one possible recommendation for multidisciplinary building design teams is that it may be worth selecting disciplines and firms that are familiar with the local practices of the project site.

2: Disciplines prefer early involvement in building design; their actual involvement depends on their tasks and roles

Recent approaches to building design are attempting to move away from the traditional Design-Bid-Build approach where disciplines are involved sequentially in building design. These approaches recommend the early involvement of disciplines – all during design rather than architects and engineers first in design, then construction managers and contractors in bid and build.

Findings confirm these recommendations of recent approaches including IPD, discussed in Section 2.1 (*Multidisciplinary Teams Versus Interdisciplinary Teams*, p. 19), that highlight the benefits of the early involvement of all project stakeholders in the building design process.

All the disciplines in the three cases expressed their preference for early involvement – as early as the predesign project stage in building design. As reported by the landscape architects in Case 1:

"And that's why the sooner the better, even if we're involved very superficially in the beginning stages, you'll at least digest all that information and why you got to there. So, we like to be involved from day one and be able to be part of the team throughout the whole process"

This preference suggests that disciplines are aware of the benefits of early involvement to building design, no matter how superficial. The disciplines are able to understand the project goals, and influence the design decisions when they can be implemented, rather than later during design when changes to decisions are more difficult to implement.

Early involvement of team members from the different disciplines taps into the benefits of familiarity, relationships and team learning. Katzenbach and Smith discuss the benefits of having team members involved early: they are able to learn from each other, share their complementary knowledge, and build rapport with each other (Katzenbach & Smith, 1993, Van Der Vegt & Bunderson, 2005).

Interestingly, though it was preferred, this early involvement of disciplines was described as uncommon. The structural engineers in Case 2 expressed their surprise at being asked to perform their tasks early:

"that's actually little earlier than we would typically meet for this project. I feel like we've done a little bit more from a structural standpoint than we normally would. We actually had a programming phase narrative which normally, we wouldn't be involved really at all, you know, throughout the programming phase just because that's so early"

This presents a difference between the stated preference of the disciplines on the multidisciplinary building design team for early involvement and their expectations. While disciplines expect to be involved early, they do not actually expect it to occur.

Findings from the cases also suggest that early involvement of all disciplines is uncommon as it only occurred in Case 2. In Cases 1 and 3, most but not all disciplines were involved early as shown in Figure 4.8.

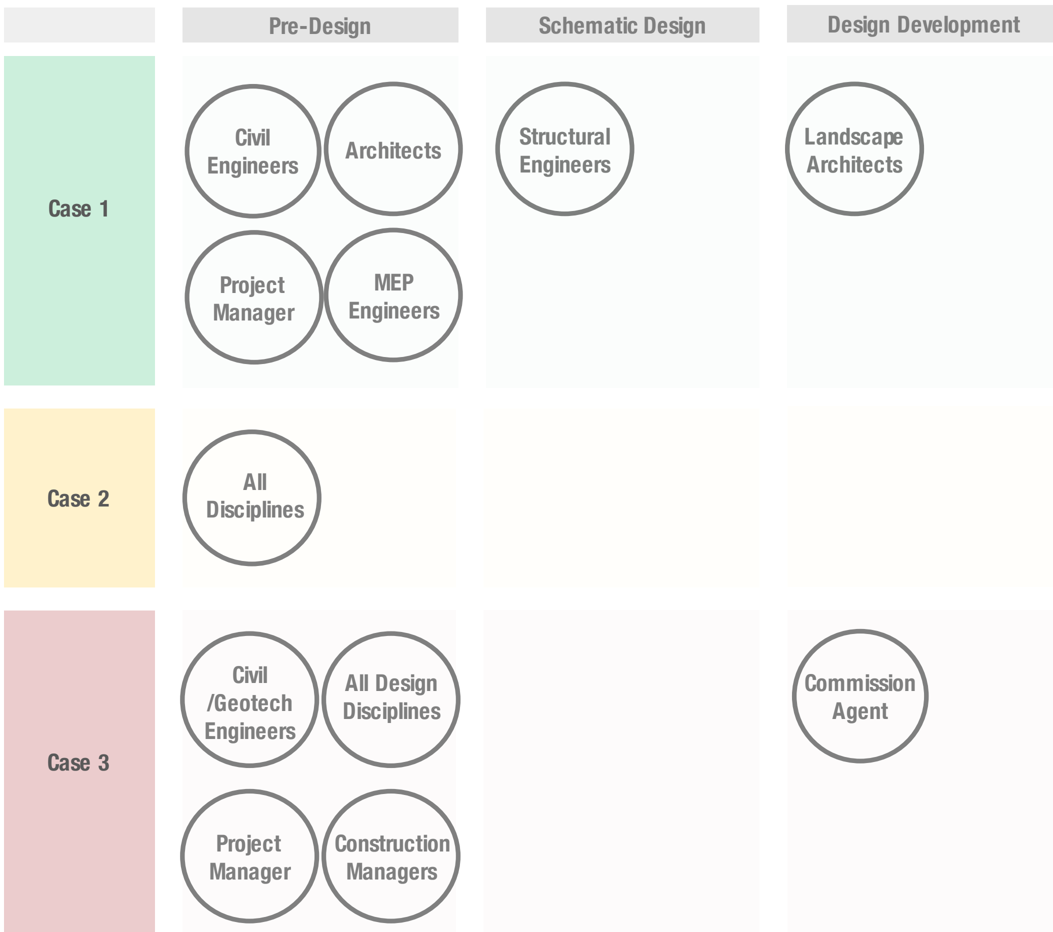

Figure 4.8 The involvement of the disciplines by project stage in the three cases

In Case 1, with the exception of the structural engineers and the landscape architects, all disciplines were involved during predesign. Similarly, in Case 3, with the exception of the commissioning agent, all disciplines were involved during predesign.

A possible explanation for the involvement of disciplines in these two cases is related to the case characteristics discussed in Section 4.1. At the time of data collection, the projects in Cases 1 and 3 were in design development while the project in Case 2 was in schematic design. As project scope and requirements may change as the project progresses – which occurred in Case 1 – it is possible that additional disciplines were required later in the process.

However, findings from the cases suggest that actual involvement depends on the specific disciplinary tasks and roles as shown in Figure 4.9.

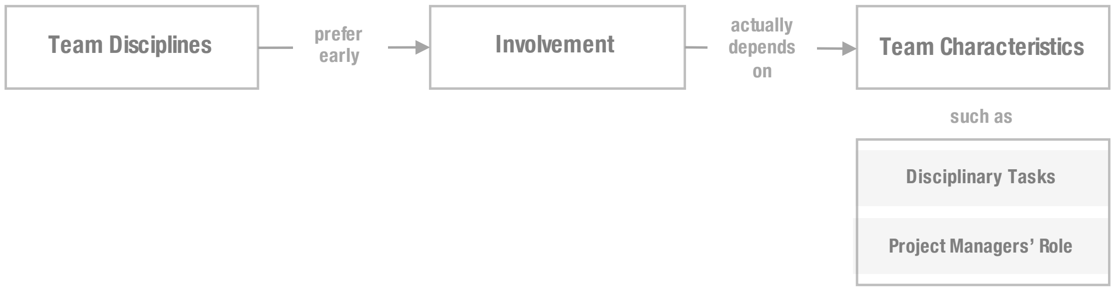

Figure 4.9 Team disciplines prefer early involvement but actual involvement depends on team characteristics

Tasks Performed by the Disciplines

Each discipline performed different tasks on their team. Findings suggest that these tasks determine the actual stage at which disciplines are involved.

The tasks performed by the landscape architects in Case 1, and the commissioning agent in Case 3 provide some explanation for their involvement at later stages of their projects.

In a scenario where the landscape architects were involved in master planning for the project, we expect that they would be involved during predesign, as master planning is a task that needs to be completed prior to the start of most design tasks. However, in Case 1, the landscape architects were asked to fill in the site on completion of the initial master planning and building design. Due to the narrow scope of this task, it was unnecessary for them to be involved as early as predesign.

Similarly, in Case 3, the commissioning agents developed the owners' project requirement (OPR) documents with specific project performance targets. As reported by the commissioning agent, this meant they did not necessarily need to be involved from the start of design:

"So, we came on towards the end of schematic design. I think that was just that the project had started. Sometimes that happens when we're brought on as a commissioning agent. I think folks sometimes think of commissioning just as sort of – testing the system, as opposed to helping create the goals and targets for the project."

Though the preference was to be involved before the end of schematic design, the commissioning agent was aware that the performance targets they developed to test the building systems were not always considered a priority at the start of design.

A contrasting example that shows how the tasks performed by the disciplines determined their involvement can be found in Cases 2 and 3. Here, the project managers were involved earlier that all the other disciplines as they represented the owner and were responsible for hiring the architects and the construction managers.

While early involvement is beneficial to building design, we can imply that disciplinary tasks and project factors place constraints that determine actual involvement. In practice, the early involvement of all disciplines may not always be feasible since project constraints such as budget or an initial lack of awareness of project complexity can limit the early involvement of the disciplines on the team.

The Project Management Approach

Due to the project managers approach in Cases 2 and 3 discussed in Finding 1, the architects and construction managers attended selection workshops with their design sub-consultants. As a result, most of the disciplines on the project were involved prior to the start of pre-design. Finding 2 suggests that the specific project management approach may determine the actual stage at which the disciplines are involved on a project.

The project managers in Case 3 reported that they preferred having the bulk of the disciplines on the design team – including the architects, design sub-consultants, and the construction managers – present at the selection workshops that occurred during pre-design:

"So, they presented to us and actually brought models in, so, they had time to think about how they would address this building. So, its kind of like, now we're not only looking at their fee, we are looking at - Hey, really how much do they really understand? And do they understand the scope? Do they understand the difficulties of the site? And how do we like some of their solutions?"

Having all the disciplines involved this early was helpful as it provided the disciplines with clear goals for the project, and allowed the project managers to understand and assess each disciplines' response to the project goals and project challenges.

This finding implies that the project managers approach to selecting firms contributes to the early involvement of disciplines on the building design team. A potential recommendation for multidisciplinary building design practice is that in projects where the project managers facilitators, having all disciplines present before the start of design is useful to understand how the whole team responds to the goals of the project. The multidisciplinary nature of building design teams makes this necessary where, as discussed in Section 2.1 (*Multidisciplinary Teams Versus Interdisciplinary Teams*, p. 18), the disciplines in a multidisciplinary team work independently on their specific aspects of the building design problem, and need to bring these different aspects together.

The findings from the first line of inquiry confirm commonsense intuition and recommendations for building design, that team contracts reflect team organization, and all disciplines prefer early involvement in building design.

Unpacking these findings shows that team organization can be modified by several team and project characteristics: the project delivery approach, the role of the project manager, preexisting relationships between disciplines, and the geographic proximity of the project to the site. Also, as actual involvement depends on disciplinary tasks and the project manager's role, early involvement is uncommon and possibly infeasible in practice.

These finding have implications for the exploratory framework introduced in Section 3.1 *(The Exploratory Framework, Lines of Inquiry, and Research Questions*, p. 47), and for multidisciplinary building design teams, further discussed in Chapter 5. The findings suggest opportunities for further research such as the organization and hierarchy of building design teams, and the impacts on trust and familiarity between team members. They also point to the role of the project manager as the team facilitator as a recommendation for multidisciplinary building design practice.

MULTIDISCIPLINARY BUILDING DESIGN TEAM COMMUNICATION

The second line of inquiry explores communication in the multidisciplinary building design team. Along this line of inquiry, the patterns of information flow, the information exchange processes, and communication technology of the disciplines were studied. The findings on communication are discussed along the three categories – communication as social behavior, as information exchange, and the use of communication technology.

Communication as Social Behavior

Communication as social behavior, as discussed in Section 2.3 (*Communication and Building Design Teams*, p. 33), explores the patterns of interaction between the different disciplines on the team. Findings suggest that in addition to shared tasks – the building design tasks that require input from several disciplines – project and team characteristics determine the information flow between disciplines.

3: Information flow between disciplines is primarily determined by shared tasks, and also by project and team characteristics

As disciplines on the multidisciplinary building design team work on their specific aspects of the design problem, there is the need for coordination among disciplines to form the whole design solution. There is always some overlap between the tasks and requirements of the different disciplines, and commonsense suggests that the flow of information between disciplines depends on the intersections between disciplinary tasks.

Finding 3 again confirms this commonsense intuition that shared tasks determine the flow of information among disciplines. Two examples from Case 1 are used to show this: the intersections in the structural design and the site design tasks.

Figure 4.10 shows the flow of information between the architects and the structural engineers in Case 1, who worked on the structural design task.

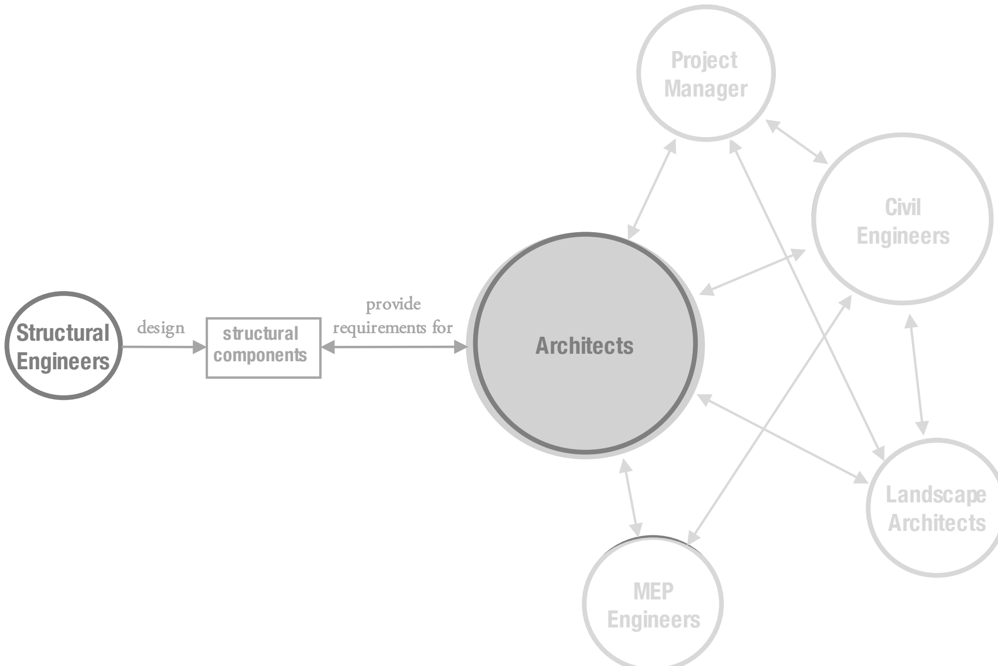

Figure 4.10 The shared structural design task 1

The architects provided the requirements for the structural components to the structural engineers who designed the components. The structural engineers then provided the architects with the structural details to support the architects design tasks.

In this instance, only the architects and the structural engineers required information from each other. Therefore, it was unnecessary for the structural engineers to interact with the other disciplines on the team.

On the other hand, the civil landscape architects, the project managers, and the architects all required information from each other as they worked on aspects of site design. Figure 4.11 shows the flow of information between these four disciplines.

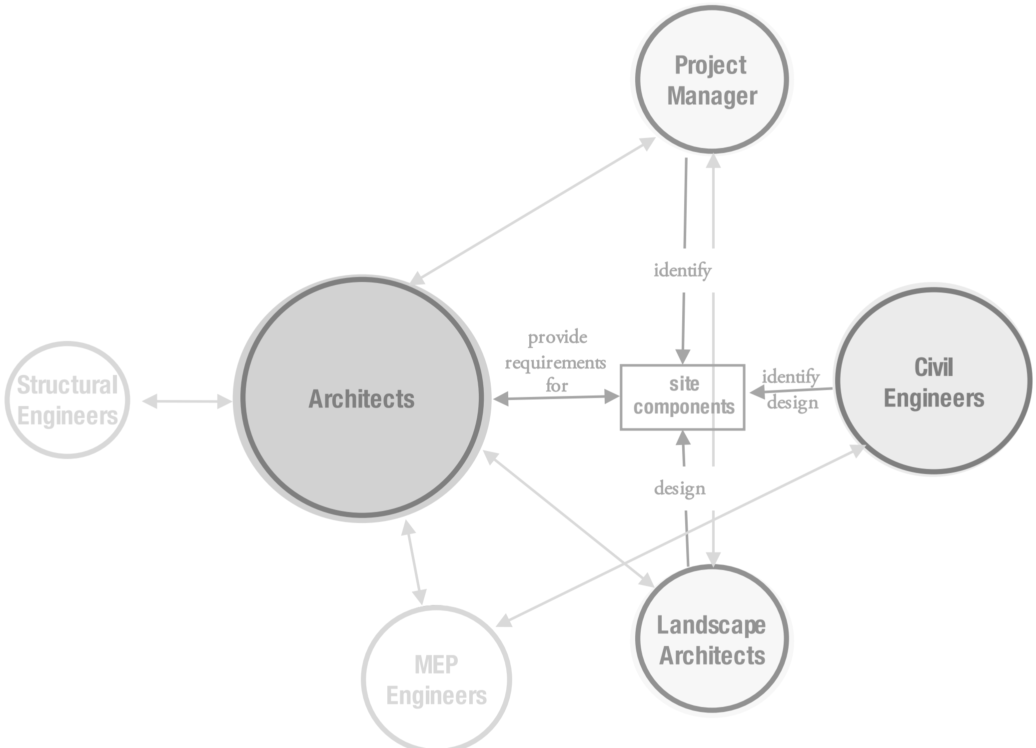

Figure 4.11 The shared site tasks in Case 1

The civil engineers worked with the project managers to identify the project site, and also with the architects and landscape architects to design the site components. As a result, there was the flow of design information among these four disciplines.

Based on this finding, it is possible to suggest that since shared tasks determine the flow of information between disciplines, the reverse should be the case where shared tasks can then be identified from patterns of information flow. This can be useful in planning or scheduling related tasks among several disciplines.

However, information flow is not only dependent on shared tasks. Findings also show that that the flow of information among disciplines is also determined by several project and team characteristics shown in Figure 4.12: the stage of the project, and preexisting relationships between the disciplines.

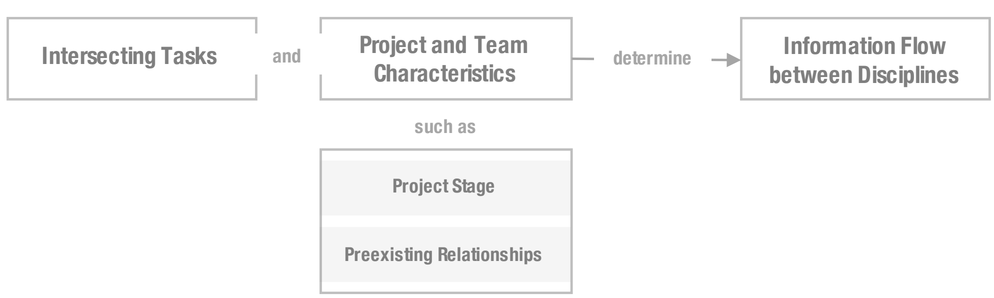

Figure 4.12 Shared disciplinary tasks along with project and team characteristics determine information flow

Information Flow and Project Stage

There were observable differences in the information flow patterns of the cases at different stages. This finding suggests that a teams' project stage contributes to the information flow among the disciplines. Comparing the information flow of team 2 against that of team 3 in the differences due to project stages.

Figure 4.13 shows the information flow between the disciplines in Case 2.

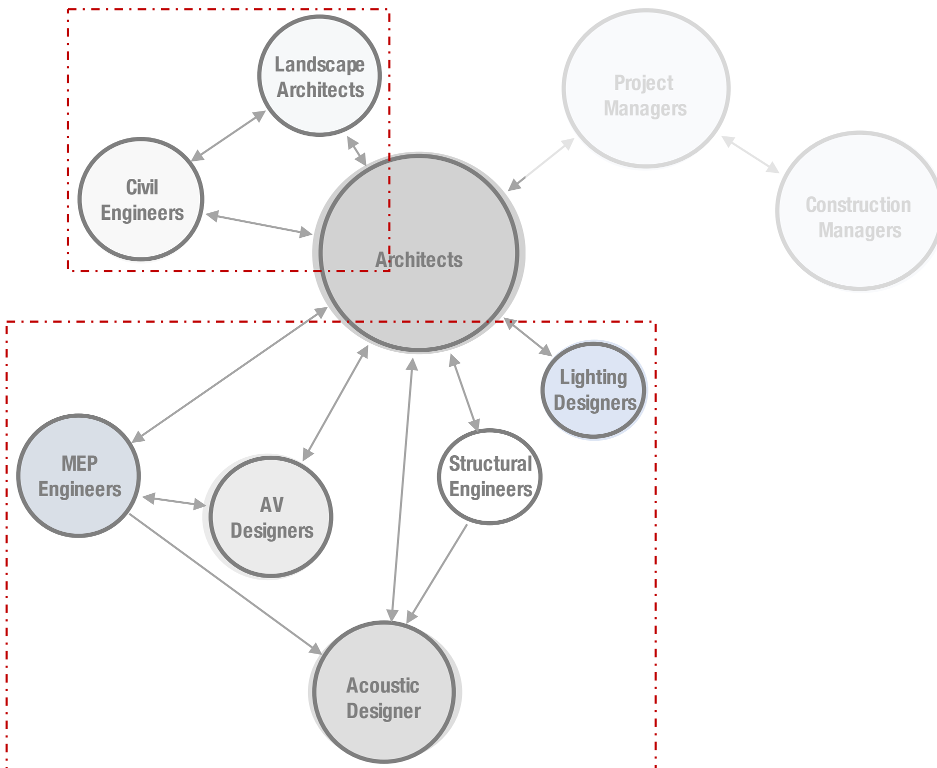

Figure 4.13 Distinct groups formed during schematic design in Case 2

In Case 2 – which was in schematic design at the time of data collection – there were two distinct groups formed based on information flow. One group comprised the architects, landscape architects, and civil engineers who all worked together on the site design. The second group comprised the architects, MEP engineers, structural engineers, AV, and acoustic designers who required equipment and power information from each other.

Conversely, as Case 3 was further along than Case 2 (Case 3 was in design development), team members were more engaged with each other. Rather than distinct groups, there were more two-way connections between disciplines representing their information flow as shown in Figure 4.14.

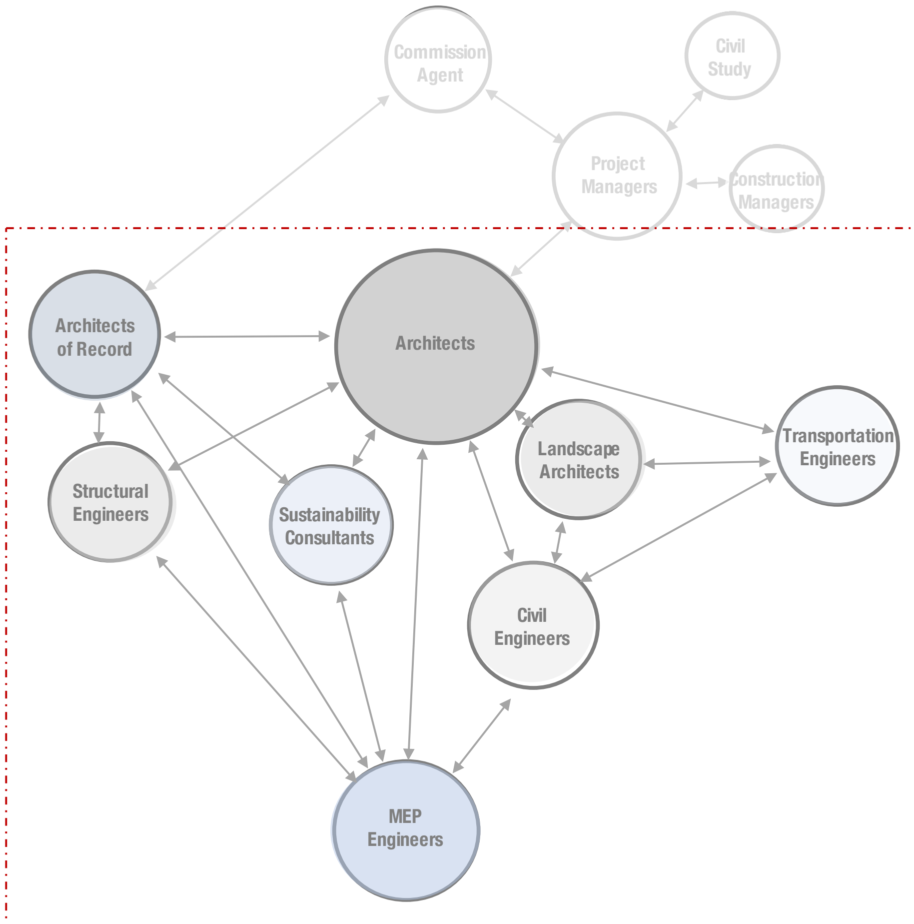

Figure 4.14 Two-way information flow during design development in Case 3

The observed differences in the flow of information between the two cases can be attributed to an increase in information requirements from one stage to another. As an illustration, the lighting designers in Case 2 reported that the flow of information among the disciplines in schematic design would be different than in design development as more information would be required from more disciplines:

"Its a bit early on the project, we've worked with just the architects for this one. As it develops and we get into details, in addition, we interact with the electrical engineer, and the AV consultant, for our conferencing center or something like that..."

This finding implies that as projects progress, the connection between tasks and the need for more interaction between disciplines increase. There would be more two-way connections among all the disciplines during design development owing to an increase in the amount of work and detail for the design package, compared to the distinct groups identified during schematic design (Kals & Houten, 2013).

This finding also has implications for the exploratory framework, challenging the assumptions of the dual-process model that functional diversity leads to information rich exchanges and categorization processes.

The information patterns suggest that there is a timing component to be considered in addition to the two processes. There is an earlier information flow process comprising distinct task groups (as shown in schematic design), and a later information process with dense, two-way connection between most team disciplines (as shown in design development).

Models of design team activity support this implication for the exploratory framework. Stempfle and Badke-Schaub found that teams operate in two 'spaces' as shown in Figure 4.15: an initial goal space where team members are engaged in exploration and generation, and a solution space that occurs later on where team members are engaged in analysis and evaluation (Stempfle & Badke-Schaub, 2002).

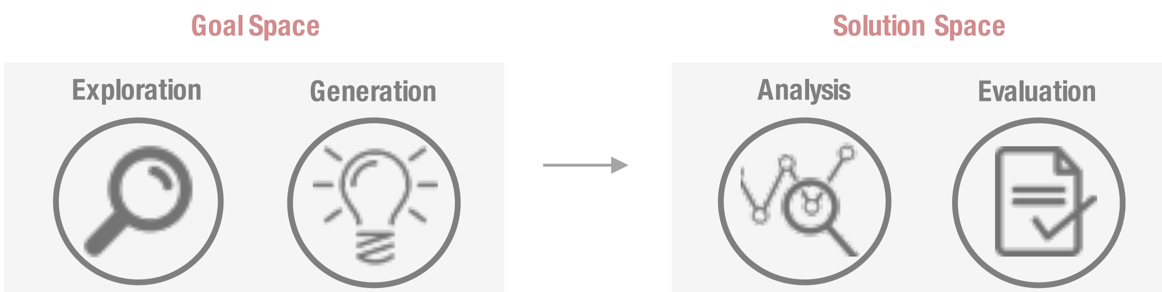

Figure 4.15 The goal space/solution space design process model (Stempfle & Badke-Schaub, 2002)

Applying this goal space/solution space model to this case, the communication patterns that occur in the early stages of design (pre-design to schematic design), can be attributed to team members working in the goal space, defining requirements and engaging in exploratory and generative activities. It is expected that communication patterns that occur later on (schematic design to design development), can be attributed to team members working in the solution space, analyzing and evaluating design options.

<u>Preexisting Relationships and Information Flow</u>

In Case 1 there was a preexisting relationship between the project manager and the landscape architect. This suggests that preexisting relationships contribute to the information flow between that emerged, as highlighted in Figure 4.16.

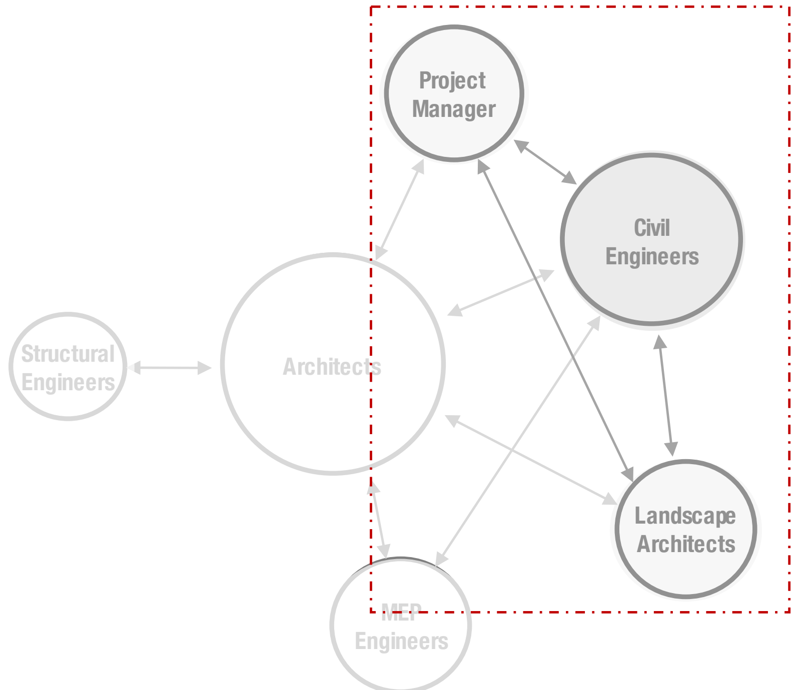

Figure 4.16 Flow of information highlighting the influence of preexisting relationships in team 1

Generally, in a scenario where all the design contracts were held by the architects, the landscape architects would be unlikely to have direct contact with the project manager. However, in Case 1, owing to the preexisting social relationships between the landscape architects and the project manager, there was a direct flow of information among them.

As discussed in Finding 1 (p. 69), preexisting relationships can help mitigate the challenges of communication in multidisciplinary teams discussed in Section 1.1 (*Functional Diversity, Fragmentation, and Multidisciplinary Building Communication*, p. 3): information silos and categorization processes. The implication for building design is that preexisting relationships improve the flow of information owing to interpersonal attraction between team members, previously discussed in Finding 1 (p. 69).

Studies show that positive relationships promote interpersonal attraction between team members across disciplines making it easy for them to work together (Sheng, Tian, & Chen, 2010). Due to familiarity and trust, team members across disciplines are able to share information easily across disciplines without being worried about giving the wrong information, or having issues resolved in a litigious manner. The similarity attraction principle suggests that people prefer to work with others they perceived as similar (Stahl et al., 2010).

The findings on communication as social behavior again confirm commonsense intuition that the information flow between disciplines on the multidisciplinary building design team depends on shared tasks. In addition, findings suggest that project and team characteristics – the project stage and preexisting relationships contribute to the information flow patterns that emerge.

These finding have implications for the communication portion of the exploratory framework, and for multidisciplinary building design teams, further discussed in Chapter 5. Findings suggest that timing and project stage are factors to be considered in the framework as it affects team communication processes. Also, findings again point to preexisting relationships and familiarity as being important to building design teams, which could be an opportunity for future research.

Communication as an Information Process

Communication as an information process, discussed in Section 2.3 (*Communication and Building Design Teams*, p. 33), explores the forms of design information and the modes of information exchange among disciplines. Two findings emerge from this exploration: effective communication involves the on-time delivery of design information, and meeting characteristics reflect aspects of the building design information process.

4: Effective communication involves on-time delivery of information that accounts for the variation in disciplinary needs

Barnlund's transactional model of communication discussed in Section 2.3 (*Communication and Building Design Teams*, p. 32) describes several components required for information transfer: the message or the information being transferred, the communicator or the individuals transferring the information, a feedback channel that allows for a back and forth between the communicators, and a time component where messages can be sent and received simultaneously.

Findings support recommendations on teamwork and suggest that these components of the transactional model contribute to effective team communication. This effective communication involves the on-time delivery (time) of the right information (message) to the right people (communicator) (Bovee & Thill, 2015).

The on-time delivery of the right information is particularly important in multidisciplinary building design where, as discussed in Finding 3 (p. 82), though the disciplines work independently on their specific areas, there are intersections between the tasks they perform.

The acoustic designer in Case 3 reported that asking the right questions early in design was one approach to ensure they received the right information from other disciplines:

"So, like I said, if I'm asking a few questions over and trying to get that sound power information, doing that early is important because the earlier I get that, the more I can just start doing my analysis on the mechanical systems to determine, especially the major pieces…"

Asking the right questions early in the process allows the disciplines on the team share accurate information with each other during design, which has implications not only during design but also during construction. As the information required for construction is developed during design, team members are less likely to be able to correct design errors during construction, which may lead to conflict, rework and delays on the project.

It was suggested that in general, the on-time delivery of the right information has to account for variations in disciplinary information needs shown in Figure 4.17. Three variations were identified in the cases studied: the variation in project stages of the disciplines, variation in the range of disciplinary involvement, and variation in disciplinary information preferences.

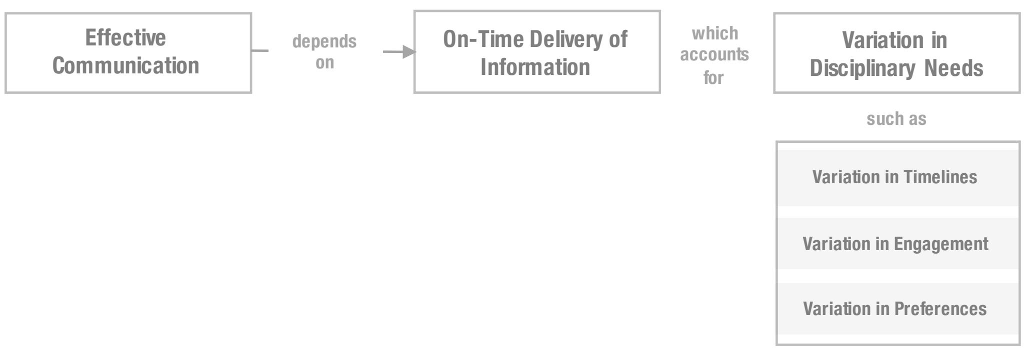

Figure 4.17 Effective communication depends on the on-time delivery of information that accounts for variation in disciplinary needs

Variation in Disciplinary Project Timelines

The requirements for shared tasks between disciplines resulted in varying project timelines. Disciplines have to account for the variation in timing of task requirements to ensure the on-time delivery of information.

An instance of this difference in timeline between the architects and lighting designers in Case 2, shown in Figure 4.18, illustrates this finding.

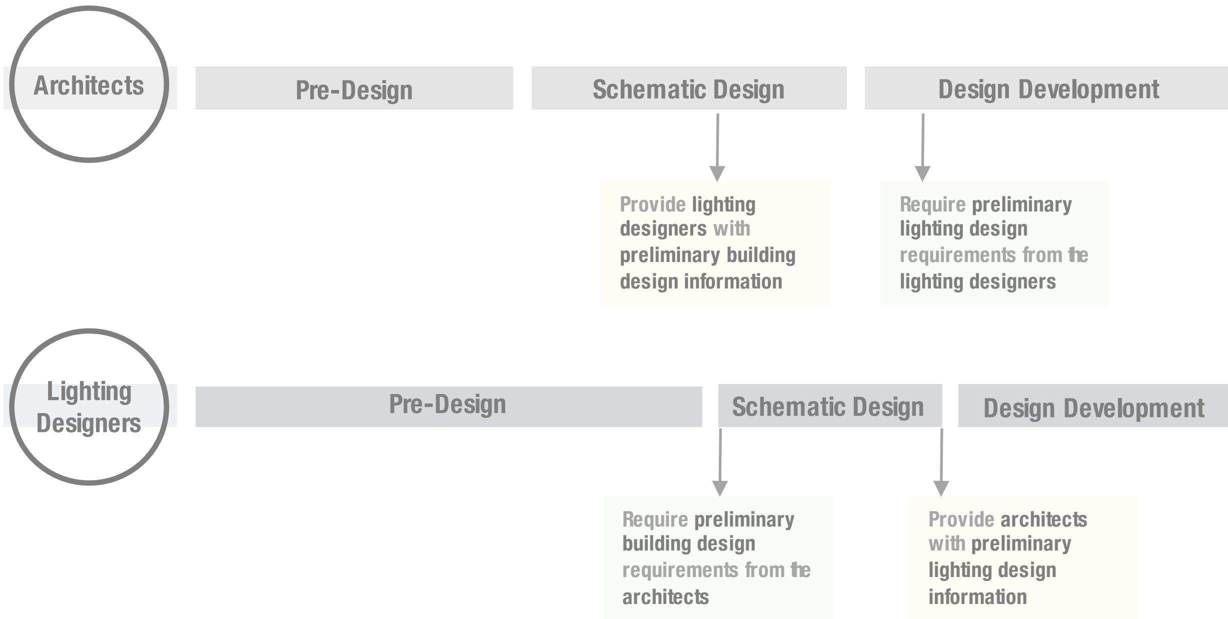

Figure 4.18 Comparison of the design stages for the architects and the lighting designers in Case 2

The architects and lighting designers in Case 2 required information from each other at different times.

First, at the onset of their schematic design stage, the lighting designers needed the project requirements and preliminary building design from the architects. The architects could only provide this information after the start of their schematic stage. As a result, the lighting designers schematic stage started about halfway through that of the architects.

Then, close to the start of their design development stage, the architects needed the lighting designers' preliminary lighting design which the lighting designers could only provide at the end of their schematic stage.

The staggered timelines for the schematic design and design development stages of these two disciplines meant that, as reported by the lighting designers, their schematic design and design development stages proceeded at such an accelerated rate:

"So, at schematic process we quickly kind of capture what the architect was trying to do in getting some sort of a sign off on that and then we quickly transition into our DD phase, in your DD phase, so we can catch up."

This example shows that the disciplines require very specific forms of information from each other at various times. While this was not problematic in this case, it is easy to see how delivering information at the wrong time can be disruptive to the entire multidisciplinary building design process.

Therefore, it is important for team members to first be aware of, then account for the difference in the project stages and timelines of the various disciplines. As this difference can occur across several disciplines, teams have to manage these differences to ensure effective communication.

Variation in the Breadth of Disciplinary Engagement

There was a difference in the breadth of engagement of the disciplines. Some disciplines had a narrow breadth of engagement while others had a wide one. Narrowly engaged disciplines (for instance, the structural engineers in Case 1 shown in Figure 4.10) had limited information requirements to and from other disciplines. Widely engaged disciplines (for instance the architects in Case 1, also shown in Figure 4.10) had their information requirements linked to several other disciplines.

Findings suggest that the range of disciplinary engagement influences when disciplines receive design information. Differences in the range of engagement have to be accounted for to ensure delivery of the on-time delivery of the right information.

Team members in Case 3 reported that in the earlier stages of the project, as the architectural definition of the design was being developed, disciplines with a narrow breadth of engagement focused on listening and understanding the project goals. For instance, the construction managers reported that they took a back seat early on: *"For us, being involved early means taking a back seat and listening and just understanding what the end users are looking for in the building."* As their engagement at this stage was narrow, the construction managers did not require design information early on, rather were interested in understanding the project requirements.

Similarly, the MEP engineers in Case 3, who also had a narrow breadth of engagement reported that earlier in design they did not require information from other disciplines:

"Early on, whether its the conceptual design or the schematic design, its more about what is the building going to look like. And then design development kind of focuses more on the details. Here, we spend a lot of focus on actually sizing the main mechanical equipment... the shafts, the boiler room... planning out the boiler room, how we vent the boilers, how we vent the water heaters, how water service comes into the building…"

Clearly, the mechanical engineers mostly required design information later in the project when they performed their tasks. While this implies that it may be better for the narrowly engaged disciplines to be involved later in design, findings also suggest that the narrowly engaged disciplines appreciated being a part of the team early.

Team members agreed that participating in design early, even when they did not require information, helped them understand the impacts of design and ask specific questions to influence the process. As reported by the civil/geotechnical engineers in Case 3: *"I think, once we get the specific details of a certain situation early, we ask very specific questions about doing further instigation or coming to conclusions about what to do and what not to do"*. Being involved early, allowed the civil/geotechnical engineers to be a part of the team and understand the impacts of the whole building design.

Accordingly, we can imply that while disciplines with a narrow breadth of involvement receive information and are more involved later in design, early involvement, as described in Finding 2 (p. 77), allows them to understand and influence the building design.

<u>Variation in Disciplinary Information Preferences</u>

There were differences in the information timing and delivery preferences of the disciplines. Findings suggest that these differences contribute to the on-time delivery of information in multidisciplinary building design.

Although not directly stated, team members gave the impression that engineering-based disciplines prefer scheduled deliverables, while in-person working meetings with more flexible delivery schedules were favored by the more design-based disciplines (the architect and the landscape architect). This creates opportunities for issues with the time of information delivery and missed deadlines since, as discussed earlier, disciplinary tasks intersect.

One possible reason for this may be that engineering disciplines generate exact, optimized outputs while the design disciplines engage in satisficing to identify an output, leading to a more iterative process than the more engineering disciplines (Simon, 1988). As a result of the iterative process followed by the design-based disciplines, having set deadlines for deliverables may not be the best approach. Design decisions and components would change repeatedly, disrupting the tasks of the more engineering-based disciplines.

This finding implies that the differences in disciplinary preferences for the timing and delivery of information is linked to differences in the problem-solving approach of the disciplines on the team. It is therefore necessary to account for these preferences of multidisciplinary building design teams. One possible approach that was offered involves the use of a master schedule or a work plan. The sustainability consultant in Case 3 reported that they used a work plan to manage the various information timelines and preferences on the multidisciplinary building design team.

5: Meeting characteristics reflect aspects of the information process which occur during multidisciplinary building design

Conventional wisdom has it that meetings are a necessary component of teamwork. Findings go on to suggest that meeting characteristics reflect aspects of the information process of multidisciplinary building design teams, shown in Figure 4.19: the type of meeting reflects the type of information process and documentation required, and the frequency of meetings reflects the amount of coordination required.

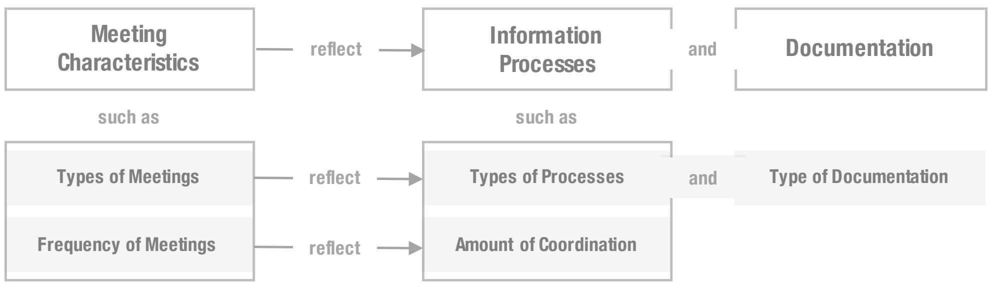

Figure 4.19 Meeting characteristics reflect aspects of information processes and documentation

Types of Meetings

There were two kinds of meetings that occurred in Cases 1 and 2: goal setting meetings and troubleshooting meetings. Findings suggest that the meeting types reflect two distinct information processes that occurred during design.

The goal setting meetings occurred early-on in design (from pre-design to schematic design), while the troubleshooting meetings occurred later in design (from schematic through design development). Figure 4.20 shows this relationship between the meeting type and the project stage.

The goal setting meetings aimed to get as many disciplines together to discuss requirements for the design. These meetings were mostly face-to face, either in person or using digital tools, and primarily involved just the leaders from the different disciplines. As reported by the architects in Case 1: *"Meetings with everyone in the same room, including the owner, in person. Those are not the meetings where you get all the wrinkles ironed out, but those are the meetings where you get all the expectations ironed out"*. These meetings addressed the team expectations, and in Cases 1 and 2 were easy to set up as the team members were in the Pittsburgh area.

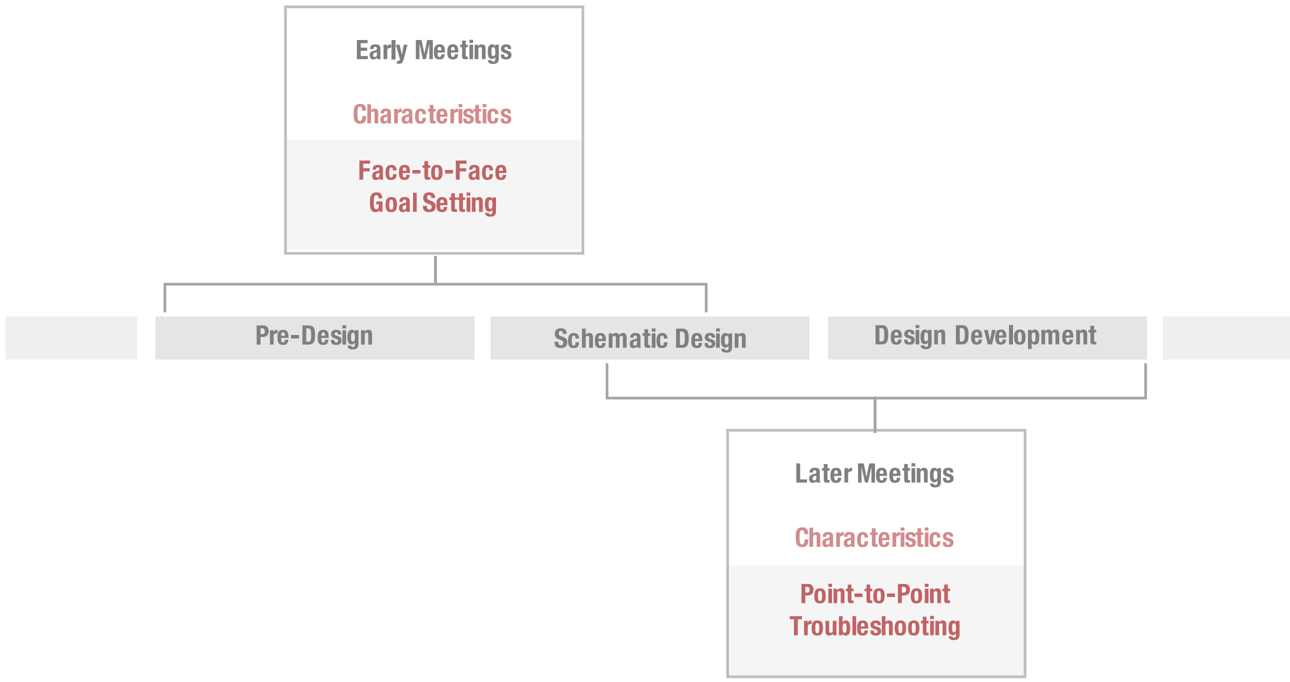

Figure 4.20 Meeting types by project stage

On the other hand, the troubleshooting meetings aimed to iron out kinks. The troubleshooting meetings were targeted, point-to-point meetings between specific individuals on the team. These targeted interactions were necessary to obtain or clarify specific information from a specific discipline. Team members reported that this happened later in the project as members of the different disciplines became familiar with the project, and with each other. Regardless, as much as possible, the architects were always formally aware of the interactions between the different disciplines.

The main advantage of the face-to-face, goal setting meetings was that the disciplines could work side by side with each other and review drawings and models with each other. The limitation was that this was not always feasible and could add to project costs. Whereas, the main advantage of the targeted, troubleshooting interaction was that they could reach out to each other to iron out and resolve discipline specific issues. However, this approach had limitations where changes could occur that all disciplines were unaware of.

The civil engineers in Case 1 provide an example that illustrates the transition from the goal setting meetings to the more targeted interaction. During pre-design, the civil engineering leader attended most of the goal setting meetings, playing the role of a coordinator between the entire design team and the civil specific team. However, further along the design process, the civil leader moved out of this role to allow the civil team members to engage in more targeted interactions with team members from the other design disciplines.

This finding also has implications for the exploratory framework, challenging the assumptions of the dual process model that functional diversity leads to information rich exchanges and categorization processes. Rather, the two types of meetings suggest that there are two distinct information processes that the model should account for: the process corresponding to the goal setting meetings, and the process corresponding to the targeted interaction meetings.

Models of the design process under the analysis-synthesis framework can be used to explain these two types of meetings. Under this analysis-synthesis framework of the design process, there is the diverging/converging model, shown in Figure 4.21, where during analysis, the process diverges to explore alternatives and create options while during synthesis, there is a convergent process on one (or more) option(s) (Cross, 1984; Dubberly, 2004).

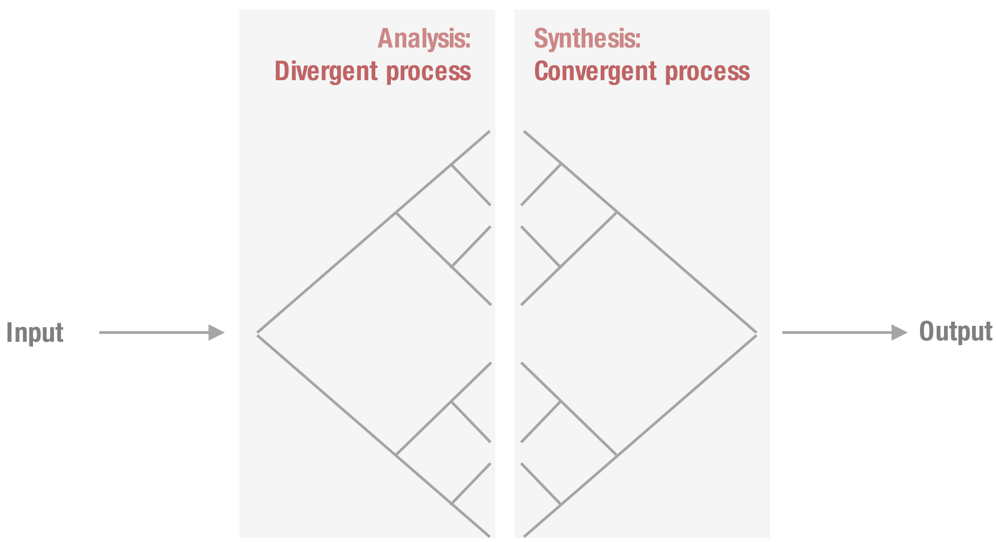

Figure 4.21 The diverge/converge design process model (Dubberly, 2004)

Applying this diverge/converge model to the meeting types and the information processes they represent, the goal setting meetings can be seen as the divergent information process where early on, there is an expansion of information due to the presence of different disciplines and different alternatives, while the troubleshooting meetings can be seen as the convergent information process where later on, there is a narrowing of information among disciplines and their alternatives.

A finding that was particularly interesting was that the meetings in case 3 did not follow the same model as that in Cases 1 and 2. In Case 3 where the design lead was based in New York while the other disciplines were based in Pittsburgh, there were regularly scheduled meetings with less of the targeted, point to point interactions. While this could be a result of the lead discipline, the architect wanting to be fully involved in the design process and in the interaction between disciplines, it also indicates the opportunity for future research on the effects of geographic dispersion on team meetings and information processes in general.

Meeting Documentation

Meeting documentation was necessary to keep track of the various design decisions, and changes made to the building design. Team members used different forms of meeting documentation to summarize meetings held. This finding suggests that using different forms of documentation to summarize meetings is important in building design.

Meeting minutes are useful because they provide a strong structure to guide meetings, particularly when they include the disciplines responsible for specific tasks and action items. Possibly the most important feature of meeting minutes, also reported by the project managers in Case 3, is that they clarify decision making and provide a reference for decisions made in the event of conflict or disagreement (Veerman, 2017):

"I think we need to redouble our efforts on documentation other than just the drawings. So, in terms of capturing meetings and sharing information proactively, I think those are going to be the things that will help us get through CDs without a whole lot of pain, and even if there is pain at least we'll have a record"

Team members are able to refer to the meeting minutes in the later design and construction stages, as they hold a record of decisions made in the earlier design stages.

Specifically, the architects' meeting minutes in Case 2 were identified as being very effective in sharing information and requirements with the disciplines. As reported by the landscape architects, this was because the minutes not only showed the decisions made but were targeted to the specific disciplines:

"the architects are very good about recapping the meetings, like meeting minutes and keeping record, I would say that. We stepped in when they – like that building is kind of complicated because its really just an addition, sort of, so they had a lot of stuff already thought through and they were good at explaining it to us because its really complicated"

The architects' minutes recapped the meetings and explained the decisions made. What was also effective about the minutes as reported by the MEP engineers was, rather than providing the disciplines with all of the details of the meetings, the architects' highlighted what was of importance to each discipline and provided clear action items:

"They've kept good meeting minutes that have definitive actions, rather than a lot of commentaries. Sometimes we got lost in commentary notes. But you need an action and then some backup from that action as to why you're doing it. So actually, it's pretty good so far."

A possible recommendation emerges from this finding. While different forms of documentation exist, using targeted minutes, rather than narrative or commentary style minutes may be best suited to multidisciplinary building design teams. Targeted minutes provide each discipline with their specific information, from which team members can identify their specific action items, rather than having to sift through a lot of commentary. A potential limitation to targeted minutes is that all the disciplines may not always be aware of each other's action items and may be left out of the loop.

Frequency of Meetings

Team members from all three cases attended regular meetings but there were more frequently scheduled meetings in Case 3 than in Cases 1 and 2. As the design architects in Case 3 were remote, this finding suggests that the frequency and attendance of meetings represented the amount of coordination required on the project.

In team 3, as reported by the landscape architects, meetings were designed to be inclusive, occurring frequently and involving as many disciplines as possible to promote openness and have the disciplines all be familiar with each other: *"I think the biggest advantage to having the pretty regular communications happening especially with the design architecture firm being remote is that we get regular updates on what's happening so I think that's good."*

The frequent meetings helped address the challenge of the design architects being remote and meant that all the disciplines got to know each other. As reported by the transportation engineers:

"Like initially you need to get to know each other by phone or in person because we're human beings and not machines. It's really helpful to know with who you're speaking to and that you could recognize them in a crowd, so that's nice."

Getting to know each other allowed team members from different disciplines form relationships, and as reported by the site civil engineers, allowed them to be aware of all major decisions that were made regarding each other's tasks: *"The group-wide, design team wide communication at times was very beneficial because it exposed you to more of the project and at a better understanding of other disciplines and what design is used that they were working towards".*

This finding implies that frequent meetings among the disciplines in the building design team address coordination issues, particularly in geographically dispersed teams.

Research supports this implication that frequent interactions between all team members in geographically dispersed teams is beneficial to team functioning where frequent interaction between the team lead and team members promotes a sense of connection between the team members (Neeley, 2015).

However, it can be argued that having all disciplines involved in as many meetings as possible may be inefficient to the building design process. This limitation was discussed by team members who reported that meetings took a lot of time, and team members were not always certain if or when they were needed in the meetings as there was a lot of information to sift through.

As the multidisciplinary nature of building design means as the various disciplines on the team work within their individual disciplinary areas, there needs to be enough time for the disciplines to actually work on their task. Thus, while taking the attending meetings with the other disciplines is beneficial to an extent, there also needs to be room for the disciplines to work on their aspects of the building design problem.

The findings on communication as an information process support conventional wisdom and recommendations on teamwork that effective communication depends on the on-time delivery of information, and meetings and their characteristics are important to building design.

Again, similar to findings on the multidisciplinary building design team, there are underlying factors and relationships within these findings. Findings also show that the on-time delivery of information depends on accounting for the variations in disciplinary information timelines and preferences, and meeting characteristics reflect different team information processes.

These findings have implications for the exploratory framework and also provide a recommendation for multidisciplinary building design practice further discussed in Chapter 5.

The Use of Communication Technology

The use of communication technology, discussed in Section 2.3 (*Communication and Building Design Teams*, p. 34), explores the interaction between the people and the tools that support information exchange between the disciplines. Two findings emerge from this exploration: the limited adoption of BIM contributes to issues of accuracy, and teams require additional functionality from project management tools.

6: The use of BIM is limited and contributes to its' issues of accuracy

Several disciplines in all cases reported the use of Building Information Modelling (BIM). Those that did not use BIM reported that it was unnecessary for their tasks. Those that did reported that while the use of BIM was beneficial to building design, issues with modelling accuracy limited the benefits for multidisciplinary teams.

The advantages of BIM for the design process are numerous and have been discussed by several scholars (for a recent overview of research on BIM, see Volk, Stengel, & Schultmann, 2014). BIM has greatly contributed to the improvements in the way building design teams work. As reported by the civil engineers in Case 2, one of its' main benefits to building design communication is the ability to visualize information and understand where things go and see the other disciplines ideas in 3D:

"We use something similar, meaning we use standard AutoCAD but the program that's specific to us is actually called Civil 3D… those two entities that the surface features, the topography, and then the utility networks are 3D Features which in turn allows you to get that third dimension feel for the site."

BIM allows the disciplines see each-others features and the intersections between them in ways they could not in 2D. In the multidisciplinary team, this should guarantee effective communication as accurate design information is shared among disciplines (discussed in Finding 5, effective communication depends on the on-time delivery of the right information. With BIM, disciplines should be able to share the right information).

However, the focus on the 3D visualization benefits make BIM unappealing to some disciplines whose tasks do not require such features. On the other hand, disciplines who used BIM reported that the design information in the model could be inaccurate. Inaccuracies occurred either due to issues with translating information from one disciplines BIM tool to another's, or due to the skills of the modeler (see Figure 4.22) as reported by the structural engineers in Case 1 and the MEP engineers in Case 3:

Figure 4.22 Current practices regarding the use of BIM limit the accuracy of design information in the model

"and this project we were the same Revit software but when that doesn't happen that can be a bit of a hindrance for us because their software does not translate to our very well"

"if we are just getting a model, a Revit model to do our MEP design, we have a procedure that cleans it up because there's just a lot of extra information that comes from that model... we don't need that and it would slow ours down cause the file sizes are so large."

A lot of research has looked into the issues of translation or interoperability between BIM tools (for a recent overview of research on BIM, see Volk, Stengel, & Schultmann, 2014). In addition, part of the issue with translating information from one BIM tool to another is that often, more information than is needed is received. The receiving discipline has to clean up the model which could cause the loss of some information leading to inaccuracy. As different disciplines often work off the same base model (using different tools), inaccuracies or inconsistencies introduced by one discipline greatly affect the work done by other disciplines.

Modelling skills – potentially limited by the current adoption of BIM – can lead to inaccuracies through mistakes and errors. As discussed earlier, team members specifically pointed to the 3D capability of BIM tools as the main benefit. This suggests that BIM is currently not being used as it should as, first, it is not as ubiquitous in practice as would be expected (some disciplines reported not having any use for BIM) and second, design team members view it only as a 3D modeling tool.

While issues with the translation and interoperability between BIM tools are important, they are not addressed in this dissertation. Rather, it is expected that issues related to modelling error might improve with further adoption of BIM. One possible recommendation is to encourage the adoption and use of BIM, which is further discussed in Chapter 5, involves increasing building design disciplines' understanding of BIM

7: Teams require additional functionality from project communication tools to support multidisciplinary building design

Technology was also used to facilitate face-to face interactions between the different disciplines through video conferencing tools and share documents through file sharing and project management tools. These tools are becoming increasingly useful as projects become more complex, and project teams become larger and geographically dispersed (in all fields, not just in building design).

With the exception of video conferencing tools, findings suggest that current tools that aim to support communication provide limited support for multidisciplinary building design, shown in Figure 4.23.

Figure 4.23 Current project management tools are limited to support building design team communication

While this is to be expected as majority these tools are not built specifically for use in building design, team members suggested that additional functionality can make them even more useful to building design teams.

Video Conferencing Tools for Meeting Facilitation

The use of video conferencing tools like WebEx and Skype for Business that allow screen sharing were described as being most useful to team member as they could point out issues and mark up drawings or models.

Findings suggest video conferencing with screen sharing eased the effects of having a remote lead discipline in Case 3. As reported by the structural engineers in Case 3: *"I find that yeah, the further and further web conferencing technology progresses, it seems the less and less I'm actually really going into architect's offices."*

Research which supports these findings suggests that geographically dispersed teams use virtual meeting tools which simulate the effects of working face to face (Gutierrez, 2015). These tools allow team members in geographically dispersed teams exchange information in ways would not be possible, although – as with all technology – unexpected issues may arise which limit their use or functionality for team members (P. J. Hinds & Bailey, 2003).

As it is not possible to always have local team members on all projects, this finding highlights the importance of these tools as being particularly necessary and highly useful for multidisciplinary teams with members working across several locations.

Project Management Tools to share Design Documents

Building design team members typically rely on file transfer protocol (FTP) sites to share documents with each other, when file sizes exceed the capability of email. FTP sites allow team members across disciplines access and store documents in a central location. However, there are challenges with the use of FTP. Setting up an FTP site requires significant startup requirements – an FTP server, accounts for each user, and a dedicated administrator; and tracking changes and updates to documents in the server can be difficult.

More recently, sharing and collaboration sites and applications such as DropBox and Box are used for building design. These tools can be integrated with team members desktops and allow them to share even larger files without the need for a server or administrator. These tools also track versions of documents allowing team members to identify the changes to design information. These sites are Having this centralized location to store and track documents is useful for building design teams as there is a large amount of documentation and record keeping, as discussed in Finding 5 (p. 97), in the design process.

Though they provide more functionality than FTP sites, team members specifically reported that the file sharing tools only serve as file storage – as they are designed to – and have no additional intelligence or capability. Project management tools such as PMWeb, Newforma, and Smartsheet, go a step further. In addition to providing team members with a central location for storing documents they also allow team members generate documents to support design - reports, budgets and so on.

Again, there are reported limitations to the current use of project management tools. Team members reported that the tools do not communicate with their design software, creating additional work for them, managing information between two different software. Also, in the multidisciplinary setting is these tools are usually firm, or discipline specific. Different firms use different tools that may not necessarily interact, leading to issues with translation across software – briefly discussed in Finding 6 (p. 100) – in the multidisciplinary setting.

These reported limitations seem to occur due a lack of awareness of these tools and their current functionality. While the few team members who discussed these tools were aware of their benefits and features, others who were unaware but were asked about these tools expressed a reluctance to use them due owing to their belief of the creation of additional or unnecessary work.

Even when aware of their benefits, as reported by the construction managers in Case 2, these tools may not be used to their full capability: *"And then, so we're not using it to its full capability yet, but one of the things that we have starting to implement is a form of cloud-based project management software."*

Since these tools contribute to the ease of working and sharing documents between building design disciplines, increasing awareness to building design firms, and their functionality for building design could make them more useful.

Exploring the use of communication technology focuses on the interactions between team members and the tools they use for design information. The findings on communication technology suggest that currently, the adoption of BIM contributes to issues with a models' accuracy, and existing project management tools require additional functionality to support building design.

Current practices regarding available tools and their use appear to be a factor influencing communication technology. Based on these findings, recommendations for multidisciplinary building design team practice that involve increasing practitioner's awareness of the currently available tools and how they function, discussed in Chapter 5.

MULTIDISCIPLINARY BUILDING DESIGN TEAM OUTCOMES

The third line of inquiry, described in Chapter 2, explores outcomes in multidisciplinary building design teams. Along this line of inquiry, team members were asked to discuss both positive design team outcomes, and negative design team outcomes that could be improved on. Findings suggest a difference between team members perceptions of outcomes, against outcomes as defined earlier in this dissertation.

8: Building design team members use perceptions of process rather than defined outcomes as a measure of their performance

Potential design team outcomes were identified in Section 2.4 (*Building Design Team Outcomes*, p. 43) as subjective or objective measures which could include: client satisfaction, design quality, innovation, delivery time, cost, and errors (Iezzoni, 1997; Teixeira et al., 2012). Findings suggest that rather than use these defined outcomes to assess their performance, building design team members use perceptions of process instead shown in Figure 4.24.

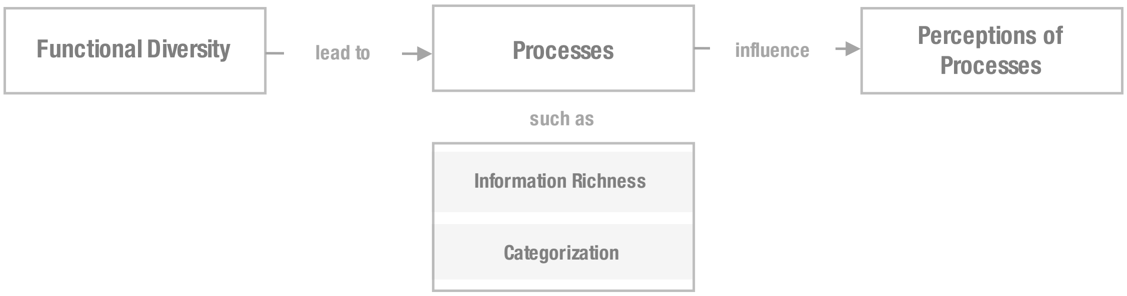

Figure 4.24 Functional diversity leads to team processes and perceptions of processes, rather than outcomes

At the outset, it is important to mention that there was almost a reluctance from team members to discuss their outcomes. One possible reason for team members were inability to discuss defined outcomes is that there are no defined outcomes of building design. Rather, the defined outcomes discussed in Section 2.4 (*Building Design Team Outcomes*, p. 43) are possibly better assessed during construction when there are physical artifacts to be measured.

Regardless, team members across disciplines in all cases pointed to processes – their ability to work well with each other, and their willingness to share information with each other – as positive outcomes.

In Case 1, team members reported that in spite of the project challenges, they were able to well together, keep up with the project changes, and share responsibilities effectively. As reported by the landscape architects:

"Like when we go into the next phase, I will and hopefully that's worth this project is going, its been a really good team. I think that that language, like good team, great process can generally as well come from the product that we get to implement at the end of the day and the ease at which we get to do it"

Clearly, the disciplines were sure they had a good and effective team owing to the ease with which they were able to perform their design tasks. Having clear expectations, a clear direction for the project, and set goals to accomplish contributed to achieving the positive outcomes described.

In Cases 2 and 3, team members reported that all the disciplines were aware of their tasks, responsive to all requests for information, and willing to share information with each other. As reported by the architects in Case 2, and the transportation engineers in Case 3:

"I think that the consultants know their discipline well enough that they can kind of jump on board quickly and get caught up and still kind of feel comfortable. And I think they understand the integrative process so going forward, I don't think there will be too many problems, but it's going to be a matter of how we lead the process"

"I think in the end, things have worked out okay. The design is something that's going to be functional and that's going to work. I thought the we listened to each other and the design architects team actually you know, listen to the consultants who are more familiar with local requirements and they took it seriously."

As the various disciplines knew their tasks well enough, they were able to work well together owing to their familiarity with the process, with the project goals, and by listening to each other. Again, this shows how team members used their perceptions of process as positive team outcomes.

Perceptions of process and the teams' response to challenges were also used as negative outcomes. Team members in all the cases were even more unwilling to discuss negative outcomes or outcomes that could be improved. The most common reason given for this was that the projects were still ongoing. When pressed, most negative outcomes discussed were related to time constraints and scope changes.

Case 1 provides the most detailed discussion on outcomes that can be improved. Team members reported that given enough time and if clear expectations were established early on, they could have produced a perfect delivery package. Due to project challenges – time pressure and scope changes – some information fell through the cracks during design. As reported by the MEP engineers:

"No. I think with this project, it was difficult because of the time frame. I know that early on, we were kind of going down the road in a certain direction and its not just a direction change at all, but the goal of like the time frame of whenever we had to have documents done from a preliminary standpoint and a final standpoint, that's kind of got cut in half, which is the mad scramble of getting information on drawings. Like you try, you have standards, but when push comes to shove and you have to react, you just you do what you got to do to kind of keep your head above water"

In other words, the MEP engineers believed that in dealing with the project challenges, team members did their best to accommodate the challenges while still performing their tasks. By discussing 'negative' outcomes in this way, team members suggested possible improvements in their responses to project challenges (the teams' process) without pointing to specific or defined outcomes. This suggests that perceptions of the teams' process were used by team members as negative outcomes.

It is again worth mentioning that as the project in Case 1 was in four phases, team members expressed team their willingness to discuss and address possible improvements in their responses to the phase one project challenges, before moving on to the next project phase.

The findings from the third line of inquiry suggest that outcomes as originally defined in this dissertation do not represent design team views. Rather design disciplines rely more on measures of team functioning and processes to assess how well or how poorly they are doing. This suggests that it is necessary to modify to the outcome portion of the exploratory framework, and reexamine multidisciplinary building design team outcomes, presented in Chapter 5.

4.3: SUMMARY

Three cases of multidisciplinary building design teams were studied in this dissertation. Data was collected using in-depth interviews from a total of 32 team members on completion of the design stages – schematic design, and design development – and was analyzed using content analysis and communication analysis described in Chapter 3.

Guided by the exploratory framework also introduced in Chapter 3, this study provides descriptions of the multidisciplinary team, the teams' communication across three categories – communication as social behavior, as an information process, and the use of communication technology – and the teams' outcomes.

The findings on the multidisciplinary team suggest that:

> **1:** A team's organization reflect its contracts which are modified by four key project and team characteristics: the project delivery approach, the role of the project manager, preexisting social and processional relationships, and the location and geographic proximity of the disciplines. Other characteristics outside this research may exist.
>
> **2:** Although disciplines prefer early involvement in building design, often times these preferences are not met. Actual involvement depends on how fundamental the disciplinary tasks are, and the significance of the discipline's role on the team.

The findings on multidisciplinary building design team communication suggest that,

> Regarding communication as social behavior:
>
> **3:** The flow of information between disciplines is primarily determined by shared tasks. In addition to shared tasks, information flow is somewhat determined by two project and team characteristics – the project stage, and the preexisting social and professional relationships among disciplines.
>
> Regarding communication as an information process:
>
> **4:** Effective communication involves the on-time delivery of the necessary information among disciplines. On-time delivery is difficult; therefore, disciplines must account for variation in their information needs resulting from differences in:

the timing of information requirements, and the deadline preferences of the different disciplines on the team.

5: Two meeting characteristics – the type and frequency of meetings –reflect the types of information process, documentation, and amount of coordination which occur during multidisciplinary building design.

Moreover, regarding communication technology:

6: Team members currently use Building Information Modelling (BIM) as a 3D visualization tool. This use is limiting, preventing some disciplines from adopting BIM, and contributing to inaccuracies in design information owing to modelling error.

7: Project communication tools allow team members store large files, track changes to documents and generate reports. Although they are an improvement on typically used file sharing systems, they require additional functionality to support building design practice.

Finally, the findings on multidisciplinary building design team outcomes suggest that:

8: Rather than defined outcomes as discussed in Chapter 2, building design team members use perceptions of process – functioning, engagement and communication – as a measure of their performance.

These findings mainly provide support and evidence for our commonsense intuition. But, they also provide descriptions of multidisciplinary building design practice, suggest modifications to the exploratory framework, and suggest possible recommendations for building design practice discussed in Chapter 5.

5: DISCUSSION

5.1: SYNTHESIS OF FINDINGS ALONG EACH LINE OF INQUIRY

The multiple case studies explored real-life multidisciplinary building design team practice. It was expected that by providing an accurate representation of practice, the cases would contribute to filling the earlier identified knowledge gaps on building design team communication and outcomes discussed in Section 1.2 (*Research Gaps*, p. 7), and possibly highlight strategies used by multidisciplinary building design team members to achieve positive outcomes.

Data was obtained from three cases using interviews as the primary method of data collection. In total, 32 team members were interviewed, with at least one team member interviewed from each discipline in each case. The data obtained was coded and analyzed along each line of inquiry guiding this research: What constitutes the multidisciplinary building design team? How do multidisciplinary building design teams exchange information? What are multidisciplinary building design team outcomes?

The case study findings, described individually in Section 4.2 (p. 68) comprise several factors and relationships which contribute to each line of inquiry. This section – and the broader chapter – reexamines and more importantly, synthesizes the individual findings to: identify the commonalities and patterns that satisfy the research questions along each line of inquiry outlined in Table 3.1; suggest a relationship between functional diversity, team communication and outcomes; and, validate and modify the exploratory framework introduced in Section 3.1 *(The Exploratory Framework, Lines of Inquiry, and Research Questions*, p. 47).

LINE OF INQUIRY 1: MULTIDISCIPLINARY BUILDING DESIGN TEAM

The first line of inquiry explores multidisciplinary building design teams to identify the disciplines on the team, their features and influencing factors. Three research questions are posed along this line of inquiry:

a. What disciplines comprise a multidisciplinary building design team?
b. How are these disciplines organized?
c. What factors influence the team, its formation, organization, and tasks?

The case study findings on the multidisciplinary team largely satisfy these questions by suggesting the following: the disciplines on the multidisciplinary team can be categorized into two – a core set and an 'ancillary' set of disciplines; and, building design team communication and outcomes are mainly influenced by two fundamental factors – project and team characteristics, and shared disciplinary tasks. The findings suggest that there may be more to the functional-diversity communication relationship, and indicate the need to modify the inputs of the exploratory framework.

Core Disciplines and Ancillary Disciplines

Findings suggest that two categories of disciplines comprise multidisciplinary building design teams: a core set of disciplines, and an ancillary, supporting set of disciplines. Core disciplines are those that are essential for a specific multidisciplinary building design project type, while supporting disciplines are those that are non-essential but required based on the project specifics.

It follows, therefore, that from this categorization, there is a core set on all multidisciplinary building design projects, with the caveat that the project type may determine the specific disciplines in the core set. For example, it is natural to expect a different core set of disciplines for renovation projects, compared with redevelopment/new construction projects.

A representative example of a core set of disciplines can be identified if we take the most frequently occurring disciplines in the three cases – each involves a new construction project. Six disciplines form the core set shown in Figure 5.1: Project managers, Architects, Landscape, Architects, Civil Engineers, Structural Engineers, and MEP Engineers.

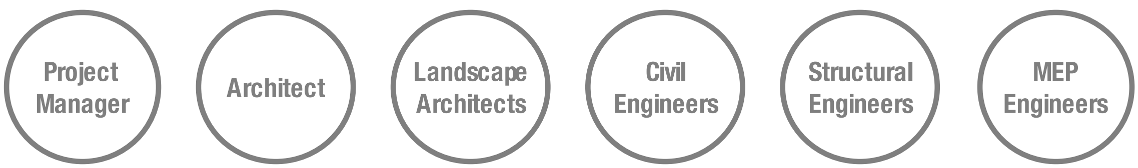

Figure 5.1 The core disciplines on the multidisciplinary building design team

These six disciplines are present in each case, leaving all other disciplines as ancillary, for instance, the Acoustic Engineer who dealt with the specific sound challenges posed by the maker space in Case 2, or Transportation Engineers who were required for the site and access issues in Case 3 (see discussions in the individual case reports in Appendix D) are among the ancillary disciplines.

<u>The Functioning of Core Disciplines</u>

To take this claim further, this research posits that the core disciplines should function differently to the supporting disciplines, acting in the manner of a cohesive subgroup within a social network (Wasserman & Faust, 1994). As cohesive subgroups within networks can be identified by closer and more frequent relationships between their members; accordingly, this research suggests that the core set of disciplines have frequent interactions and function more like an interdisciplinary subgroup. Disciplines in the core set need to have an understanding of each other's tasks, and may benefit from having a shared language, which can potentially address issues of fragmentation and silo culture that challenge multidisciplinary building design team communication, previously discussed in Section 1.1 (*Functional Diversity, Fragmentation, and Multidisciplinary Building Communication*, p. 3).

As an interdisciplinary subgroup, a core set of disciplines should function as a 'super-discipline" with its' specific preferences, requirements for involvement, and organization. However, counter-intuitively, the categorization of disciplines into core and ancillary sets only affects the involvement of disciplines in the team, but does not appear to affect their organization in the team.

This research also posits that core disciplines on the multidisciplinary team be involved early based on the case study findings. Finding 2 (p. 77) suggests that disciplinary tasks determine the involvement of disciplines on the team and Finding 4 (p. 92) suggests that the timing of disciplinary involvement depends on the breadth of disciplinary tasks and roles. It is expected that core disciplines – the disciplines whose tasks are not only essential to building design but also broad, requiring information and input from several disciplines – are should be involved earlier than those with non-essential and narrower tasks.

While findings also suggest that all disciplines prefer to be involved early (Finding 2), this research acknowledges that project constraints can limit early involvement of all disciplines, therefore core disciplines be involved earlier than the ancillary disciplines. This is not to say that the ancillary disciplines should not be involved early if possible, rather the early involvement of the core disciplines should be prioritized.

Surprisingly, prioritizing the involvement of core disciplines does not have a bearing on the importance or organization of the disciplines on the team. As core disciplines are always on the team for any building design project to occur, we would expect that this distinction between the core and ancillary set would affect the team organization. Instead, the organization reflects the contracts between disciplines on the team.

Perhaps the reason for this lies in the meaning attributed to team organization, which in this research, indicates the connections and structure among disciplines. We speculate that, as discussed in the previous section, if the core set of disciplines are a subgroup within the disciplines, this should affect the frequency of their interactions without affecting who was connected to who.

Factors Influencing the Multidisciplinary Building Design Team

The exploratory framework in Section 3.1 *(The Exploratory Framework, Lines of Inquiry, and Research Questions*, p. 47) included team characteristics as a component to be explored, that contributes to the effects of functional diversity on building design team communication and outcomes. This research identifies two additional factors that are fundamental to multidisciplinary building design practice: project characteristics and shared disciplinary tasks

These factors were identified from the hierarchy that emerges when considering the commonalities across the case study findings, illustrated in Figure 5.2.

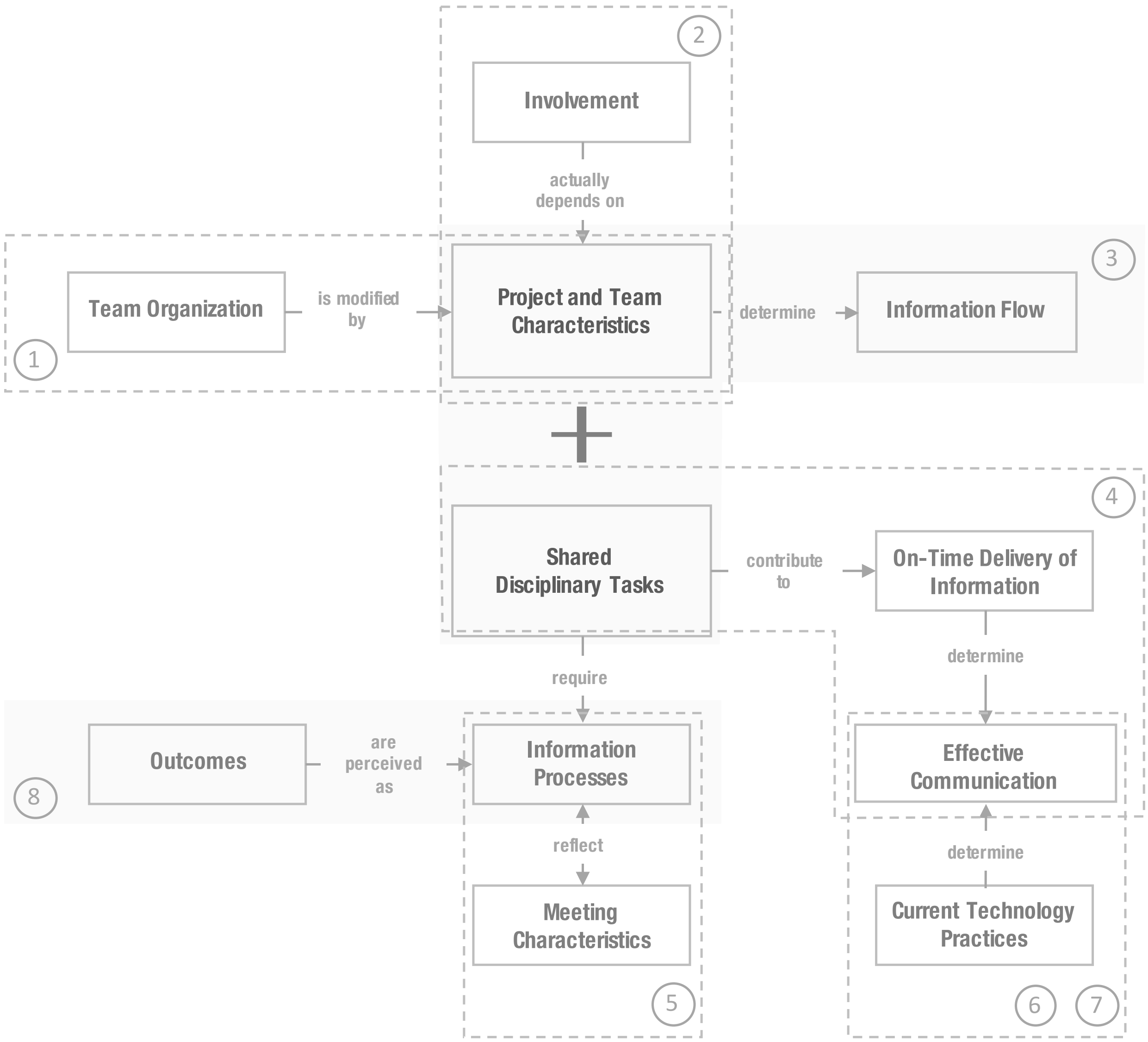

Figure 5.2 Connections between the eight case study findings

The figure shows that project and team characteristics, and shared disciplinary tasks are common to most of the case study findings. This research posits that the commonalities among findings suggest an order of importance and influence where the project and team characteristics, and shared disciplinary tasks are most important and fundamental to multidisciplinary building design practice.

Project and team characteristics were common to Findings 1 to 3 – they modify team organization, contribute to actual disciplinary involvement, and determine information flow as shown in Figure 5.3. Shared disciplinary tasks were common to Findings 3 to 8 – they determine information flow patterns, require information processes, and contribute to effective communication.

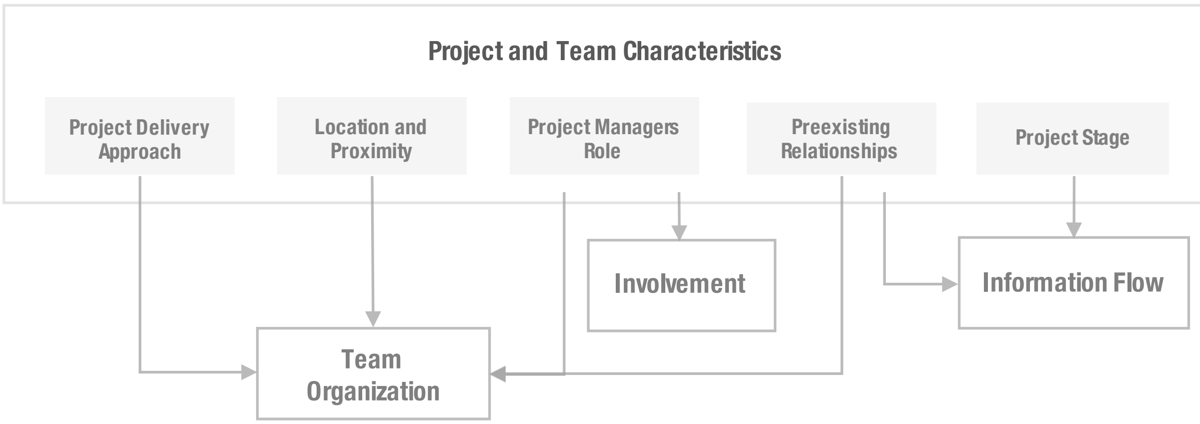

Figure 5.3 The project and team characteristics in the case study findings

Project characteristics from the case findings include: the project challenges described in Section 4.1 (*Case Characteristics*, p. 65); the project delivery approach and project location that contributes to team organization (Finding 1); and, the project stage that contributes to information flow (Finding 3). Team characteristics from the case study findings include: the geographic proximity of the disciplines, the project manager's role, and preexisting relationships. All three contribute to the team organization (Finding 1), the project managers role contributes to the involvement of disciplines on the team (Finding 2), and preexisting relationships contribute to information flow (Finding 3).

This research further posits that of the project and team characteristics identified in the cases, the role of the role of the project manager and preexisting relationships between disciplines are more influential to building design practice. The two characteristics each contribute to two categories of findings, and as such are more common to the case study findings.

This research posits that a core set of disciplines exist on multidisciplinary building design teams though the specific disciplines may vary by project type. This core set could function as an interdisciplinary subgroup, and their early involvement needs to be prioritized. This research also posits that in addition to team characteristics, two factors are most fundamentally to building design practice: project characteristics and shared disciplinary tasks.

LINE OF INQUIRY 2: MULTIDISCIPLINARY BUILDING DESIGN COMMUNICATION

The second line of inquiry explored communication in multidisciplinary building design teams to identify the patterns, processes and technology of information exchange. Four questions were posed along this line of inquiry:

a. What modes and tools do team members use to exchange design information?
b. Do these forms, modes, and tools vary by disciplines on the team?
c. Do team members take advantage of the information rich environment that exist because of functional diversity?
d. Do categorization processes, also attributed to functional diversity, influence team communication?

The case study findings on multidisciplinary team communication satisfy these questions by suggesting the following: communication preferences can be categorized by discipline; information flow patterns and meeting types indicate the team's information processes; and the current use of BIM and Project Management (PM) tools is limited. These findings point to the importance of timing to multidisciplinary building design practice and offer modifications to the inputs and processes of the exploratory framework.

Categorizing Team Communication Preferences

All disciplines expressed preferences, not just for the timing of their involvement on projects, but also in their modes and tools of information exchange, including how and when they preferred to receive design information. Findings suggest that these communication preferences vary by discipline, but also can be categorized by the type of discipline. As discussed in Finding 4 (p. 93), some disciplines prefer to work alone and deliver design information with set deliverables while others prefer working with other disciplines and deliver information on a flexible schedule, and the design based discipline's preferences differ from the engineering based discipline's preferences.

It was suggested that differences in communication preferences could be attributed to the different problem-solving approaches used by the design and engineering based disciplines where the design disciplines (Architects and Landscape Architects) attempt to find a satisfactory solution, while the engineering disciplines attempt to find an optimal solution (Simon, 1988). Differences in preferences could also be attributed to the variation in disciplinary requirements and timelines discussed in Finding 4 (p. 90).

However, this research posits that there is another explanation for the differences in communication preferences among disciplines where the core discipline's preferences vary from the ancillary discipline's preferences. If we expect the core disciplines to behave in similar ways and function as an interdisciplinary subgroup, then, based on the definition of interdisciplinary in Section 2.1 (*Multidisciplinary Teams versus Interdisciplinary Teams*, p. 18), the core disciplines should also have similar preferences. We expect the disciplines in the core, interdisciplinary subgroup to function as a single 'super-discipline' where the different disciplines work jointly on all aspects of the problem, share all tasks, and have common roles. As findings suggest that preferences vary by discipline, this super-discipline's preferences should differ from those of the ancillary disciplines on the building design team.

While this categorization of preferences is mainly speculative, it suggests an area for future research involving an in-depth examination of the functioning of core disciplines on multidisciplinary building design teams.

Information Flow Patterns, Meeting Types and Information Processes

Findings from the case studies suggest that there are two distinct information flow patterns and building design team meeting types. The team information flow patterns varied as the project progressed. There was an earlier pattern with distinct task-based subgroups (see Figure 4.13), and a later pattern with denser, two-way connections between the disciplines (see Figure 4.14). These patterns were attributed to the team working in the goal space earlier in design and in the solution space later in design, per Badke-Schaub's goal/solution space model (see Figure 4.15).

The two types of meetings held during building design echo these information flow patterns: goal-setting meetings and troubleshooting meetings. The goal setting meetings were held earlier in the process to identify and define the project requirements, while the troubleshooting meetings held later during design to resolve specific issues between disciplines.

This research posits that combined, these findings indicate the presence of two information processes: an earlier information-rich goal-related process followed by a later targeted, one-on-one, interaction process shown in Figure 5.4.

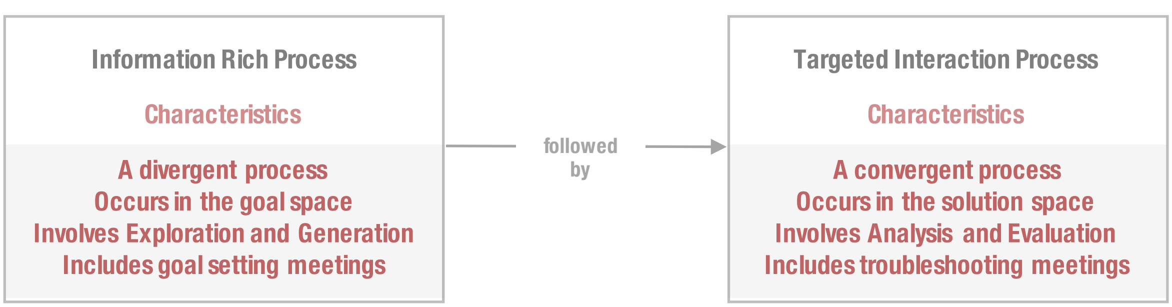

Figure 5.4 The information rich and targeted interaction processes

This has implications for the communication as an information process portion of the exploratory framework (see Figure 3.1) where previously, based on the dual process model, the framework included an information-rich process and a categorization process.

Findings from the case studies suggest that first, there is an information-rich, goal setting process. Information richness, per the dual process model occurs as a result of the diversity of information present due to the different disciplines on the team. Findings on the patterns and the types of meetings suggest that while this information richness does occur, team members take advantage of it early in the design process, primarily when working in the goal space, at the goal setting meetings.

However, this information richness is not the only process required by building design teams. The complexity of building design problems and the multidisciplinary nature of the team means that eventually, as team members work in the solution space, more targeted interactions occur. The additional targeted interaction process follows the information rich process, occurring later on in the design process as team members work in the solution space, at the troubleshooting meetings.

These differences between the information processes of the initial exploratory framework and those identified from the findings is discussed further in Section 5.2 as a modification to the framework.

BIM and PM Tools

Findings from the case studies suggest that while there are advantages to BIM and Project Management (PM) tools, their current use is limited. BIM is currently used as a 3D visualization tool and PM tools are used for their document management features, but they can be used as much more. This research posits that the use of these tools can be improved by increasing the awareness of their current features and functionality.

<u>BIM as More Than a 3D Visualization Tool</u>

Case study findings suggest that BIM is primarily used for its 3D visualization benefits in multidisciplinary building design. While this is helpful as disciplines in the multidisciplinary team are able to see how the individual design solutions come together, this use of BIM for its visualization benefits is narrow.

BIM can be broadly described as a "shared representation of physical and functional characteristics" of a building or built object, which can be used to support building design and construction activities through "preplanning and design, clash detection, quantification and costing, data management" (Volk et al., 2014). Physical characteristics include the modeling of the physical components of building design – walls, windows, ducts – while functional characteristics include the parameters and properties of the components – dimensions, materials and so on.

The focus on visualization mainly addresses the representation of physical characteristics and largely leaves out the functional characteristics. This narrow use of BIM limits its adoption by disciplines who do not have the need for 3D visualization, as reported by the transportation engineers in Case 3:

"No, we have no use for it because of what we do, yeah. Well, right, and certain fields just not -- its not worth the expense of having it and getting people educated to use it and such when it absolutely is never used for any of our projects. Send me a PDF or send it to me in CAD so then I can use my software on it."

The transportation engineers expressed a preference for 2D rather than 3D representation. The result of this is that they see no use for the physical representation of BIM, and do not receive the benefits of its functional representation as well. Increasing the awareness of practitioners on the full capability will allow teams to obtain the benefits of BIM not only as a physical, but also as a functional representation of the building's design.

The Functionality of Project Management Tools

Finding from the case studies suggest that project management tools require additional functionality to support building design. Team members reported that as PM tools do not communicate with their design tools, this creates additional work in order to manage the information between the two different tools. However, it is evident that these tools are useful and have untapped functionality that can be adapted to building design (A survey of project managers conducted in the UK found that about 77% of project management professionals from several industries use these tools to some extent (White & Fortune, 2002)).

A rudimentary examination of existing project management tools summarized in Table 5.1 shows the range of functionality of these tools that building design practitioners may not be aware of including: document management, schedule management, compliance management, and task management. (A descriptive list of the project management tools examined is included in Appendix C).

Table 5.1 Summary of current project management tools

Project Management Tools		Number (Percentage)
Targeted Users	**For construction teams only**	18 *(50%)*
	For design and construction teams	18 *(50%)*
Features and Functionality	**Document Management** Storage and track of building design and construction documents – drawings, reports, budgets, meeting minutes etc. – within a central database.	24 *(67%)*
	Financial Accounting and Budgeting Manage all project costs including billing, budgeting, project cash flow records. Document changes and update costs as changes occur.	12 *(36%)*
	Task and Schedule Management Track and update team member tasks and how they relate to the overall project schedule.	10 *(20%)*
	Bid/Contract Management Track sub-contractor vendor lists, invitations to bid and all activities involved in the bid process.	10 *(20%)*
	Compliance Management Tracks requirements and manages documents required for compliance with regulatory codes and standards.	2 *(6%)*
	Commissioning and Operations Management Auto-populate records and forms including punch lists to streamline commissioning and operations activities.	3 *(9%)*

The bulk of the tools examined were designed for use in construction teams. Of the thirty-five identified project management tools (construction project management, program management, or portfolio management tools) specifically for the building design and construction industry, 68% were specified for use with construction teams, while only 32% were specified for both design and construction teams.

It makes sense that PM tools are built for both design and construction teams as these processes are interdependent. But even the ones for both design and construction teams are marketed towards the construction end of projects and leave out design.

This research posits that features that seem most suited to construction teams can also be applied to building design teams and their tasks. Document management provides teams with the ability to store and track documents and is their most common and easily applied feature. Compliance management and task/schedule management are two features that can also be applied to multidisciplinary building design teams. Compliance management can be used to check the progress of the building design against codes, and task/schedule management can be used to keep track of the various disciplinary design tasks and components on the project, preventing important information from falling through the cracks.

This research posits that there are three building design team information processes that occur, rather than just the two suggested by the dual process model, that is: an information rich process followed by a targeted interaction process and a categorization process. This research also posits that communication preferences can be categorized according to disciplines in which core disciplines have similar preferences which may differ from those of the ancillary disciplines. Lastly, this research indicates that there are functionalities of BIM and PM tools that design teams are not taking advantage of. These have implications for the exploratory framework as they suggest modifications both to its inputs and processes.

LINE OF INQUIRY 3: MULTIDISCIPLINARY BUILDING DESIGN TEAM OUTCOMES

The third line of inquiry explores outcomes of building design teams to identify the ways in which team communication processes influenced team outcomes. Three questions were posed along this line of inquiry:

a. What do team members identify as positive and negative team outcomes?
b. What outcomes can be attributed to an information rich environment?
c. What outcomes can be attributed to categorization processes?

The case study findings imply that it is necessary to redefine building design team outcomes. In contrast to specific outcomes discussed in Section 2.4 (*Building Design Team Outcomes*, p. 43), for example, cost, innovation and design quality. team members use their positive and negative perceptions of process to assess their performance on how well they: are able to work together; keep up with the project changes; and share responsibilities (although team members were less likely to discuss negative perceptions). This suggests a modification to the outcome components of the exploratory framework.

There is research to support this finding, and suggests that there is a distinction between team and project outcomes, although, in practice, typically, both outcomes are equated together (Anantatmula, 2010; Munns & Bjeirmi, 1996). A simple explanation for this distinction is that it is possible to have a successful team work on an unsuccessful project. Similarly, it is possible to have an unsuccessful team work on a successful project. This is possible because a teams' primary objective is to implement the project. Therefore, team outcomes are related to how they were able to implement the project which would explain why team members discuss their perceptions of the process as outcomes, while project outcomes would include the quality of the design, and how well the project was able to achieve its established goals.

Consequently, this research posits that there is a distinction between team outcomes and project outcomes as the latter are dependent on more than just the team inputs. Other factors, including the project features and challenges discussed in Section 4.1 (*Case Characteristics*, p. 65) contribute to overall project outcomes. Based on this distinction, it is likely that the framework for studying team communication and outcomes would be different from that for studying project communication and outcomes as project outcomes would include, but go beyond team outcomes.

These commonalities and patterns that emerge from the synthesis of the case study findings have implications for the following: the relationship between functional diversity, communication and outcomes in the multidisciplinary building design team; the exploratory framework; and by extension, the dual process model. These findings also offer recommendations for multidisciplinary building design practice discussed in the sections that follow.

5.2: MODIFYING THE EXPLORATORY FRAMEWORK

When we take into account the commonalities between the case study findings discussed in Section 5.1 (p. 109), it becomes apparent that the initial exploratory framework introduced in in Section 3.1 (*The Exploratory Framework, Lines of Inquiry, and Research Questions,* p. 47) needs to be modified to fully capture the complexities of multidisciplinary building design team communication and outcomes. This modification is based on the relationships in the case study findings, and suggests that that the dual process model can be expanded.

FUNCTIONAL DIVERSITY – COMMUNICATION – OUTCOME RELATIONSHIP

Guided by the exploratory framework in Figure 5.5, this research suggested a relationship between the functional diversity in multidisciplinary building design teams, team communication and outcomes.

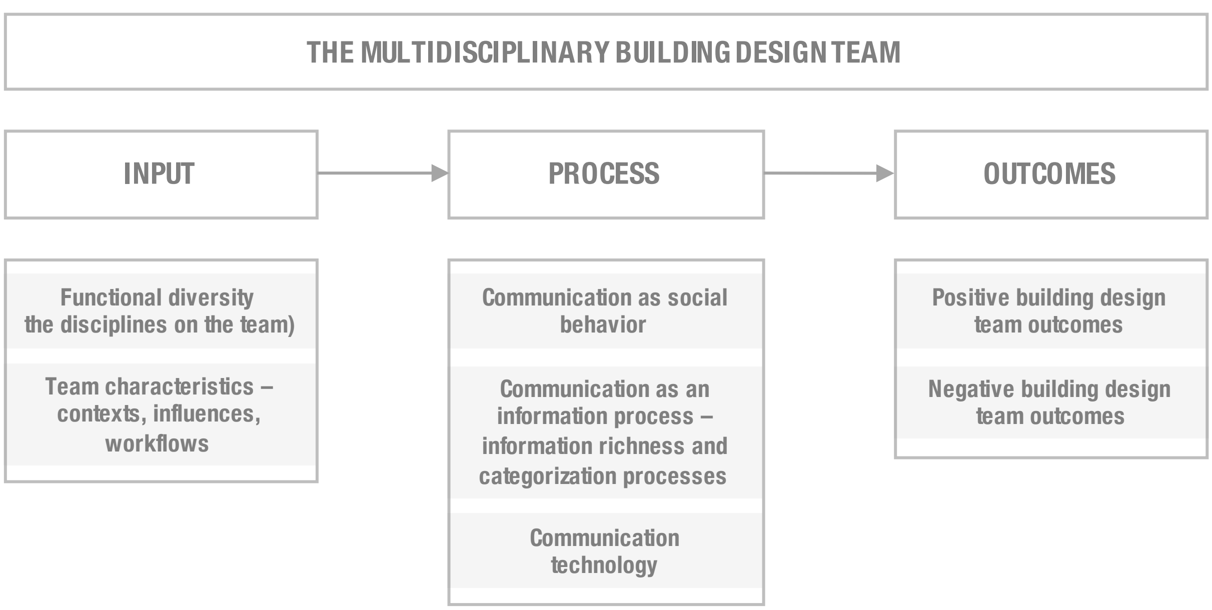

Figure 5.5 The initial exploratory framework introduced earlier in this dissertation

This relationship, illustrated in Figure 5.6 combined aspects of the input-process-outcome model discussed in Section 2.2 (*Diversity in Teams*, p. 20), the dual process model of diversity discussed in Section 2.2 (*The Dual-Process Model of Diversity*, p. 28), literature on functional diversity discussed in Section 1.1 (*Functional Diversity, Fragmentation and Multidisciplinary Team Communication*, p. 3), and on design team communication discussed in Section 2.3 (*Communication and Building Design Teams*, p. 32).

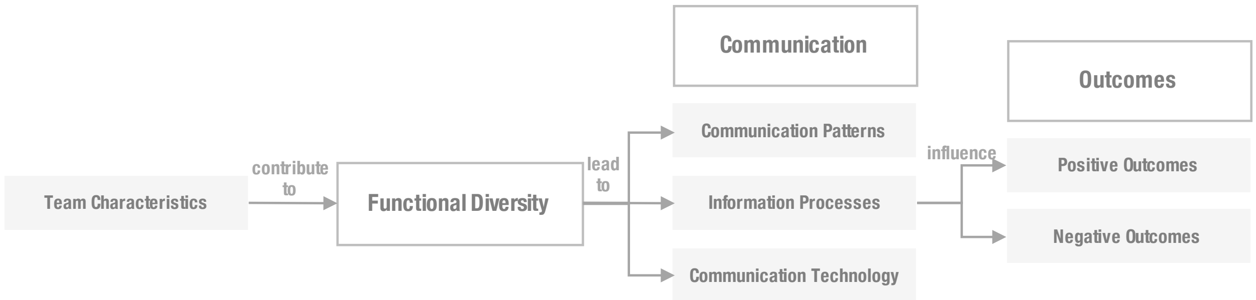

Figure 5.6 The initial functional diversity – communication – outcomes relationship

This research initially suggested the following: functional diversity as an input influences team communication and team outcomes; it leads to both positive and negative team outcomes through different information processes, and influences the social behavior and use of technology categories of communication; and, team characteristics are a factor that contributes to the effects of functional diversity on multidisciplinary building design team communication and outcomes.

However, the synthesis of the case study findings provides additional insights that shed light on this relationship and expand it as illustrated in Figure 5.7.

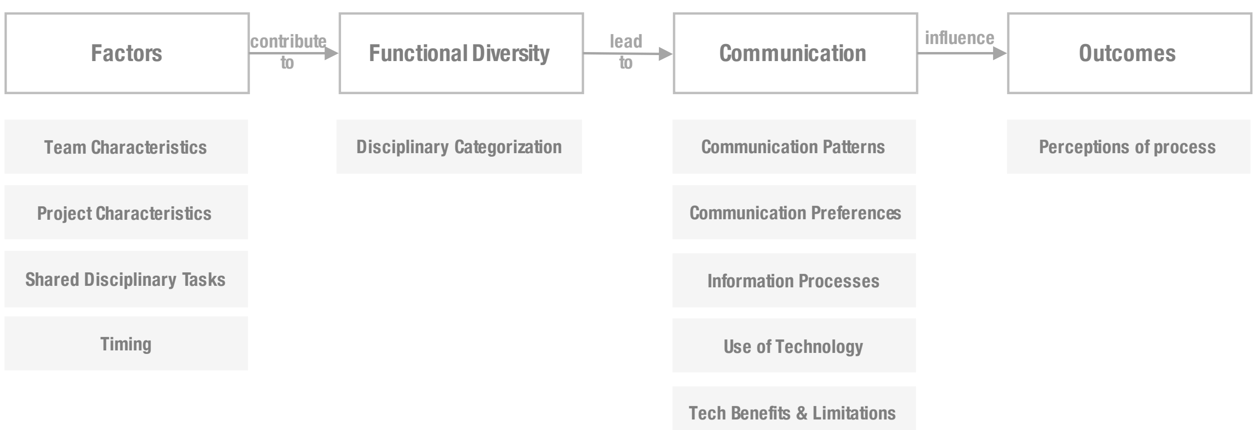

Figure 5.7 The functional diversity – communication – outcomes relationship suggested by the findings in the case studies

Based on the case study findings, this research suggests a more accurate, detailed relationship between functional diversity in the multidisciplinary building design team, its' communication and outcomes that includes two additional process models. This research suggests:

a. In addition to functional diversity, disciplinary categorization and the presence of sub-groups on the team influences building design team communication patterns, preferences and outcomes (*Line of Inquiry 1: Multidisciplinary Building Design Team*, p. 110).
b. Project characteristics and shared disciplinary tasks are also factors that contribute to the effects of functional diversity on team communication and outcomes (*Line of Inquiry 1: Multidisciplinary Building Design Team*, p. 111).
c. Timing also influences the multidisciplinary building design team, its communication and outcomes. Specifically: the project stage influences communication patterns and information processes per the goal space/solution space model and the diverging/converging model; and current practices influence the use of technology, its benefits and limitations (*Line of Inquiry 2: Multidisciplinary Building Design Communication*, p. 114).
d. The functional diversity, disciplinary categorization in the multidisciplinary team, influencing factors and communication all contribute to the team's perception of processes and team functioning (*Line of Inquiry 2: Multidisciplinary Building Design Communication*, p. 119).

This relationship from both literature and the case study findings suggest that the exploratory framework needs to be revisited. Revising the framework is necessary to accurately capture the nuances and complexities of multidisciplinary building design communication. This should increase our understanding of multidisciplinary building design teams as a critical first step to improving communication in multidisciplinary building design teams.

THE EXPLORATORY FRAMEWORK REVISITED

The initial exploratory framework in Figure 5.5 suggests that in order to study multidisciplinary building design team communication and outcomes, it is necessary to describe and analyze the following: functional diversity and team characteristics as inputs; the three categories of communication as processes; positive and negative team outcomes; and the relationships between them.

However, the findings in the cases studied suggest that this initial framework should be modified to accurately describe and analyze multidisciplinary building design team communication and outcomes. To account for these findings, the framework's inputs are expanded, its' processes redefined, and its outcomes replaced, shown in Figure 5.8.

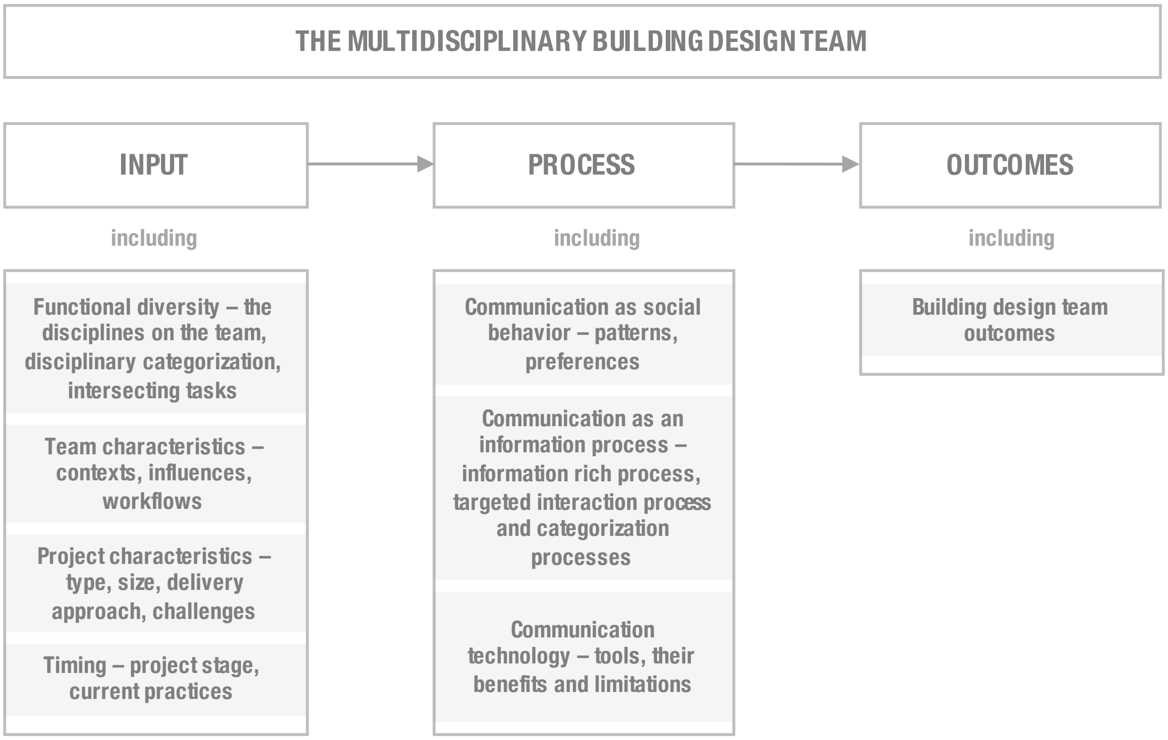

Figure 5.8 The revised exploratory framework

The changes to the framework are discussed below:

The Exploratory Framework Inputs

The synthesis of findings on the multidisciplinary building design team discussed in (*Line of Inquiry 1: Multidisciplinary Building Design Team*, p. 109) and the relationship discussed in the previous section suggest that understanding multidisciplinary building design team communication requires describing and analyzing additional components: project characteristics and timing. In this revised framework, functional diversity is also redefined as an input.

The inputs of the modified framework keep functional diversity and the team characteristics as components. Functional diversity is expanded to include the disciplinary categorization and shared disciplinary tasks, which also contribute to multidisciplinary building design team communication and outcomes. In contrast, team characteristics - such as the fundamentally influential factors, organization and involvement (or contexts and workflows) – remain unchanged.

However, findings also suggest that in addition to team characteristics, project characteristics and nuances also contribute to multidisciplinary building design team communication and outcomes. For instance, cases showed that the project stage influenced the team communication patterns that emerged (*Line of Inquiry 2: Multidisciplinary Building Design Team*, p. 115), and other project characteristics – the project location and project delivery approach – contributed to team communication and outcomes. As a result, project characteristics such as the project type, size, and challenges, discussed in Section 4.1 (*Case Characteristics*, p. 65) are included as inputs to be described and analyzed when studying multidisciplinary building design team communication and outcomes.

Similarly, timing is included as a component in the framework's inputs as the findings suggest it contributes to building design communication and outcomes in two ways. First, timing as the project stage contributes to communication processes and leads to two distinct information patterns discussed using the Stempfle and Badke-Schaub's goal space/solution space model in Figure 4.15, and distinct information processes discussed using Dubberly's diverge/converge model in Figure 4.21. Then, in a broader sense, timing viewed as current practice contributes to the limitations of the communication tools and technology of building design discussed in (*Line of Inquiry 2: Multidisciplinary Building Design Team*, p. 116).

The Exploratory Framework Processes

While there are no additional components to the processes in the modified framework, the synthesis of findings on multidisciplinary building design team communication discussed in Section 5.1 (*Line of Inquiry 2: Multidisciplinary Building Design Team*, p. 114) and the relationship discussed in the previous section suggest that the three communication components of the exploratory framework can be redefined.

<u>Communication as Social Behavior</u>

In the revised framework, communication as social behavior component includes both communication patterns and preferences. Communication preferences discussed in Section 5.1 *(Line of Inquiry 2: Multidisciplinary Building Design Communication*, p. 114), are included to be described and analyzed as it was suggested that communication preferences vary by the disciplines on the team and possibly by their categorization

<u>Communication as an Information Process</u>

The initial framework suggests that functional diversity leads to information rich exchanges due to the presence of diverse knowledge sources and categorization processes due to the presence of different identity groups. As discussed in Section 5.1 (*Line of Inquiry 2: Multidisciplinary Building Design Communication*, p. 115), the findings confirm that these two processes occur. In addition, findings first add to the description of the information rich exchanges, then include the new targeted interaction process, and finally redefine the categorization process.

In the revised framework, information richness is an early, diverging information process that occurs in the goal space where team members are involved in the exploration and generation of information. This information rich process is followed by a targeted interaction process, a converging process that occurs in the solution space where team members are involved in the analysis and evaluation of information.

Interestingly, categorization processes occur but do so in a different way than described in the dual process model. The dual process model suggests that categorization occurs as team members work within their individual disciplines and do not exchange information with each other. In contrast, the case findings suggest that categorization occurs but rather than leading to negative outcomes, is necessary owing to the multidisciplinary nature of the team where disciplines need to work on their individual problem areas without significant input from other disciplines. Categorization is managed by the team as the different disciplines engage in coordination activities to work together.

The use of communication technology

In the initial framework, communication technology focused on identifying the tools used by the disciplines on the multidisciplinary building design team. However, as the findings suggest that current practice also influences the use of their tools, their benefits and limitations, the revised framework includes descriptions and analyses of the use, benefits and limitations of the tools to support multidisciplinary building design communication.

The Exploratory Framework Outcomes

Rather than expand the outcomes like with the inputs and processes, the findings suggest that the positive and negative outcomes in the initial framework be replaced with one building design team outcome component.

The initial framework used the dual process model to suggest that positive team outcomes are achieved through the information rich process while negative team outcomes occur due to categorization processes. However, the findings suggest that team members use perceptions of process to describe their positive and negative outcomes. This implies that, rather than communication processes leading to either positive or negative outcomes, the three processes in the expanded model – information richness, targeted interactions, and categorization – all lead to some perception of team processes. The revised exploratory framework accounts for this finding by replacing the positive and negative outcome categories in the initial framework with a general building design team outcome category.

Studies of building design team communication and outcomes using this revised exploratory framework should follow the input-process-outcome model. Inputs should address functional diversity which can be defined in different ways as discussed in Section 2.2 (*Measuring Functional Diversity in Teams*, p. 26) and include categorization and shared tasks, the team's critical characteristics including the team's context, influencing factors and organization, the project characteristics including its challenges, and timing including current practices and the effects of the project stages.

Processes should address the three categories of communication. Communication as social behavior would include the patterns and preferences that emerge, communication as an information process would include the three processes that occur and communication technology would address the benefits and limitations of the different tools to support building design communication. Finally, outcomes should address building design team outcomes, as separate from, but a contributor to defined project outcomes.

These revisions improve the initial exploratory framework, allowing for the complete and systematic exploration of multidisciplinary building design teams, their communication and outcomes. They also suggest a potential modification to the dual process model discussed below.

POTENTIAL MODIFICATION TO THE DUAL PROCESS MODEL

The revised exploratory framework suggests a potential modification to the dual process model. While the initial model suggested that two processes occurred as a result of functional diversity, the case study findings and framework suggest that there are actually three processes that lead to team outcomes as illustrated in Figure 5.9.

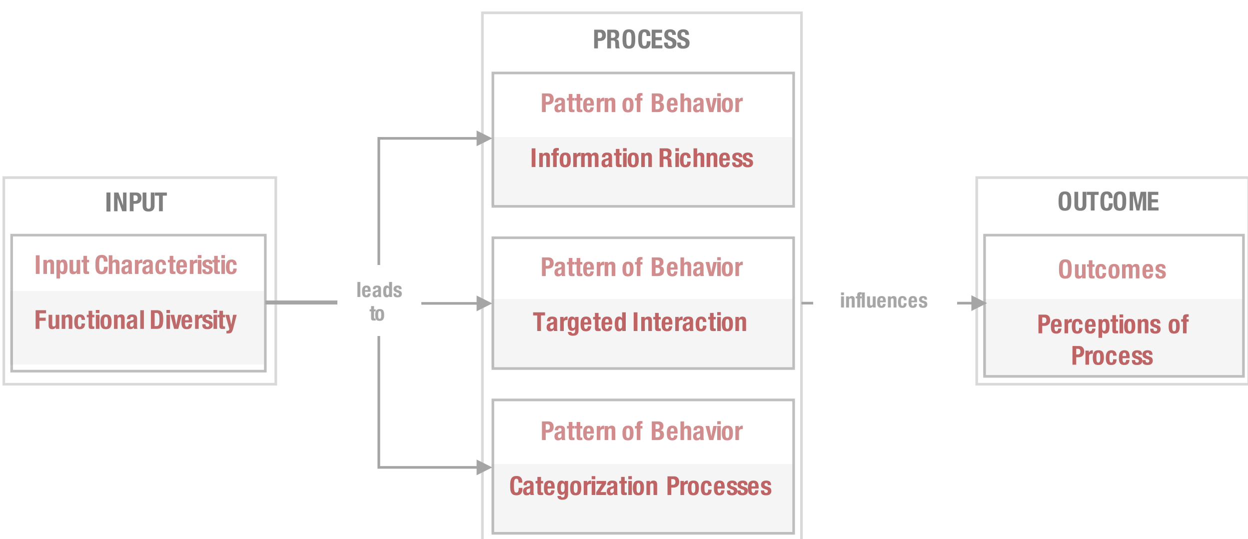

Figure 5.9 Potential modification to the dual-process model

It is necessary to mention that this modification does not imply a limitation of the dual process model. Rather, this modification, resulting from the self-reported data implies, for instance, that perceptions of process are how team members measure their own performance and outcomes. It is probable that in cases where outcomes are not self-reported, a different modification to the dual process model will be obtained.

The modification also suggests that while the dual-process model does represent functionally diverse teams, it is limited in the multidisciplinary building design team context. Again, it is important to note that the modifications suggested here are specific to the findings from the cases studied in this research. Other cases from other contexts may offer other modifications.

These relationships, frameworks and modifications all point to the complexity of multidisciplinary building design communication. Building design team members use several strategies to deal with this complexity, some of which were identified in the case study findings. Two of these strategies and the recommendations they offer are discussed in the final section of this chapter.

5.3: STRATEGIES FOR BUILDING DESIGN TEAM COMMUNICATION

The case findings, relationships and exploratory framework all point to the complexity of communication in multidisciplinary building design teams. Nonetheless, team members are able to perform their tasks and reported that they used certain strategies which were useful when dealing with the complexity of multidisciplinary team communication. This research reports on two of these strategies: project manager's role and meeting documentation. Given that there may be several factors outside the cases studied that can influence multidisciplinary building design communication, practitioners should consider these strategies within the context of their individual projects.

THE FUNDAMENTALLY INFLUENTIAL PROJECT MANAGER

Project managers are tasked with leading and managing projects to achieve project goals by making decisions and guiding the team members through their various tasks (Anantatmula, 2010; Munns & Bjeirmi, 1996). In multidisciplinary building design, this involves making design decisions and coordinating the activities of the various consultants and stakeholders.

In all three cases studies, project managers were involved to some extent. They were responsible for coordinating between the disciplines, checking in with the owner to manage their interests, and overall, keeping the project on track. This was necessary due to the complexity of building design projects discussed in Section 1.1 (*Complexity and Multidisciplinary Teams in Building Design*, p. 1), and the multidisciplinary nature of building design teams discussed in Section 2.1 (*Multidisciplinary Teams versus Interdisciplinary Teams*, p. 18).

Often, building design project managers are connected to a specific discipline which creates an opportunity for competing foci and interests. For instance, the project manager for a multidisciplinary building design project would be within the architects (though this varies with project size and complexity). In addition to coordinating with other disciplines on the team, they have to manage their architecture specific issues as well.

To avoid these competing foci and interests, this research recommends that there should be dedicated project managers on multidisciplinary building design teams, whose only task is coordinating and guiding disciplines through projects. Focusing on this one broad task will allow project managers to effectively conduct their activities and manage the team communication without distractions. These activities may include defining the project requirements, planning the activities and information flows for the project, and accommodating the changes that occur on the project (Munns & Bjeirmi, 1996).

However, this research recognizes that projects vary by size and complexity, and have constraints – for instance the budget – that may limit the range of involvement of the project managers. To account for variation and constraints on projects, this research recommends that at the least, dedicated project managers should be cross-functional connectors on the multidisciplinary building design teams, and at the most should be project facilitators.

Project Managers as Cross-Functional Connectors

Project managers are responsible for bridging the gaps between the disciplines on the team. This role differs from that of functional project managers, described either as disciplinary team leaders or team coordinators, who are responsible for coordinating and managing tasks and activities only within a specific discipline.

Cross-functional project managers (who may also perform the tasks of the functional project manager) are responsible for coordinating with other disciplines on the multidisciplinary team. For instance, in a multidisciplinary team, each project manager – as a cross-functional connector – is responsible for connecting their discipline with all the other disciplines on the team. Figure 5.10 shows a typical communication path between cross-functional project managers.

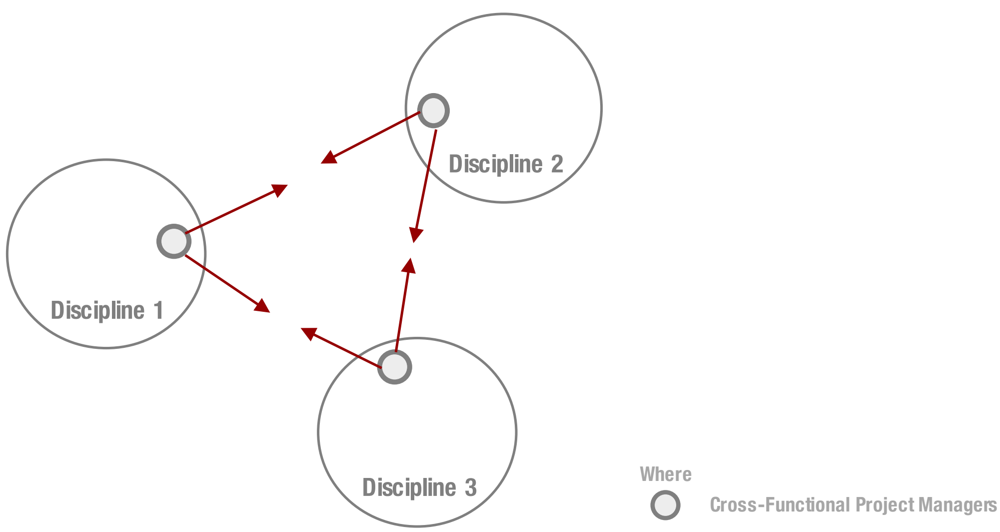

Figure 5.10 Project managers as cross-functional connectors

As mentioned by the project managers in Case 2, they do not perform design tasks or generate design information: *"it's not that we are generating the content, we help move it and keep it updated throughout the process."* Rather they connect and coordinate the information exchange between their discipline and other disciplines on the team. This connection and coordination across disciplines is important due to the multidisciplinary nature of the building design team.

Project Managers as Design Team Facilitators

Facilitation goes beyond the "command and control" of traditional project management and leadership and provides teams with the "support and framework" to work together successfully (Ellinger, Watkins, & Bostrom, 1999). Rather than only make decisions and coordinate activities, project managers as facilitators are involved in guiding every step of the design process.

Examples of project facilitation can be found in Cases 2 and 3 where the project managers were the intermediary between the different disciplines on the team. They also connected the team with the stakeholders who were external to the design team such as the owner, the user groups, planning and regulatory institutions, illustrated in Figure 5.11.

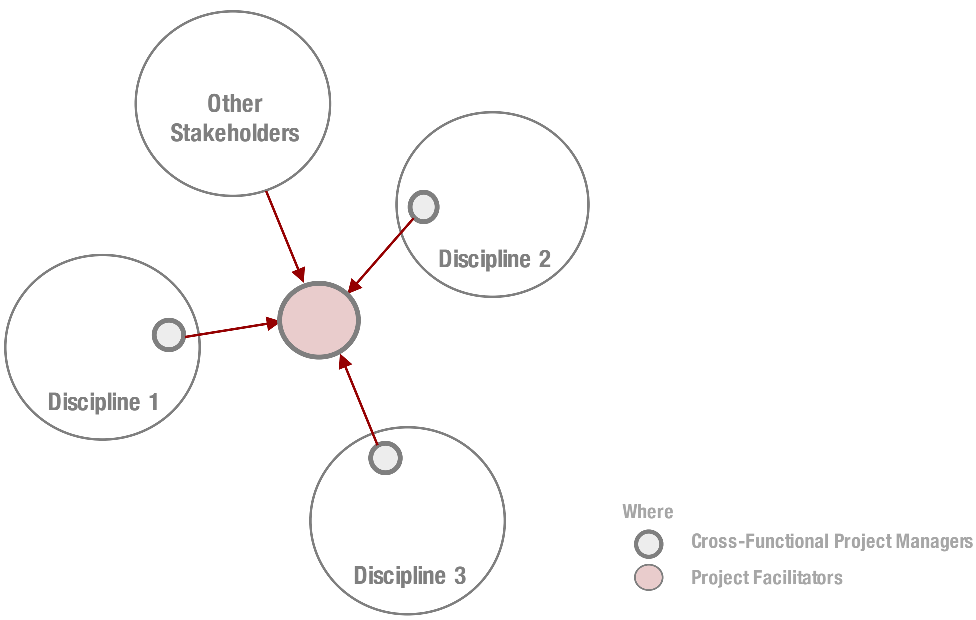

Figure 5.11 Project managers as facilitators

Building design facilitation, as described by the project manager in Case 3, involves recognizing the needs and requirements of the various disciplines and stakeholders, and identifying and responding to the intersections between these needs and requirements, discussed in Finding 3 (p. 82) at the whole project level:

"I would say facilitation is being that intermediary, that common thread between all the different parts of the project. And what's interesting is that every part of the team has their own project management. But, from our perspective, we need to manage the entire project and rather than interface with sub-sub consultants, sort of have our finger on the entire process."

"The project manager is primarily the conduit of information between disciplines and the maintainer of the schedule… when you're facilitating information sharing, you're recognizing that somebody else needs a piece of information that they may not be contractually obligated to get. The project manager is that person who has to bring all these disparate parts together."

The quotes suggest that as facilitators, project managers connect all the parts of project rather than just a specific disciplinary piece. This research offers a definition of building design team facilitation based on the case study findings. In this model, project managers as facilitators perform two main tasks: they identify project goals and implement the project process, both of which can be sub-divided into two tasks illustrated in Figure 5.12.

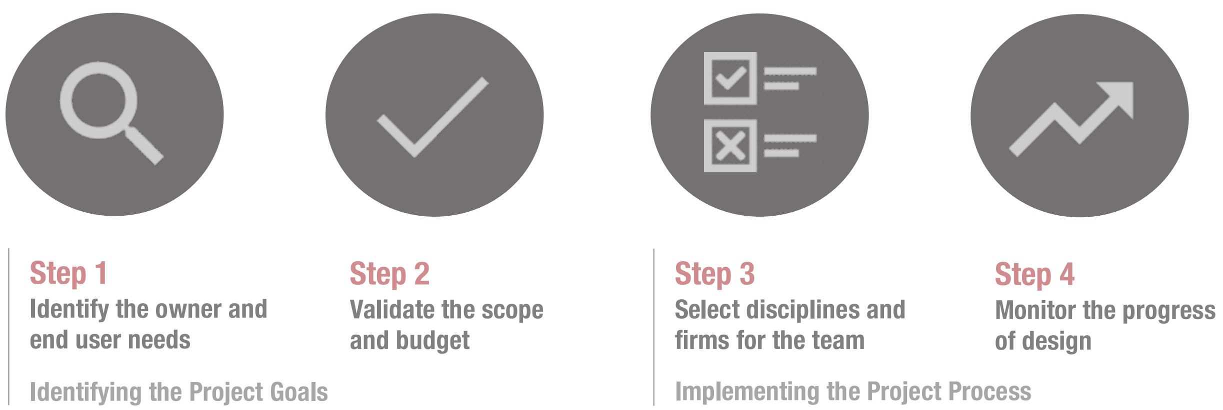

Figure 5.12 Task model of building design facilitation

Cases 2 and 3 provide an example of these tasks. To identify goals, project managers in Cases 2 and 3 performed two sub-tasks. First, they held kick-off meetings to identify the owner and potential end user needs. Then, they validated the scope and the budget before the start of actual design, to ensure that they were able to manage the expectations of the client regarding how much of the scope the budget could cover, and of the users, regarding the features that could be included in the building. These sub-tasks ensure that all disciplines are on the same page from the start of design, and minimize the potential for errors and rework further along in the design process.

To implement the project process, project managers again performed two sub-tasks. They first ran selection workshops (described in detail in the individual case reports for Case 2) to understand how the firms would respond to the project goals, not only

> from a single disciplinary perspective. Then, they monitored the progress of design through regular consultant meetings. These two sub-tasks contribute to project efficiency as disciplines regularly interact with each other and the project stakeholders outside of design.

This definition of facilitation represents the fully involved role of the project managers on building design projects. It is possible that project constraints may limit the extent of this role. To address this, this research suggests that project managers serve as cross-functional connectors in instances where they cannot be facilitators.

THE VARIOUS FORMS OF MEETING DOCUMENTATION

Documenting meetings allows teams keep track of decisions and changes through building design. Tracking decisions contributes to multidisciplinary team communication as disciplines are all kept in the loop, and are aware of decisions made, including those unrelated to their specific tasks. Tracking changes provides teams with a record which is useful when transitioning between design stages, as changes made during design have implications that go into construction.

As reported by the construction managers in Case 2, tracking the decisions and changes to design is especially useful when closing out projects:

"We also found that its easier when you're closing out the job, for instance where there's some issues with mechanical systems that were built and/or that were designed and installed and their people are referencing the design discussion where there's really no documentation on those design discussions so we're still trying to close out a project, is now been turned over for a year and that obviously costs money."

Building design team members can refer to their documentation during the close of design and minimize situations of uncertainty regarding design decisions and changes as the project moves into construction.

The case study findings suggest that the type of meeting documentation is a reflection of the types of meetings held by team members, and the information processes. It follows then that these distinct meetings also involve different forms of information and design decisions. To account for these differences, this research recommends that for practitioner's meeting documentation to be effective, it should complement the information and decisions made during the different types of design team meetings. The meeting minutes provided by the architects in Case 2, described by all the other disciplines in Case 2 as being very effective at tracking decisions and changes, provide examples this complementary meeting documentation.

The architects developed different types of minutes to complement their meetings with the project stakeholders and consultants: coordination memos, agendas and task lists. The coordination memos provide a reference to design decisions made, particularly those external to the design team (the owner and the construction team), and the agendas and task lists summarize information for various design disciplines.

The coordination memos were based on their meetings with the owners, project managers and construction managers. As conceptual, owner-driven design decisions were made at these meetings, the coordination memos contained a narrative description of these owner-driven decisions. This was helpful for the design disciplines as they were unlikely to attend the meetings. As reported by the landscape architects in Case 2, these coordination memos allowed them follow along with the discussions that occurred in meetings between the architects and owners which they did not attend.

"They're very good about recapping the meetings, like meeting minutes and keeping record, I would say that. We stepped in when they – like that building is kind of complicated because its really just an addition, sort of, so they had a lot of stuff already thought through and they were good at explaining it to us because its really complicated."

From the narrative descriptions in the coordination memos, the landscape architects could understand what occurred prior to them joining the design team. An excerpt of the architect's coordination memo is included in Appendix B.

The agendas and task lists were based on the architect's meetings with their design consultants. As the decisions made during these meetings were specific to the disciplines at the meetings, the agendas and task lists included less of a narrative. Rather they summarized key information discussed in meetings, and provided each discipline with their individual tasks and action items. These were described by team members as being useful in providing the disciplines with reminders, preventing tasks and relevant information from falling through the cracks. As discussed by the team members in Case 1, when there are time constraints and team members are working against a clock, it becomes easier to have information fall through the cracks. An excerpt of the architect's agenda is included in Appendix B.

While these types of meeting documentation complement the two types of meetings identified in this study, it is possible that there may be others outside of the cases. Therefore, practitioners should ensure that their meeting documentation always supports the types information and the decisions made in multidisciplinary building design team meetings.

5.3: SUMMARY

The case study findings in Chapter 4 are synthesized along each line of inquiry. From this synthesis, this research offers answers to the research questions posed in Chapter 3 and does the following: suggests a relationship between functional diversity, multidisciplinary building design team communication and outcomes; modifies the exploratory framework to allow for the complete and systematic exploration of multidisciplinary building design teams, their communication and outcomes; and offers two strategies for building design teams to deal with the complexity of multidisciplinary communication.

6: CONCLUSION

6.1: REVIEW OF THE RESEARCH

This research is motivated by the challenges and complexities of communication in multidisciplinary building design teams. Communicating effectively in multidisciplinary teams is difficult owing to functional diversity as team members have to share information across functional boundaries, and the fragmented building design process that allows information fall through the cracks. We care about communication as it has been shown to influence project outcomes, and thus is a critical component of building design.

However, several gaps in knowledge on multidisciplinary building design team communication were identified. Foremost, there is a lack of literature on multidisciplinary teams in building design as much of the literature comes from other domains. This lack of literature means we do not have approaches to studying multidisciplinary building design communication that account for its challenges, complexities, and influence on outcomes. Furthermore, we do not know how functional diversity influences the multidisciplinary building design team communication and outcomes.

To address these gaps, this research has developed an exploratory framework to describe and analyze communication and outcomes in multidisciplinary building design teams, and has applied this framework to three cases on real-world multidisciplinary building design teams along the following three lines of inquiry: What constitutes a multidisciplinary building design team? How do multidisciplinary building design teams communicate through social behavior, information process and use of technology, given the presence of functional diversity? And how do these communication categories affect team outcomes?

In this dissertation, I identify and discuss key background literature on the definitions, theories and approaches to analyze teams and teamwork, functional diversity, communication, and outcomes (Chapter 2). From this background literature, an initial framework is developed and followed by a description of the specific methods and procedures used to collect and analyze data from real-life multidisciplinary teams (Chapter 3), a description of the cross-case analysis of the case study findings using the framework (Chapter 4), and a synthesis of the case study findings, their implications and recommendations for research and practice (Chapter 5).

This chapter concludes this dissertation by discussing the contributions, limitations and future directions of this research. Contributions are given within the context of the gaps and objectives of this research, and the limitations suggest opportunities for future research.

RESEARCH CONTRIBUTIONS

The main contributions of this research are as follows:

Contribution 1: Documented insights into multidisciplinary building design team practice

Overall, this research contributes to an increased understanding of multidisciplinary building design practice, as it relates to a team, its communication and outcomes. The cases studied provide detailed descriptions (in Appendix D) of multidisciplinary building design practice, with the exploratory framework and its' lines of inquiry as a guide. Insights from these descriptions confirm that building design teams are indeed multidisciplinary as a result of their functioning, provide support for our commonsense intuition and beliefs regarding building design practice, and uncover strategies used by building designers to address their communication challenges.

In existing literature, the terms multidisciplinary and interdisciplinary have been used interchangeably in existing literature on building design, and by practitioners as well. This research explored these terms and has shown that they function in different ways, each with their own strengths and challenges. This research clarifies that overall, building design teams are indeed multidisciplinary, although they may comprise sub-groups that function in different ways. Clarifying these terms and describing building design the right way allows for accurate descriptions of practice that identify the right issues and solutions for building design teams.

Despite there being little in the literature reviewed on the communication processes and outcomes of multidisciplinary building design teams, there are commonsense intuitions and axioms about building design practice. The findings described in this dissertation provide documented evidence that supports our intuition about building design practice, but also gives us information on the functional diversity, communication and outcomes in multidisciplinary building design. Along with providing evidence, this research has uncovered several factors, relationships and patterns that underlie our intuition to serve as a reference and a starting point for future research.

In providing these insights into multidisciplinary building design practice, strategies used by team members to ensure effective communication are uncovered. This research describes two strategies for dealing with the challenges of multidisciplinary team communication, based on recommendations from team members: the role of the project manager as a cross-functional connector and project facilitator; and meeting documentation that reflect information types. These strategies can be applied to building design teams within the context of their individual projects.

Contribution 2: Exploratory framework for studying multidisciplinary building design team communication

This research has developed a usable exploratory framework that contributes to knowledge by offering a systematic approach to describing and analyzing multidisciplinary building design communication. While prior research offers several approaches to analyze communication, there is none that accounts for the challenges, complexities, and nuances of multidisciplinary building design communication.

The exploratory framework combines aspects of models and definitions from teamwork and organizational studies, diversity studies, communication theory, and design studies, along with the findings from the cross-case analysis in Chapter 4. The initial version of the framework combined components of the input-process-outcome model, the dual-process model, studies of teamwork and the categories of communication while the framework revised using the case study findings include components of the goal space/solution space model, the diverge/converge model.

By combining these models, definitions, and insights from the case studies, in order to study multidisciplinary building design communication, we need to: study functional diversity, team and project characteristics, and timing as inputs; include all three categories of communication as processes; and consider building design team outcomes.

A framework provides the flexibility required when studying a topic as dynamic as team communication. The components of the framework can be adapted as we learn more about multidisciplinary building design teams, their communication and outcomes, and inputs applied to other aspects of functional diversity, say for instance we are interested studying the effects of team member roles, or prior experiences (the other conceptualizations of functional diversity) on building design team communication.

This combination offers a new, robust approach to studying multidisciplinary building design communication that considers functional diversity and its contributing factors including project and team characteristics, and timing, all the three categories of design team communication – communication as social behavior, an information process, and the use of communication technology – and team outcomes as differentiated from project outcomes. This approach can be placed within the growing "DesignOps" field which aims to help design teams increase the value they produce by focusing on their operational processes, practices and tools (Malouf, 2017).

Based on this framework, this research posits a relationship functional diversity, communication, and outcomes in multidisciplinary building design teams that highlights several areas for future research including: the disciplinary categorization and the presence of sub-groups on the multidisciplinary building design team; and team and project characteristics that influence team communication and outcomes.

6.2: LIMITATIONS AND FUTURE RESEARCH DIRECTIONS

There are limitations to the research presented in this dissertation which are mainly due to the study design and methods used including: the number and type of cases studied in this research, self-reported data, and the communication analysis approach. These limitations and approaches to address them in future research are discussed below:

The range of project types in the cases

The number and range of projects in the cases studied poses a limitation to this research. The three cases spanned a small range of project types. All the projects were new construction and there were two types of buildings across all the cases, mixed-use and institutional buildings. This poses a limitation as the findings and conclusions from the data obtained from these cases may not provide insight into other project types. This limitation can be addressed in future work by obtaining data from more robust building types, possibly including project types beyond new construction, and comparing findings across these project types.

It is important to mention that access was a significant challenge in obtaining cases. This contributed to the narrow range of projects in the study as the teams that participated were the ones who were available to participate. This access issue meant that more selective criteria than the three used in this research could not be applied. Having a wider initial sample could address this limitation where a more robust sample of cases could be obtained. However, there is the need to address issues of transparency in the building design where people are almost unwilling to talk about project experience or to address or reflect on practice, particularly when things go wrong.

Data collection and self-reporting

The nature of this study where data was collected from teams at one point during their project poses a limitation as building design teams are dynamic and change as projects progress with time. The challenge of finding teams to serve as cases meant that the time of engagement with the team had to be minimal. In addition, the primary data collection method – interviews – meant that the bulk of the data in the study was self-reported. Self-reported data poses a limitation as it is difficult to verify without triangulation and is susceptible to interpretive biases by the researcher, and inconsistencies.

Longitudinal studies – following the same project over time, rather than at one time – can address this limitation. As building design projects often go on for a while, following a project through its different stages and collecting data through different approaches including observations and follow up interviews can address the data collection and self-reported limitation.

Communication analysis approach

The current form of communication analysis is limited as it studies communication patterns broadly and identifies subgroups without going in detail about the nature and characteristics of the subgroups. Future studies can address this limitation in the analysis of communication by conducting an in-depth network analysis of the multidisciplinary team's communication patterns. This would include an analysis of cliques and cohesive subgroups that appear in order to understand, rather than speculate on how they function within the multidisciplinary building design team. An opportunity arises to study multi-mode networks where other types of communication actors, not just the disciplines on the team are included.

This research presents a general framework for describing and analyzing building design team communication. It is expected that with more cases and a deeper understanding of multidisciplinary building design practice, the framework can be formalized into a methodology to study and even evaluate building design team communication.

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APPENDICES

A: RECRUITING STUDY PARTICIPANTS

PHONE SCRIPT FOR FIRST CONTACT WITH AEC FIRMS

=========

Hello, my name is Olaitan Awomolo. I am a doctoral candidate in the School of Architecture at Carnegie Mellon University. I obtained your contact information from the AIA Pittsburgh website and am hoping to talk to you about my research study. Do you have a couple of minutes to have a conversation about my study?

=========

(If no); Could you suggest a better time for me to call back?

=========

Thank you for your time. I will call back at (xx) time.

(If yes, brief description); My research is exploring multidisciplinary building design teams. As designers, we all agree that communication is key in successful design activity. However, studies show that we may not always gain the results we expect from multidisciplinary teams. Factors such as the diversity of professionals can lead to adverse effects on multidisciplinary team communication.

Therefore, I am conducting a research study on communication in multidisciplinary building design to gather information from team members to understand the communication processes, map the information flow between team members and identify effective communication strategies that teams use.

=========

(Respond to any questions)

If this is of interest to you, I would like to speak with key team members on a recently completed project. Please let me know of a time that will be suitable to call back for or a longer discussion.

I will be happy to answer any questions you have about the study. You may contact me at (412)-925-3481, oawomolo@andrew.cmu.edu or my faculty advisor, Omer Akin, (412)-268-3594, oa04@andrew.cmu.edu if you have study related questions or problems. If you have any questions about your rights as a research participant, you may contact the Office of Research Integrity and Compliance at Carnegie Mellon University. Email: irb-review@andrew.cmu.edu. Phone: 412-268-1901 or 412-268-5460.

=========

(Respond to any questions)

(If not interested); Thank you for taking the time to speak with me. Your time is greatly appreciated.

(If interested); Thank you for your consideration. If you are interested, I will follow up with a letter of invitation to participate in the study. Your time is greatly appreciated.

note:
========= indicates response

INVITATION TO PARTICIPATE IN RESEARCH STUDY (FIRMS)

Dear ___________________:

Thank you for taking the time to speak with me about my upcoming academic Research Study. I am writing to provide you with some more details about the Study and to ask whether your firm is willing to participate.

study objectives

The Study will involve case study research that will explore communication and outcomes in building design teams. Using interviews with team members as the primary method of data collection, the Study aims to understand the relationship between the functional diversity of multidisciplinary building design teams and team communication and outcomes.

study lines of inquiry

What/Who constitutes a multidisciplinary building design team? How do multidisciplinary building design teams exchange information? How does team communication influence team outcomes?

participation by your firm

Your firm's participation in the Study is completely voluntary, and your firm will not be compensated for its participation. To conduct the Study, I will request to speak with certain individuals in your firm. I do not expect the actual data collection period to exceed one month.

Data collection will involve a one hour interview with key team members from each discipline on the team. The Interview can be conducted either in person, or over the phone and will be recorded and transcribed to allow for later analysis

data protections

Information initially collected for the Study analysis may include the name of your firm, the names of your firm's employees and clients, information about your firm's projects or other identifiable information. To the extent possible, identifiers will not be included in the notes and information reported as part of the Study (for example I will refer to your firm by a number or other identifier rather than by its name).

Any reports or publications resulting from the Study will not include identifiers of your firm, your clients and/or the individuals participating (i.e., they will not include the name of your firm, any names of participating firm employees, name of the client for whom the relevant project was performed, or the relevant project name and address).

research and results

The Study is of a research nature and is done on an AS-IS basis. So, there are no assurances that any specific outcomes will result from the Study and/or will be available for your firm's use or benefit. Also, the Study is contingent upon the receipt of certain required Carnegie Mellon approvals, and therefore it may be delayed to the extent such approvals are pending. If your firm elects to participate, I will keep in contact regarding these matters to coordinate with you regarding the expected start date of the Study and any delays.

Any individuals (such as principals, project managers and/or team members) who elect to participate in the Study may be required to sign individual written Carnegie Mellon-approved consent forms to participate in the project. Also, depending on the requirements of Carnegie Mellon's Institutional Review Board, I may need to coordinate with you regarding any such requirements that are not already addressed by this latter.

To move forward, I need receive confirmation of your firm's willingness to participate in the Study. If your firm is interested in participating in the Study and willing to provide the access and use of your firm's information as described in this letter, please have an authorized signatory for your firm sign this letter where indicated below and return a copy to me. If it is more convenient, you can scan your signed letter and return it to me via email at oawomolo@andrew.cmu.edu.

Thank you for your assistance, and I look forward to working with your firm.

Thank you,

Olaitan Awomolo

Accepted and agreed, effective as of the date of this letter:

[INSERT NAME OF FIRM]

By: ____

Printed Name:

Title:

FLYER FOR PARTICIPATION IN RESEARCH STUDY

INVITATION TO PARTICIPATE IN RESEARCH STUDY
on

COMMUNICATION AND OUTCOMES
IN MULTIDISCIPLINARY BUILDING DESIGN TEAMS

The Study will involve case study research that will explore communication and outcomes in building design teams.

Using interviews with team members as the primary method of data collection, the Study aims to understand the relationship between the functional diversity of multidisciplinary building design teams and team communication and outcomes.

PRINCIPAL INVESTIGATOR: OLAITAN AWOMOLO
School of Architecture, 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 4129253491
Email: oawomolo@andrew.cmu.edu

FACULTY SUPERVISOR: OMER AKIN

There may be no personal benefit from your participation in the study but the knowledge received may be of value to your design process knowledge and design team communication.

There will be no compensation and participation is confidential.

Please contact (first contact) for more information, or if you are interested in participating.

INVITATION TO PARTICIPATE IN INTERVIEWS (TEAM MEMBERS)

Dear ___________________:

My name is Olaitan Awomolo. I am a Doctoral Candidate in the School of Architecture at Carnegie Mellon University. I am conducting a research study as part of the requirements of my degree in Architecture-Engineering-Construction Management (AECM), and I would like to invite you to participate.

My research is exploring the impact of communication in multidisciplinary design teams. You were included as a potential study participant based on your recent participation in (project name). Your input will be very valuable in my research.

If you decide to participate, I will be conducting a recorded interview. The interview is expected to last approximately 1 hour. Please let me know if you would prefer a face to face interview or a telephone interview and inform me of your available dates and times. I will be happy to come to your preferred location anywhere in the Pittsburgh area.

Participation is confidential. Study information will be kept in a secure location at Carnegie Mellon University. The results of the study will be published or presented at professional meetings, but your identity will not be revealed.

I will be happy to answer any questions you have about the study. You may contact me at (412)-925-3481, oawomolo@andrew.cmu.edu or my faculty advisor, Omer Akin, (412)-268-3594, oa04@andrew.cmu.edu if you have study related questions or problems. If you have any questions about your rights as a research participant, you may contact the Office of Research Integrity and Compliance at Carnegie Mellon University. Email: irb-review@andrew.cmu.edu. Phone: 412-268-1901 or 412-268-5460.

Thank you for your consideration. If you would like to participate, please review the attached consent documents. Your time is greatly appreciated.

Thank you

Olaitan Awomolo

Ph.D. Candidate, AECM

School of Architecture

Carnegie Mellon University

Pittsburgh, PA 15213

CONSENT FORM FOR INTERVIEW PARTICIPATION

Carnegie Mellon University

Consent Form for Participation in Research

Study Title: Functional Diversity, Communication and Outcomes in Multidisciplinary Building Design Teams.

Principal Investigator: Olaitan Awomolo
School of Architecture, 5000 Forbes Avenue, Pittsburgh, PA 15213, Phone: 4129253491, E-mail address: oawomolo@andrew.cmu.edu

Faculty Advisor: Omer Akin

Purpose of this Study
The purpose of the research is to explore communication and outcomes in building design teams. Using interviews with team members as the primary method of data collection, the Study aims to understand the relationship between the functional diversity of multidisciplinary building design teams and team communication and outcomes.

Procedures
The Semi-structured interview will be a one-time meeting with you. The interview will be facilitated by the PI and ask questions that will provide information on the team's communication processes during the building design. The interview session should not exceed one hour and will be audio recorded for improved data analysis. The audio recorded interview will be transcribed and supported with notes will be taken by the PI during the interview. The interview will be recorded using the iPhone voice recorder application. An SD card will be used to transfer the data to the secure data storage location.
The interview session will be structured in three parts: 1) An introduction; 2) Questions and; 3) Conclusion. At the beginning of the session, the research study will be introduced, providing information on its intent and the purpose behind the data collection activity. Background questions on the firm's approach to design will be asked followed by more specific questions on the communication modes between the design professions during different design process stages.

Participant Requirements
Participation in this study is limited to individuals age 18 and older who are design professionals that are a part of a multidisciplinary building design team.

Risks
The risks and discomfort associated with participation in this study are no greater than those ordinarily encountered in daily life or during the performance of online examinations or tests.

Benefits
There may be no personal benefit from your participation in the study but the knowledge received may be of value to your design process knowledge and design team communication.

Consent Form for Participation in Research

Compensation & Costs
There is no compensation for participation in this study. There will be no cost to you if you participate in this study. The PI will provide digital copies of the final report with the final report of the study as desired by participants.

Confidentiality
By participating in the study, you understand and agree that Carnegie Mellon may be required to disclose your consent form, data and other personally identifiable information as required by law, regulation, subpoena or court order. Otherwise, your confidentiality will be maintained in the following manner:

Your data and consent form will be kept separate. Your research data will be stored in a secure location on Carnegie Mellon property. Sharing of data with other researchers will only be done in such a manner that you will not be identified. By participating, you understand and agree that the data and information gathered during this study may be used by Carnegie Mellon and published and/or disclosed by Carnegie Mellon to others outside of Carnegie Mellon. However, your name, address, contact information and other direct personal identifiers will not be mentioned in any such publication or dissemination of the research data and/or results by Carnegie Mellon. Note that per regulation all research data must be kept for a minimum of 3 years.

Your confidentiality will be maintained during data analysis and publication/presentation of results by any or all the following means: (1) each participant will be assigned a number, (2) the researchers will save the data and/or any audio recording by your number, not by name, (3) only the PI or Faculty Advisor will view collected data in detail, (4) any original recordings or data files will be stored in a secured location accessed only by authorized researchers.

Rights
Your participation is voluntary. The decision to participate or not participate will have no effect on employment. You are free to stop your participation at any point. Refusal to participate or withdrawal of your consent or discontinued participation in the study will not result in any penalty or loss of benefits or rights to which you might otherwise be entitled. The Principal Investigator may at his/her discretion remove you from the study for any of several reasons. In such an event, you will not suffer any penalty or loss of benefits or rights which you might otherwise be entitled.

Right to Ask Questions & Contact Information
If you have any questions about this study, you should feel free to ask them now. If you have questions later, desire additional information, or wish to withdraw your participation please contact the Principal Investigator by mail, phone or e-mail in accordance with the contact information listed on the first page of this consent.

If you have questions pertaining to your rights as a research participant; or to report concerns to this study, you should contact the Office of Research Integrity and Compliance at Carnegie Mellon University. Email: irb-review@andrew.cmu.edu . Phone: 412-268-1901 or 412-268-5460.

Carnegie Mellon University

Consent Form for Participation in Research

Voluntary Consent

By signing below, you agree that the above information has been explained to you and all your current questions have been answered. You are encouraged ask questions about any aspect of this research study during the study and in the future. By signing this form, you agree to participate in this research study. A copy of the consent form will be given to you.

____

PRINT PARTICIPANT'S NAME

____ ____________________

PARTICIPANT SIGNATURE DATE

I certify that I have explained the nature and purpose of this research study to the above individual and I have discussed the potential benefits and possible risks of participation in the study. Any questions the individual has about this study have been answered and any future questions will be answered as they arise.

____ ____________________

SIGNATURE OF PERSON OBTAINING CONSENT DATE

Optional Permission

I understand that the researchers may want to use a short portion of any audio recording for illustrative reasons in presentations of this work for scientific or educational purposes. I give my permission to do so provided that my name will not appear.

Please initial here: ________YES _________NO

ADMINISTRATIVE REQUIREMENTS AND COMPLIANCE

APPROVAL OF SUBMISSION

May 24, 2016

Type of Review:	Initial Study
Title of Study:	Functional Diversity, Communication and Design Changes in Multidisciplinary AEC Design Teams
Investigator: Study Team Members:	Olaitan Awomolo Omer Akin
IRB ID:	STUDY2016_00000143: Functional Diversity, Communication and Design Changes in Multidisciplinary AEC Design Teams
Funding:	None

The Carnegie Mellon University Institutional Review Board (IRB) has reviewed and granted **APPROVAL under EXPEDITED REVIEW on 5/24/2016 per 45 CFR 46.110 (6, 7a, 7b) and 21 CFR 56.110. This APPROVAL expires on 5/23/2017.**

If continuing review approval is not granted before the expiration date of **5/23/2017,** approval of this study expires on that date, unless suspended or terminated earlier by action of the IRB. **Note that submitting for continuing review in a timely manner is the responsibility of the PI.**

Unanticipated problems and adverse events must be reported to the IRB within three (3) working days. Any additional modifications to this research protocol or advertising materials pertaining to the study must be submitted for review and granted IRB approval prior to implementation.

The Investigator(s) listed above in conducting this protocol agree(s) to follow the recommendations of the IRB of any conditions to or changes in procedure subsequent to this review. In undertaking the execution of the protocol, the investigator(s) further agree(s) to abide by all CMU research policies including, but not limited to the policies on responsible conduct of research and conflict of interest.

Sincerely,

B: DATA COLLECTION

THE SEMI-STRUCTURED INTERVIEW GUIDE

The interview guide was developed based on the lines of inquiry and research questions It was used to direct the conversation between the researcher and the semi-structured interview participants while leaving room for elaboration and further exploration of participants' responses. The guide has five sections: the interview, participant, the project, the team and communication specifics.

interview specifics:

The information for this section is obtained prior to the start of the semi-structured interview.

- Interview date:
- Interview time:
- Interview location:

participant specifics:

Question 1: Tell me a little about yourself…

- Name? (or identifier)
- Discipline?
- Position in firm?
- Prior experience?
- Role on the team?

project specifics

Question 2: Tell me about the project…

- Involvement on the project?
- Project information?
- Project challenges?

team specifics

Question 3: Tell me about your in-house team (if available) …

- Team member selection?
- Team role?
- Team tasks?

Question 4: Tell me about the design team …

- Team organization?
- Team dynamics?

- What worked well (and rationale)?
- What could be improved (and rationale)?

communication specifics

Question 5: Tell me about communication on the team, from your disciplinary perspective …

- Design information?
- Modes of communication?
- Frequencies between disciplines?
- Communication technology?
- What worked well?
- What could be improved?
- Suggestions for improvements?

EXCERPT FROM THE SEMI-STRUCTURED INTERVIEW TRANSCRIPTS

This ten minute excerpt is from the transcribed data obtained from a participant in semi-structured interview. Names and identifiers have been removed.

[begin excerpt from transcript]
0.04.00

[OA]: So, your team specifically now

[Interviewee]: Structural engineering

[OA]: Yes, the structural engineering team, what were the, could you give me an example of the sorts of tasks you performed as a group?

[Interviewee]: Sure, you know our responsibility is to design the structure... so typically we receive plans from the other disciplines and specifically we receive plans from the architect and it is our responsibility to make their building stand, right... so we would normally go through the process of reviewing their plans and try to find areas where we think we can make the structure more efficient

0.05.00

[Interviewee]: which would require them to report to change some architecture. Our attitude is that we don't want to change their architecture. We want them to… this is what the owner thinks they're getting so we want to make it work. There are times where some of the things that are shown are so inefficient that it doesn't make any sense, that... you know... our first set of tasks are to review the architecture plans and come up with the framing options for the architect... and then including some ideas for maybe changing things to be more efficient

0.06.00

[OA]: so at the point where your team becomes... became involved in the project... do you think that tweaking that or moving that up would change the process in any way?

[Interviewee]: well in this instance we were involved fairly early... so you know very different stages of the project... you have schematic design, design development and construction documents. We encourage our clients to have us and as early as possible... when we are involved in the schematic design phase things usually go much much much smoother... when we get involved later after the architect has already issued the schematic design drawings and are into design development…

0.07.00

[Interviewee]: that's when sometimes they get themselves in trouble without doing that so we encourage the client to lose involved early on... so in this project we are involved early on

[OA]: At schematic design

[Interviewee]: schematic design yes

[OA]: So internally, within the team, how to how do you pick people to be involved on the team. I don't imagine its like a volunteer process

[Interviewee]: in our office, there two things we look at... its the schedule and availability of the other engineers to work on the project. schedule usually drives it, but also experience in that certain type of projects

0.08.00

[Interviewee]: in this instance, the project was a conventional foundation with a steel pedestal... the steel and concrete pedestal and then wood framing... so there are other engineers in our office who have performed those types of designs... so from an efficiency standpoint for us it makes sense to involve the same engineers. So, in this instance those were the two driving factors so that's how we did it

[OA]: So, you've talked about efficiency and I'd like to go into that and a bit more detail

[Interviewee]: Efficiency a big deal yes

[OA]: what does efficiency mean from a structural standpoint... how do you define it?

0.09.00

[Interviewee]: efficiency on our end, from a design standpoint is not having to redesign it multiple times and not having to model and or draw it... as you know we don't draw on paper anymore, but, you know, the fewer times you have to make major design changes the more efficient you going to be... that's the importance of the schematic design phase... because at that point we recommend to the architects design options that we think are going to fit the project... and then hopefully by the time development... design development starts, that has been selected, and then we can be efficient in terms of how we define and design things and how we move through the project

0.10.00

[Interviewee]: so, from an architectural standpoint they're always developing the project as it goes along... and they're always changing and we recognize that... and lots of the changes are owner driven and there's nothing they can do about that... so what we tend to do to be more efficient is to design the things we know aren't going to change. So, we do the things we know we can control and then we move forward from there...so there's efficiency from our standpoint in terms of not burning our feet... and there's efficiency in terms of the structure that we're providing that's a little different you know its efficient in terms of its costs and its erection time and all these other factors.

0.11.00

[OA]: Okay... so from your perspective now... in the way the design team as a whole worked... what are things that you think worked really well?

[Interviewee]: well the communication was open at all times... that's typically the most important thing was communication... and then the sharing of the other disciplines documents also went very well I thought

[OA]: was there a certain type of system

0.12.00

[OA]: used to ensure documents were received, or was it just that everyone was willing to share documents.

[Interviewee]: Yes, and yes. There were milestones that the design team would have to meet on a weekly or monthly basis... or whatever it was, to share documents... so that was one of the things that worked well but just the open communication. If I needed something, I would just request it... you know... we've been doing this... I've done this long enough to know that when I need things and when I and what I need. I think that experience helps

0.13.00

[Interviewee]: I know when I don't need something you know what I mean... so we know what the critical path items are from a structural standpoint... so we were giving those items when we request them

[end excerpt from transcript]

EXCERPT FROM THE SEMI-STRUCTURED INTERVIEW FIELD NOTES

Project Contents → Roles
Team → selection
working
Communication
Outcomes →

MEETING WITH [redacted] 04/07/17

- Capital projects → life safety
  Require building permits.

① lots of disciplines – project management
② Hiring of the project
③ facilitation – Reach out to the end users.
  ③ – strong expectations.
④ managing expectation

managing expectations
⓪ sitting down with clients
⑪ Discuss issues. / Resolve issues.
Many discussions for possible stuff.
Early planning / schematics.
Establish early limits.

Approval → RFQ – Requests for qualifications. for arch.
One day workshop – infrastructure
  – Master plan
  – Program.
⇒ how much did they understand? selection process.

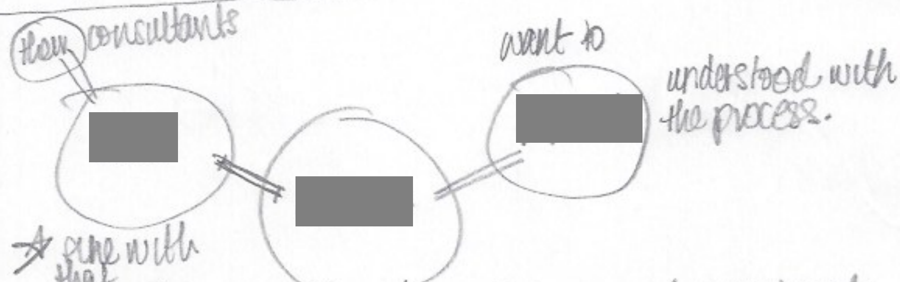
[redacted] hadnt worked with recently - were on short lost.
[redacted] - have a few alum, no ~~personal~~ work experience
[redacted] - construction managers
similar process.

[redacted] has to bring their team to the workshops.
Brings in their team.

Brings in a good team ⟹

(i) Experience on campus
(ii) listening
(iii) Adaptable to visions.

(iv) Budget ☆



☆ fine with
that
Personal information/ point to point occasionaly.
Calling is necessary.

---

forms of comm - have the arch/project manager from
another project - connected

Working group meetings.
(i) = at every stage -
schematic design.

Smaller group meetings
with meetings

Smaller group meetings

Engagment with everyone.
different groups.
Engage them this early. -> happy to be in early.

EXCERPTS OF DOCUMENTS OBTAINED

meeting minutes – coordination memo

[redacted]
Architecture Planning Interior Design
[redacted]

Meeting Minutes

[redacted] Hall
[redacted] Project No. 16205
[redacted] Project No. 37356
Date: Friday, February 17, 2017
Time: 12:00am – 1:00pm
Location: [redacted] SH 401 [redacted]
Subject: [redacted] Hall Casting subgroup meeting

Issued: Monday, February 20, 2017

Attendees:

Attendee		Company	Role
[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	Architect - [redacted]

Meeting Minutes:

1. **GENERAL NOTES**
   a. The purpose of the meeting was to understand the user needs for the Casting spaces within [redacted] Hall, such that Design Team can proceed with design layout.
   b. It was noted that the [redacted] Hall High Bay shall remain a flexible space, and placement of Casting equipment within the space shall not preclude other functions (Soft Materials Fabrication, Elec Fab, Welding, etc) from working within or moving around the space.

2. **DISCUSSION OVERVIEW**
   a. Currently there are dedicated rooms within the [redacted] Hall ground level abutting [redacted] Hall, for Casting, Welding and a Paint Booth. The modalities to be conducted in the Casting room include plastic, silicone, and carbon fiber casting. There was mention of metal casting within the Welding room, though the feasibility of this needs to be investigated with respect to spatial limitations and safety concerns (i.e. hazardous fumes), and shall be reviewed with EH&S. [redacted] stated that injection molding shall not be conducted in [redacted] Hall, as Stanford equipment not often used.
   b. Access control shall be provided for all dedicated rooms associated with High Bay. Prior to access being granted, students shall be instructed in the use of equipment. The double door into the Casting rooms seems appropriate to [redacted]
   c. [redacted] and [redacted] described workflow for both silicone and carbon fiber casting. Paper is first placed on benchtop. Users compile supplies/materials from various shelving/drawers. Users work with a variety of benchtop equipment, such as portable vacuum chamber, curing oven, scale, etc. Once casting is complete, project is set on shelves to continue curing for approximately 24 hours. Casts off-gas through curing phase, so exhaust shall be provided, either whole-room or directly above shelves. **Additional description of workflow per users attached. **

Architecture Planning Interior Design
[redacted]

[redacted]

d. Carbon fiber casting involves use of tooling equipment, including drill press, belt sander, band saw and possibly benchtop CNC milling machine. This equipment shall be located in MakerWing, adjacent to shop office, to ensure proper supervision. Tooling results in dust creation, which is toxic if inhaled. Focused exhaust shall be provided at carbon fiber tooling equipment, and students shall be responsible for cleaning equipment after each use.

e. Two (2) double benches shall be provided in Casting Room. Benchtop material options include butcher block, chemical resistant surface (i.e. epoxy), or stainless steel. [redacted] expressed preference for SS.

f. [redacted] mentioned the possibility of installing a fume hood in the Casting room, particularly due to projects by SAE (Society of Automotive Engineers). [redacted] questioned which chemicals would require a fume hood. From there, the group discussed possibly having a prescriptive chemical list for each of the dedicated rooms, to minimize the potential for mixing of hazard/toxic/flammable chemicals.

g. [redacted] addressed waste management as a concern, and discussed whether a strategy should be in place to organize waste streams, particularly if chemical formulations become more bio-based in the future. Additional discussion required.

h. Cameras shall be installed in dedicated rooms, helping to ensure students feel a level of responsibility to clean up their supplies/projects. Live-streaming of rooms shall be available to all students with access to the room.

i. [redacted] mentioned that Design Team should review possibility of limiting dust from High Bay from entering Electronics Fabrication area.

3. ACTION ITEMS

a. [redacted] and [redacted] shall complete equipment spreadsheet, noting access control or safety concerns for each item in the "Remarks" column.

b. [redacted] to schedule meeting with Welding group, as well as other subgroups within High Bay, as required.

c. Upon receipt of equipment lists, [redacted] shall develop layout of High Bay for coordination with [redacted].

4. UPCOMING MEETING SCHEDULE

a. The Project Team is tracking the following meetings over the next two months:

i. Schematic Workshop 2 – February 23
ii. Schematic Workshop 3 – March 9
iii. Schematic Workshop 4 – March 23
iv. *Subgroup Meeting: [redacted] Environmental Health and Safety – date TBD*
v. *Testing: Sewer Video Investigation – date TBD*
vi. *Testing: Hydrant Flow Test – date TBD*

Submitted by,

[redacted] *AIA, WELL AP, LEED AP*

This report represents the Architect's summation of the proceedings and is not a transcript. Unless the Architect receives written notice of any corrections or clarifications within seven (7) days of issue, this report shall be considered factually correct and will become part of the official project record. Distribution of these minutes beyond the list shown above is at the discretion of the Owner.

[redacted]
Architecture Planning Interior Design
[redacted]

Agenda

[redacted] Hall
[redacted] Project No. 16205
[redacted] Project No. 37356

Issued: August 9, 2017

Subject: [redacted] Hall – Consultant Team Call
Date: August 9, 2017
Time: 1:30pm

Agenda:

1. **PRICING UPDATE**
   a. [redacted] processing [redacted] questions
   b. [redacted] conducted a partial review of the 50% DD package, focusing primarily on MEP+FP and structural scope. [redacted] reviewed the 50%DD pricing on 8.8.2017. [redacted] is not decreasing the contingency, but is allowing team to proceed without identifying additional Add Alt items or value engineering.

2. **PROJECT MILESTONES**
   a. Final Design Development package – Friday, August 25 (consultant documents due by Tues, Aug 22)
   b. Early Bid Packages
      i. Sitework/Foundation Permit/Bid Package – October 6, 2017
      ii. Structural Steel Bid Package – November 10, 2017
   c. Permit/Bid Package (GMP Set) – late December 2017
   d. Final CD/Conformed Set – mid March 2018
   e. Occupancy – early August 2019
   f[redacted] [redacted] has provided an updated preconstruction schedule to [redacted]

3. **COORDINATION ITEMS**
   a. Sewer investigation by [redacted] – Sewer has been generally located and confirmed to be in use. **Manhole contained concrete; investigation could not be conducted. [redacted] on site this weekend to conduct additional test pits to identify elevations of the combo line and the electrical line.**
   b. Existing conditions site exploration
      i. Geotech and Survey - one (1) deep boring at center of site, (2) shallow borings at site wall, plus (3) exploratory test pits at adjacent buildings – Test pits scheduled for the week of June 26-30; Borings anticipated on June 29-30.
      ii. **[redacted] to update on site exploration results. Awaiting official report.**
   c. Updated basement layouts with revised MEP room size/located based on [redacted] meeting
      i. [redacted] o issue a base option and alternate for [redacted] to price. Consultants to only coordinate with the current base for July 19th.
      ii. Alternate will increase basement square footage, adding more lab space and relocating electrical rooms to the north
      iii. **[redacted] team to survey [redacted] Mech Basement next week to determine allowable space.**

Architecture Planning Interior Design
[redacted]

C: DATA ANALYSIS

EXCERPT OF CODED TRANSCRIPT DATA

	results. You know, more eyes, more experience on them.	

2: [redacted] Structural Engineers
Interview Transcript
Olaitan [redacted]

Speaker	*Transcript*	*Code*
Olaitan	Alright hi [redacted] So I have a little script that I'm going to follow... I have like five main questions. But I would like this to be a bit more of a conversation	
[redacted]	Sure	
Olaitan	So could you tell me a little bit about yourself?	
[redacted]	uh...I'm [redacted] I've been here over 20 years and I enjoy what I do. In my personal life I am married and I am a father. I am a father of a five-year-old boy. So that's pretty much it.	TEAM EXPERIENCE
Olaitan	And what was your role on the Arsenal project	
[redacted]	I was...uh... My role for [redacted] was the team leader. In terms of our engineering team we, had three other engineers involved... And I was basically the one who coordinated getting the work done... And was the primary contact for the other disciplines, the architects, mechanical engineers, civil engineers and whatnot	TEAM ROLES TEAM MEMBER
Olaitan	So you've been here for 20 years. Is that your entire career?	
[redacted]	Yes	
Olaitan	That's very impressive... So you mentioned you were the there was the architect, mechanical engineer and you were the point of contact for [redacted].	TEAM ROLES
[redacted]	Yes	
Olaitan	With those other teams... If I asked you to sketch your sense of the organizational the hierarchy of the team	
[redacted]	Of the entire design team	
Olaitan	Of the team of the design team yes	
[redacted]	Well obviously there's the owner. And then the architect is typically the team leader for the entire project. And then the engineering disciplines typically... fall in line behind the architect. So I don't think that the tree below that is all equal, you know it's civil and mechanical and structural. And when I say mechanical it's MEP	TEAM HIERARCHY
Olaitan	Yeah	
[redacted]	So mechanical electrical and plumbing... and then outside of that which would come off the tree of the owner would be... they are responsible for hiring the geotechnical engineer.	TEAM HIERARCHY
Olaitan	Okay	
[redacted]	So that would be in terms of design process...That would be typically be a project of this type would be put together	Project
Olaitan	Okay	
[redacted]	so it would be a traditional design build, well not a design-build... You know architect design	Project process
Olaitan	design bid build	
[redacted]	yes design bid build	
Olaitan	So I'm curious do you find the that's more common in the projects that you've worked on	
[redacted]	Yes it's only been in the last 3 or 4 years that design-build has taken shape... you know in terms of the owners hiring the contractor and the contractor hiring the Architects and the engineers... where the owner holds the contract and not the architect. But that's pretty standard	This is a fairly standard procurement Project
Olaitan	So your team specifically now, the mechanical engineering, civil engineering, no	
[redacted]	Structural engineering	
Olaitan	Yes the structural engineering team, what were the, could you give me an example of the sorts of tasks you performed as a group?	

THE INDIVIDUAL CASE REPORT GUIDE

executive summary

introduction

The introduction contains a brief description of the team, the project, data collection and analysis. The introduction includes:

- Brief introduction of the team
- Brief introduction of the project
- Discussion of data collection and interviews (modes, number of participants, location)
- Discussion of data analysis (codification, development of themes)

results

The results identify the findings from the case study. In the result section, trends are discussed and supported with data. If necessary or if available, sub-trends and unexpected findings are discussed as well. The results include:

- The project team characteristics including
  - Location of members
  - Contracts
  - Project involvement
  - Tasks/Roles
  - Prior relationships
  - Organization/Hierarchy
  - Project strengths and challenges
- Project team communication (trends, sub-trends and unexpected findings)
  - Forms of design information
  - Modes of information exchange (information process)
  - Patterns of information exchange (social behavior)
  - Technology for information exchange (technology interface)
- Project team outcomes (trends, sub-trends and unexpected findings)
  - Positive outcomes
  - Outcomes that could be improved

discussion

The discussion sections comments on the results obtained, providing an explanation for the findings and comparing them to other research. The discussion section includes:

- Explanations for the findings
- Implications of the findings for practice and for the dual-process model

DEVELOPMENT OF VALUE FLOW DIAGRAM FOR THE TEAM IN CASE 1

VALUE FLOW DIAGRAMS FOR TEAM 1

STAKEHOLDERS: OWNER, PROJECT MANAGER, ARCHITECTS, CIVIL ENGINEERS, STRUCTURAL ENGINEERS, MEP ENGINEERS, LANDSCAPE ARCHITECTS

TOUCHPOINTS: SITE WORK, STRUCTURAL DESIGN, MEP DESIGN, SPATIAL & INTERIOR DESIGN

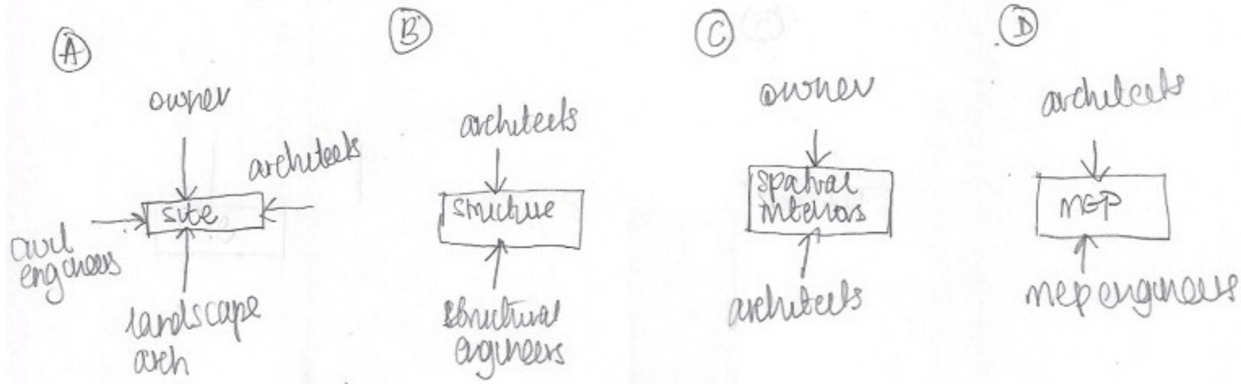
The exchanges include:

A The owner develops the site with the civil engineers. The civil engineers, architects and landscape architects are involved in the site design

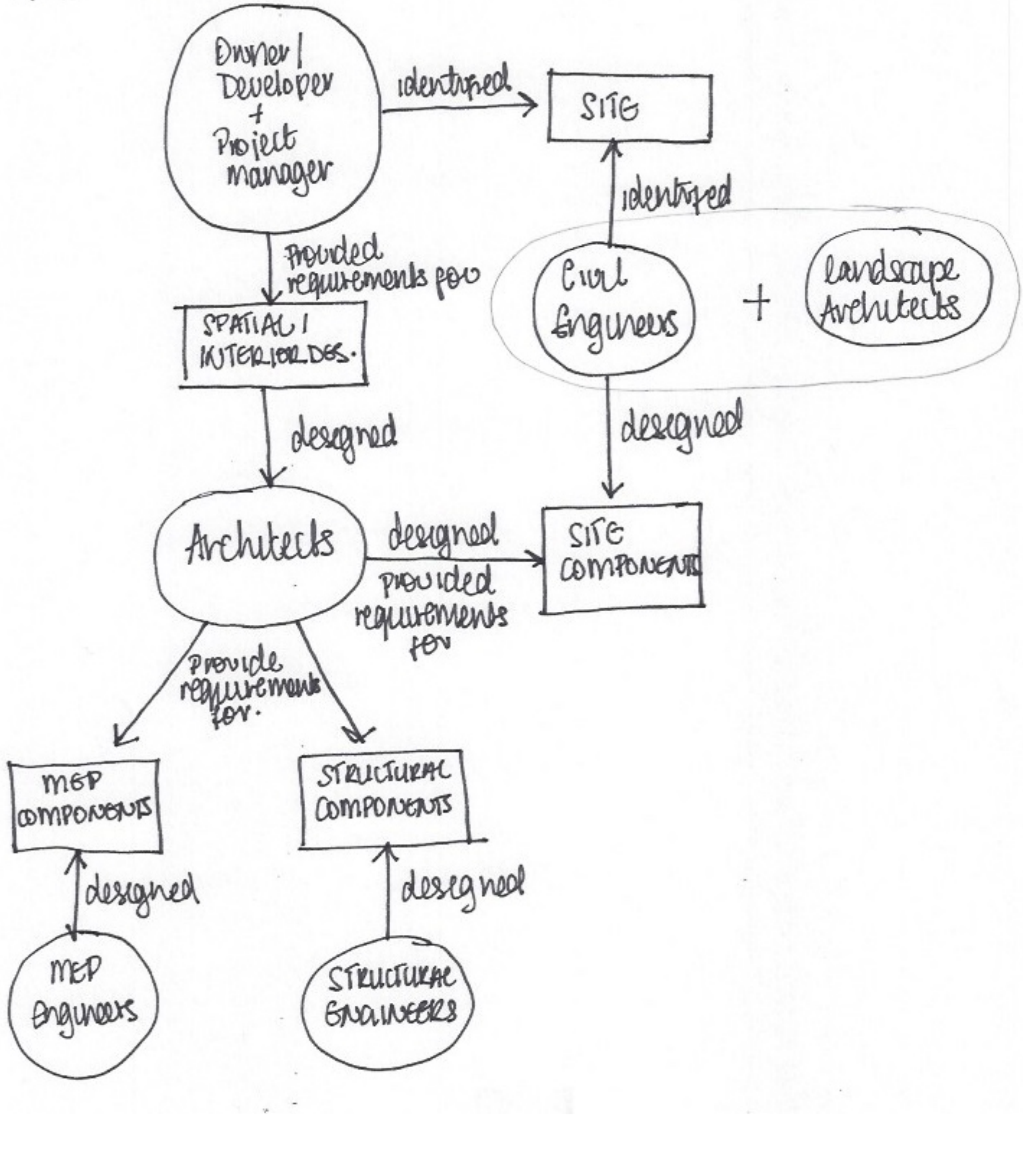
B The architects and structural engineers develop the site design

C The architects, along with the owner/developers and project managers designed the spatial and interior layout of the building

D The architects and MEP engineers designed the MEP components



VALUE FLOW DIAGRAM FOR TEAM 1



COMPARISON OF PROJECT MANAGEMENT SOFTWARE

	Project Management Software	Targeted Users		Features					
		Design Teams	Construction Teams	Document Management	Financial Accounting	Task Management	Bid Management	Compliance	Operations Management
1	Procore	•	•	•					
2	CMiC		•		•				
3	Paskr Project Management Suite		•	•		•			
4	PlanGrid	•	•	•		•			
5	PMWeb	•	•	•	•		•		
6	Sage Construction Project Center	•	•		•		•		
7	BuildBinder	•	•	•					
8	VPO	•	•	•					
9	Prolog		•	•					
10	PM Vitals		•			•			
11	E-Builder		•	•					
12	Gate Three	•	•	•	•		•	•	•
13	Builderbox.io	•	•	•					
14	Aconex	•	•	•		•			
15	DTC		•			•			
16	APE Mobile		•	•				•	
17	Primavera P6 Enterprise Project Portfolio Management		•	•	•	•	•		
18	Xactimate		•		•				
19	NoteVault	•	•						
20	Relatics		•	•	•	•	•		
21	BIM 360 by Autodesk	•	•	•					•
22	EADOC by Bentley		•	•					
23	Projectmates		•						
24	Owner InSite	•	•	•	•				
25	Spitfire Project Management System	•	•	•					
26	Corecon		•			•			
27	Fluid Contract Manager		•		•	•	•		
28	BuildingBlok	•	•	•	•	•	•		
29	BuilderStorm		•	•	•		•		
30	Fieldwire	•	•						

31	SKYSITE	•	•	•					
32	Projectteam.com	•	•	•			•		•
33	FACS Project Controller & Project Inspector		•						
34	Newforma Project Cloud	•	•	•					
35	IPM Global by Microsoft		•	•	•		•		

Source: Top Construction Software – 2017 Reviews (Software Advice, 2017)

D: THE INDIVIDUAL CASE REPORTS

CASE REPORT – TEAM 1

executive summary

The case study presents the analysis and results from the interview data of members of multidisciplinary building design team 1. Team members worked on the phase one of a large, mixed used redevelopment project in Pittsburgh, PA. The team comprised six disciplines: project managers, architects, landscape architects, civil engineers, structural engineers and MEP engineers. Data was obtained from ten team members across five of the disciplines on completion of the phase one project was design development, and was analyzed using content analysis and value flow diagrams described in Chapter 3. Excerpts from the data collected and the analysis are shown in the appendices.

Guided by the exploratory framework to suggest a relationship between functional diversity, team communication and outcomes, this study provides descriptions of the multidisciplinary team, the teams' communication across three categories – as social behavior, as an information process, and communication technology – and the teams' outcomes.

The findings suggest that:

- Although the contractual structure of the team forms the basis for how a team is organized, this structure is influenced by the preexisting relationships between the disciplines and the individual team members, and the location of each team member.
- The stage at which a discipline becomes involved in the project is driven in part by the tasks the discipline performs. The project stage determines information delivery and the kinds of meetings – goal setting meetings and troubleshooting meetings.
- Patterns of information flow that emerge in the project are a function of the organization of the team, the disciplinary roles and tasks, and the pre-existing relationships on the project.
- Outcomes that describe the process, rather than tangible outcomes are preferred by building design team members.

Moreover,

- Ensuring model accuracy among disciplines is essential for successful Building Information Modeling, and additional functionality is required by file sharing software, to be fully useful to multidisciplinary building design.

In addition to the research and practice implications of these findings, the report finds that the exploratory framework needs to be modified to accurately represent multidisciplinary building design team practice. The framework should be expanded to include team and project characteristics – such as the relationships among disciplines, the proximity of disciplines and the involvement of disciplines – which contribute to the effects of functional diversity, additional communication processes – such as the targeted interactions that occur, and process-based outcomes.

The findings from this case report will be compared against those from the other teams studied and presented in Chapter 4.

introduction

At the time of this report, the team comprised approximately thirty members from five design disciplines – each within a firm – and the Project Manager from the developer. The design disciplines were the Architects with four team members, the Landscape Architects with two team members, the Civil Engineers with about fifteen team members, the Structural Engineers with four team members, and the Mechanical Electrical and Plumbing (MEP) Engineers also with four team members.

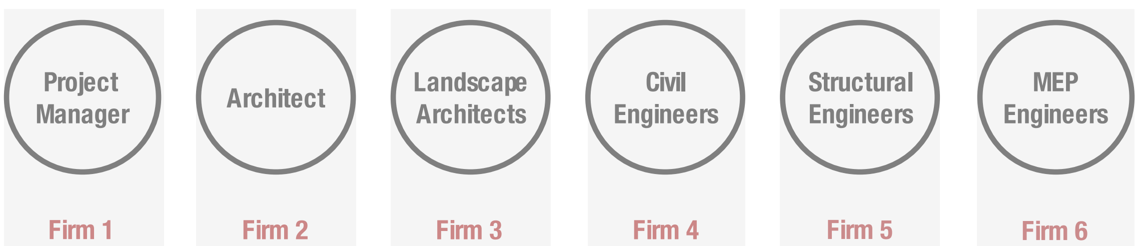


Figure 1 The design disciplines in team 1 across different firms

The team worked on a large, approximately 12.75 acre, campus-style, mixed-use redevelopment project in Pittsburgh, Pennsylvania. The project consists of multiple buildings and is expected to contain 650 residential units and 20,000 sq. ft. of commercial space (Henry, 2016; Schooley, 2015).

Figure 2 Map of Pittsburgh highlighting the neighborhood of the project

Owing to its size and scope, the project was to be completed in four phases. Each phase included master planning to provide a framework for the development of the residential and commercial buildings, circulation, streets and relationships within it (Philipsen, 2015). The project followed a traditional design-bid-build process, and the owner held the contracts of the architects for the design team and the contractors of the construction team.

Figure 3 The project site highlighting the area of the phase 1 development (Strada, 2016)

Data for the case study was collected on completion of the design development of the first phase of the project, which has three distinct buildings, containing about 243 residential units.

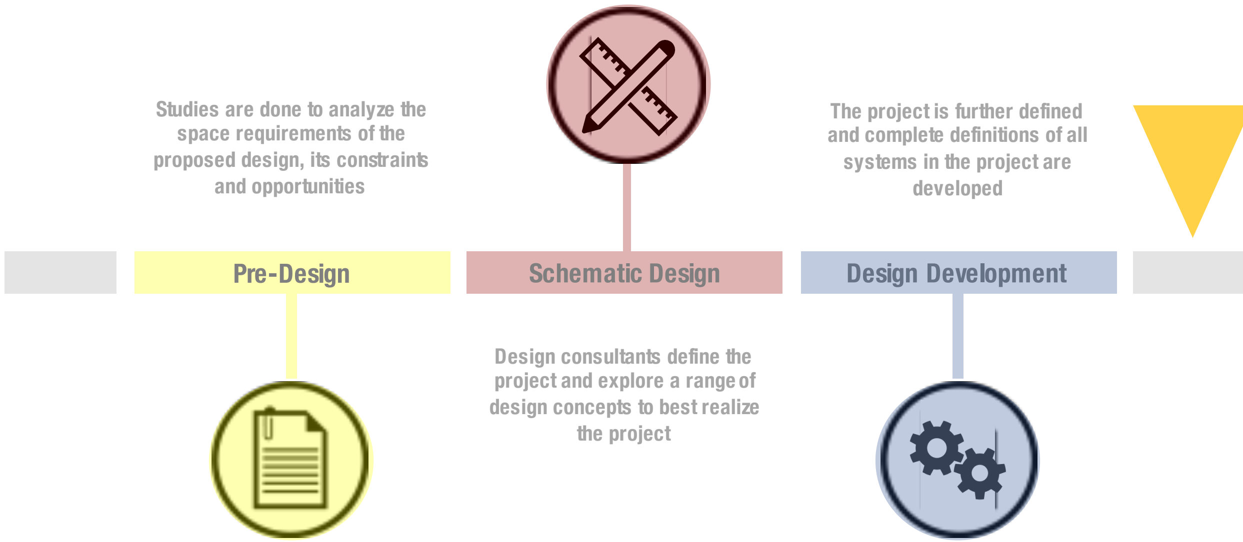


Figure 4 The Stages of the building design process showing data collection for team 1 after Design Development. Adapted from (UCOP, 2013)

To obtain the data for this case study, ten team members were interviewed, six were interviewed in person while the remaining four were interviewed over the phone. Table 1 summarizes the data collection for this case study.

Table 1 Summary of Data Collection

Disciplines	Number of Interviews	Mode of Interviews
Architects	1 team member	In-person interviews
Landscape Architects	2 team members	In-person interviews
Civil Engineers	1 team member	In person Interviews
Structural Engineers	4 team members	In-person interviews
MEP Engineers	2 team members	Phone interviews

The interview data is coded according the coding protocol developed from the review of existing literature described in Chapter 2, and the research questions outlined earlier in Chapter 3. An excerpt of the coded data is shown in Table 2 while the coding protocol is shown in Table 3. The findings from the data collected are presented in the following section.

Team 2 Excerpt from coded data for team 1

Person	Description	Code
Interviewee	In terms of our engineering team we, had three other engineers involved... And I was basically the one who coordinated getting the work done... And was the primary contact for the other disciplines, the architects, mechanical engineers, civil engineers and whatnot	Team involvement Tasks/Roles
OA	So, you've been here for 20 years. Is that your entire career?	
Interviewee	Yes	
OA	That's very impressive… So, you mentioned you were the there was the architect, mechanical engineer With those other teams… If I asked you to describe the team's organization	Team members Organization
Interviewee	Of the entire design team	
OA	Of the team of the design team yes	
Interviewee	Well obviously, there's the owner. And then the architect is typically the team leader for the entire project. And then the engineering disciplines typically… fall in line behind the architect. So, I don't think that the tree below that is all equal, you know its civil and mechanical and structural. And when I say mechanical its MEP	Organization
OA	Yeah	
Interviewee	So, mechanical electrical and plumbing... and then outside of that which would come off the tree of the owner would be... they are responsible for hiring the geotechnical engineer. So that would be in terms of design process...That would be typically be a project of this type would be put together	Organization
OA	Okay	
Interviewee	So, it would be a traditional design build, well not a design-build... You know architect design	Description
OA	design bid build	
Interviewee	yes, design bid build	
OA	So, I'm curious do you find the that's more common in the projects that you've worked on	

Table 3 The final coding protocol

Codes	Sub-Code	Definition	Example
Project	Description	General information about the project, specific project features that differentiate it from others	in terms of design process...That would be typically be a project of this type would be put together, so, it would be a traditional design build
	Challenges	Project issues and concerns that could not be controlled or accounted for.	And at a certain point in that process, we actually switched contractors which was very, very, disruptive to the process
Team	Location	The location of the different disciplines with respect to each other and the project	We want to be close to our architectural clients, which is why we are located…
	Involvement	Design stage when the different disciplines were involved on the project	well in this instance we were involved fairly early... so you know very different stages of the project... you have schematic design, design development and construction documents
	Tasks	The specific tasks and roles performed by the different design disciplines on the team	Sure, you know our responsibility is to design the structure... so typically we receive plans from the other disciplines
	Relationships	Prior working relationships and personal relationships between team members and the different disciplines	Yes, so I've worked on this team with on multiple projects
	Organization	Descriptions of the team structure and hierarchy	So, we had myself, who could sort of manage and be in parts of different things, and we also have an interior designer on the project
Communication	Design information	The kinds of information team members exchanged with each other	So architecturally we would release CAD backgrounds, a description of what they should be looking for that's changed
	Social behavior	Patterns of information exchange, descriptions of interactions between team members	I think there's a trust factor that gets developed. I think there's a, you know, there's a frankness and an honesty.
	Information process	Modes of information exchange	There were milestones that the design team would have to meet on a weekly or monthly basis... or whatever it was, to share documents...
	Technology	Tools and software that facilitated the exchange of design information	yes absolutely...in a 2d World there are things that can be missed. When you're able to take a model, and spin it and see how the structure interacts with the architecture... it really makes it a smoother process.
	Recommendations	Descriptions of approaches to ensure and improve effectible communication between disciplines	quite often the model... is not... their model isn't to the point where I can figure things out. they say now… oh you needed a dimension,
Outcomes	Positive	Outcomes showed the team was effective	So, along those lines we have gotten feedback that the clients are very pleased with our efforts…
	Improvements	Outcomes that indicated the possibility of improvement for the team	So, it certainly hasn't been as perfect as a delivery package as I would generally want to see, but I don't see that as a result of a shortcoming and our process

results

The findings from this case study are presented in three sections, along each of the lines of inquiry discussed in Chapter 1: the multidisciplinary building design team, multidisciplinary design team communication and multidisciplinary design team outcomes. At the outset, it is important to mention the unique challenges faced by the project to provide some context for the findings and discussion that follows: a change in the project manager in the middle of design development, and the need to reduce the project budget. These challenges caused a change in the vision and goals for the project and a compressed time frame to develop the project delivery package.

The Multidisciplinary Building Design Team

Team members from the different disciplines were asked to describe their experience with the project design team, including its organization, its dynamics, their disciplinary roles on the team, the team strengths and its limitations.

All five disciplines reported that the project challenges influenced all aspects of the team functioning but what was most affected was the time that team members had to work on the project. However, in-spite of the challenges, the disciplines reported that they were able to work well together.

As reported by the architect:

"So, it certainly hasn't been as perfect as a delivery package as I would generally want to see, but I don't see that as a result of a shortcoming in our process. I see that as a as the result of the challenge that was thrust upon us." [1]

The different disciplines also reported that several team characteristics such as the location of team members, and the preexisting relationships between team members helped mitigate some of the project challenges. These characteristics are presented in two categories: the organization of the team and the involvement of the team on the project.

<u>Team Organization</u>

Findings on team organization suggest that the contractual structure of the team forms the basis for how the team is organized, although in the case studied this structure was influenced by the preexisting relationships between the different disciplines and individual team members, and the location of the team members.

1. *Contractual Structure*

The project was described as architect-led, rather that developer-led. This project delivery approach meant that most of the design consultants were contracted to the architect and provided services to support the architect's design, as discussed in the introduction, rather than being contracted directly to the developer (the owner in this case).

The architect-led nature of the project meant the disciplines on the design team were organized around the architects, with the exception of the civil engineers. This structure is shown in Figure 5.

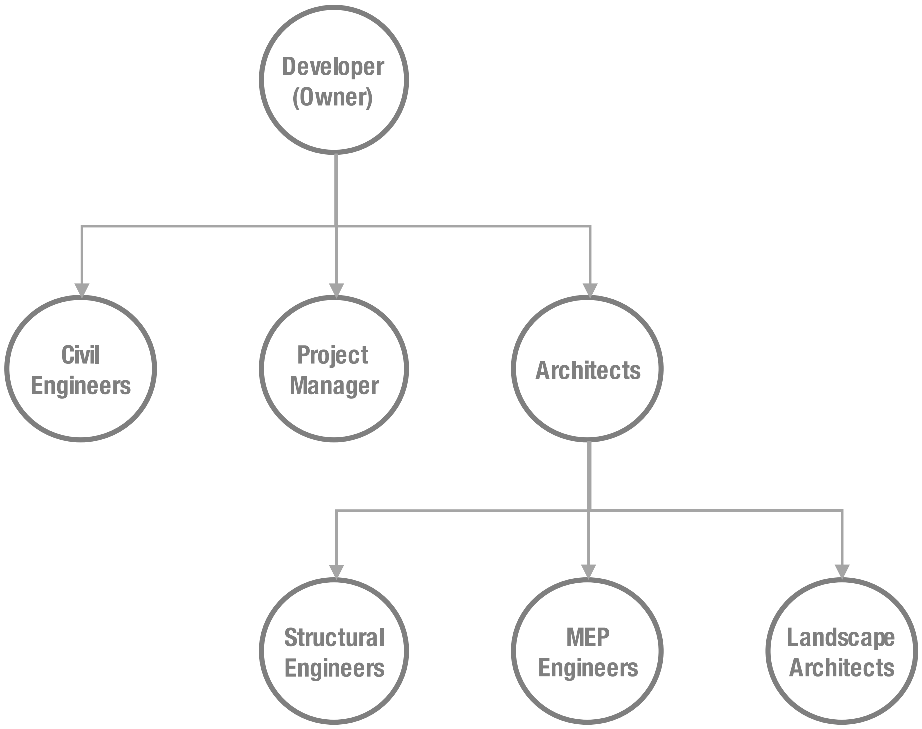


Figure 5 The organizational chart of the design team showing the hierarchy of the team members

The contract structure and organization around the architects has implications for the patterns of information exchange among the disciplines on the team which will be discussed in the section on communication.

2. *Preexisting Relationships*

The civil engineers were familiar with the owner-developer as they worked with them on a prior project and contributed to finding the project site for with the owner. As a result of this preexisting relationship, the civil engineers were in direct contact with the developers.

As reported by the civil engineer:

"Actually, in this case, we knew the developer before the project. You know we worked with this developer in their other, in some of their other regions, like in Indianapolis suburbs particularly. So, when they were coming to Pittsburgh to look, some of our people introduced them to us and actually did some help with… sort of with the ground work…" [2]

Other disciplines reported preexisting relationships with each other: the architecture firm had worked with the landscape firm on prior projects, and the architects had previously worked with the structural, civil and MEP engineers. There were also close personal relationships between certain team members across different disciplines as some of the civil engineering team members reported having personal relationships with the MEP engineers.

As reported by the architect:

"So, I had a lot of familiarity with the structural engineer, and the civil engineer. The firm had just…we are just wrapping up a project with the mechanical engineers. There are a lot of good working vibes and a positive working environment. The landscape architects, I haven't worked with them personally but my firm has, maybe 15 to 20 times, and I know them personally, you know from the industry" [3]

As reported by the structural engineers:

"We have worked with the architects on multiple projects, they're pretty easy to work with. They know what we need and we know what they need so there is an understanding of what the other is looking for" [4]

The preexisting and positive relationships meant that disciplines could anticipate what the other would need even before the start of design, which made them accountable to each other.

3. Location: The Pittsburgh Factor

The close relationships between the disciplines and the members on the team existed partially because all team members were in the Pittsburgh area while the owner-developer, and project manager were based in Indianapolis. Team members described Pittsburgh as having a close-knit building design community, where design firms and consultants regularly work together on similar projects.

As reported by the civil engineer:

"You know Pittsburgh is this big small town and the civil engineering community, or the design…development community is…Very close-knit. Yeah. Everybody knows each other." [5]

"You know you're in a room with a bunch of people which you've known for a long time. You know how they function a little better and just more comfortable, more relaxed, and lot easier to have a dialogue with somebody which you have history with." [6]

These findings suggest that there are benefits to multidisciplinary building design from having the disciplines in the same location with each other and with the project.

Team Involvement

Findings on team involvement suggest that the stage at which the disciplines became involved on the project was in part driven by the tasks each discipline performed.

4. Disciplinary Involvement

Owing to the size and complexity of the project, most of the design disciplines were involved early on in design – as early as schematic design. This approach was reported to be uncommon but preferred by most of the disciplines on the project. Figure 6 shows the timeline of the involvement of the disciplines on the project.

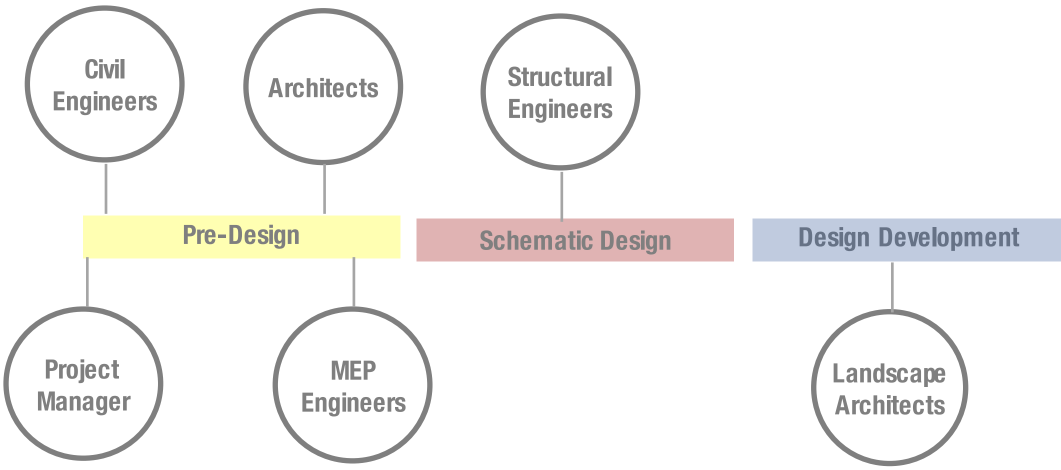


Figure 6 Timeline of the involvement of the different disciplines in the design process

The civil engineers and MEP engineers were involved during pre-design, the structural engineers were involved during schematic design, and the landscape architects were involved during design development.

All disciplines reported that they preferred being involved early on – if possible during pre-design – as it allowed them to influence the design decisions being made.

As reported by the landscape architects:

"And that's why the sooner the better, even if we're involved very superficially in the beginning stages, you'll at least digest all that information and why you got to there. So, we like to be involved from day one and be able to be part of the team throughout the whole process" [7]

This implies that early involvement of the disciplines on the multidisciplinary building design team can positively impact design decisions and outcomes.

5. Disciplinary Tasks and Roles

The differences in the time of involvement of the disciplines is in part dependent on the tasks they performed.

For instance, the architects worked with the civil engineers to develop the master plan, and they also designed the individual buildings and their interiors. The landscape architects were asked to fill-in the site after the individual buildings and master planning were completed. The civil engineers were responsible for the initial master plan and site planning including developing the parking layouts. The structural engineers came up with efficient framing options for the individual buildings on the site – with one engineer working on one building, and the MEP engineers designed the HVAC and fire safety systems for the three buildings on the project.

However, it is important to note that there were sub-disciplines and different roles within each discipline. The structural engineers and landscape architects were single disciplinary, the architects had an interior designer in their firm, the MEP engineers had mechanical engineers and a fire safety designer, and the civil engineers had engineering sub-disciplines spanning environmental, ecological, traffic, and geotechnical engineering.

While each discipline had a team leader who was primarily responsible for coordination between the different disciplines, the architecture team leader was the overall design team leader and was responsible for connecting the entire design team with the owner-developer.

A summary of the disciplinary tasks and roles is shown in Figure 7.

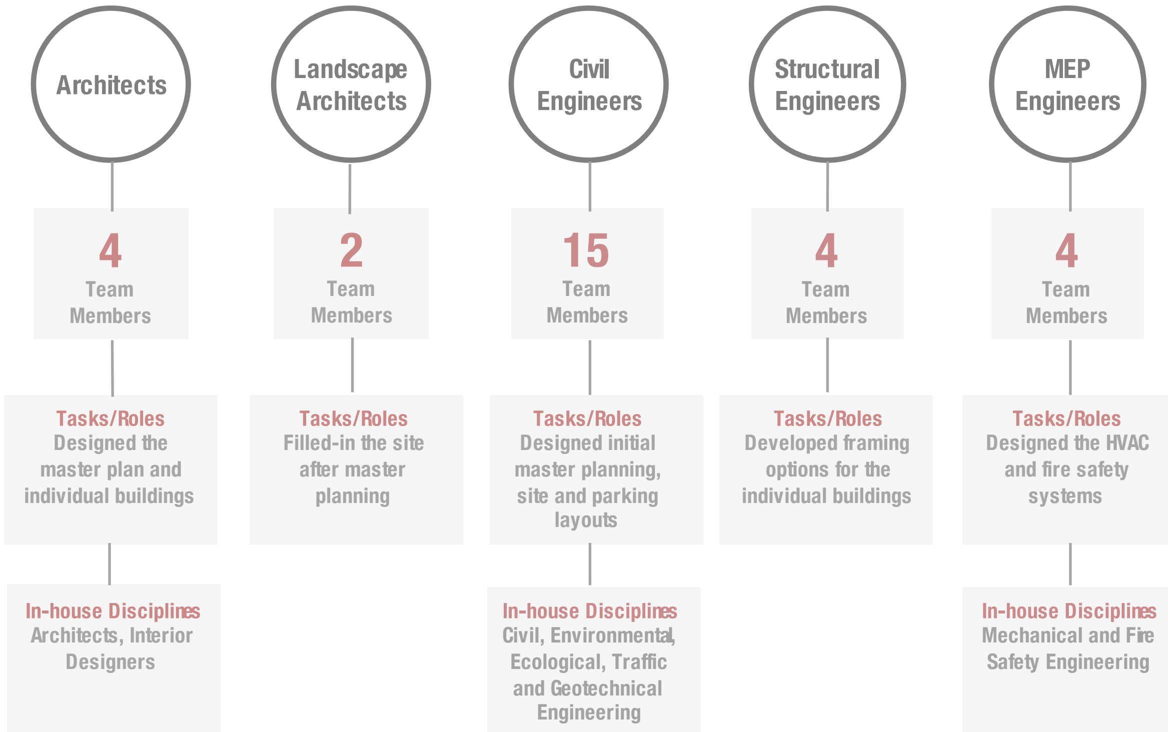


Figure 7 Summary of the tasks and roles of the design disciplines studied in team 1

These findings highlight the importance of disciplinary tasks and roles as a main driver of multidisciplinary building design team characteristics such as involvement and suggest that they are an influencing factor of team communication processes.

Multidisciplinary Building Design Team Communication

Three categories of design communication guide the inquiry – communication as social behavior, communication as information exchange, and the use of communication technology. The findings are discussed along each of these categories.

<u>Communication as Social Behavior</u>

Communication as social behavior, discussed in Chapter 2, explores the patterns of interaction between the different disciplines on the team. Team members from the different disciplines were asked to describe the flow of information between the different team members on the project.

Figure 8 shows the flow of information between the different disciplines.

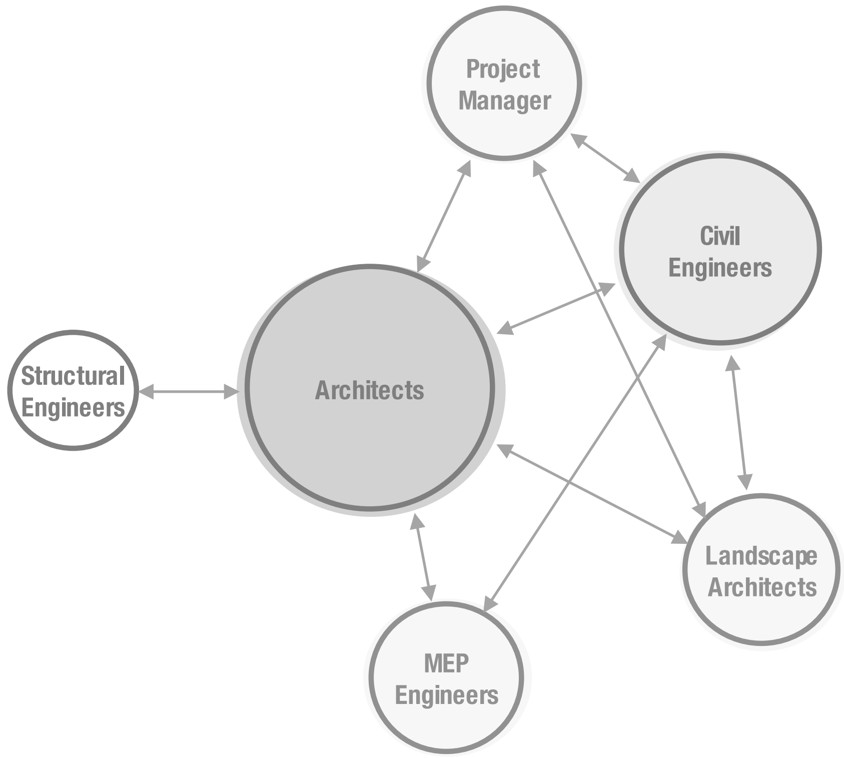


Figure 8 Flow of information between the different disciplines in team 1

The flow of information is represented using circles (or nodes) and arrows. The diagram uses color coded and labeled nodes to represent each discipline on the team. The size of the node indicates the connections between other disciplines while the arrows indicate the flow of information between disciplines. Figure 9 shows this in more detail.

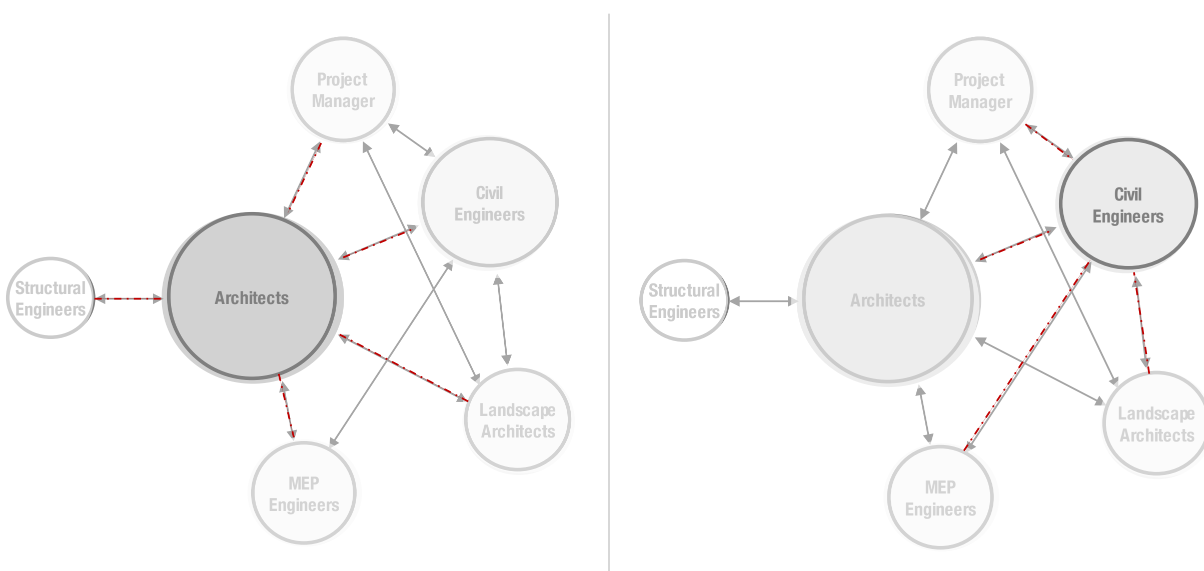


Figure 9 Comparison of architects' node and arrows with the civil engineers' node and arrows

The comparison presented in Figure 9 shows that the architects have the largest node as they both receive from and send information to all five other disciplines on the team. On the other hand, the civil engineers' node is slightly smaller than the architects' node as they only exchange information with four disciplines on the team.

Team members suggested that in this case, the patterns of information flow that emerged on the project were a function of the organization of the team, the disciplinary roles and tasks, and the pre-existing relationships on the project. The findings on these relationships are presented below.

6. Information Flow as a function of Disciplinary Tasks

The disciplinary tasks performed influenced the flow of information. Three examples are used to show this: the structural engineers, the MEP engineers' and the civil engineers.

Figure 8 shows that the structural engineers only interacted with the architects. The nature of the tasks they performed meant that it was unnecessary for them to interact with the other disciplines. The structural engineers also had a unique situation where the three engineers worked individually on one of the buildings in the project.

The MEP engineers also worked closely with the architects and with the civil engineers. The influence of the MEP's tasks (HVAC equipment sizing and ductwork) and the civil engineers' tasks (where things would go on the site) led to a lot of back and forth between these two disciplines.

The civil engineers worked primarily with the owner/developer's project manager and the architect. Due to the overlap in site issues, they worked with the landscape architects on the site design. The civil engineers had no direct interaction with the structural engineers.

7. Information Flow as a function of Team Organization

The information flow between the different disciplines on the team is in part a result of the organization, specifically the contract structure of the team illustrated in Figure 5. As mentioned earlier, the architects held the contracts with the structural engineers, landscape engineers and MEP engineers. This meant that all communications and interactions between these disciplines went through the architect. This is shown in the central position of the architects in Figure 8. The exception to this were the civil engineers, who as mentioned earlier, have a preexisting relationship with the project managers.

8. Information Flow as a function of Preexisting Relationships

In general, in a scenario where the design contracts are all held by the architects, the civil engineers would be less likely to have direct contact with the project manager. However, in this particular case, because of the civil engineers' prior work history and their preexisting relationship with the project manager, there was a direct flow of information between them. This was also the case with the landscape architects and the project manager where there existed prior personal relationships among individual members from both disciplines.

This finding suggests that the preexisting relationships between team members of different disciplines on the multidisciplinary building design team can modify the expected flow of information among the disciplines on the team.

It is necessary to mention that the flow of information in this case is also influenced by the stage at which data was collected. This is presented in the cross-case report in Chapter 4.

<u>Communication as an Information Process</u>

Communication as an information process, as discussed in Chapter 2, explores the forms of design information and the modes of information exchange. Team members from the different disciplines on the team were asked about the types of design information they sent to other disciplines and how they sent this information.

The results obtained highlighted the importance of information delivery, and the different kinds of meetings – goal setting meetings and troubleshooting meetings – with respect to project stage.

9. Information Delivery and Timing

Design information was exchanged primarily in the form of 2D CAD drawings, 3D BIM models, technical reports and meeting minutes. The drawings and models were managed by the architects with the landscape architects, the civil and MEP engineers worked off the base drawings developed by the architects. The structural engineers worked primarily on calculations. In this case, they did not develop a model but had draftsmen working on developing the structural 3D model. The architects were also responsible for documenting the team meetings that occurred.

Several modes were used to exchange design information. In this case, email and meetings were the primary mode of information exchange. Email was useful as team members could access information as and when they needed it.

As reported by the architect:

"I think it works because you can take a snapshot of the screen, you can send it over, you can give a description, you can get back to it when you have time to focus. If I'm working on something and then I get a call out of the blue, and I'm switching my mind over, that may or may not be effective to me.

And what I've seen is that younger people have a tendency to prefer email, or more passive communication modes over just about anything else…" [8]

Team members reported that the primary disadvantage of email for exchanging information was that the file sizes allowed by email were limited. In such situations, FTP sites were used instead. This will be further discussed in the communication technology section. Meetings were the other mode of information exchange and are discussed below.

Regarding information timing, two factors were identified as being most critical: the on-time delivery of design information from the disciplines on the team, and the delivery of the right information from other disciplines.

As reported by the structural engineers:

"because the way that... the contractor wants to deal with constructing the building is... foundations going first and then they erect the steel or erect the structure first... so their information... they're feeling is they want the structural information ahead of everybody else…" [9]

As reported by the MEP engineers:

"Sometimes, we don't always get the information that we need. Sometimes, for one reason or another…" [10]

Team members suggested that generally, not receiving the right information at the right time could be attributed to the different disciplines not accounting for, or being unaware of each other's needs, and the connections between each other's tasks.

This finding implies that it may be useful to explicitly provide disciplines with clear lines of information that detail what kinds of information are required from each other, when they are needed and who they should go to.

10. Meetings! Meetings!! Meetings!!!

Meetings were reported to be a critical aspect of team communication. There were two kinds of meetings as shown in Figure 9 – early-on, goal or expectation setting meetings, and troubleshooting meetings that occurred later on.

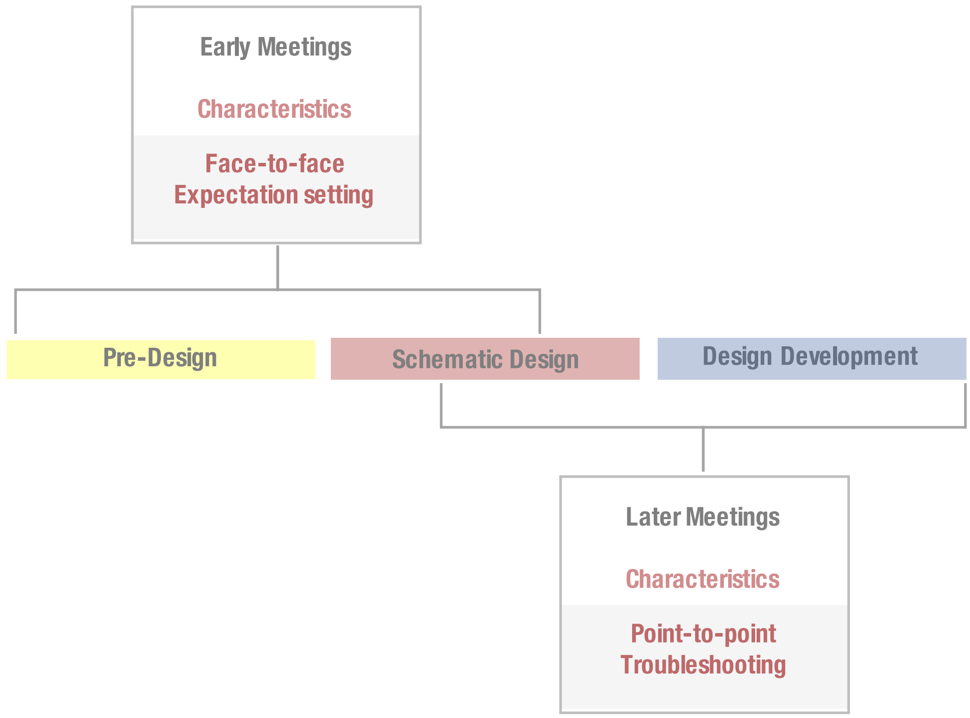


Figure 9 Meetings at the different stages of design.

The goal/expectation setting, early-on meetings occurred from the beginning of pre-design through to schematic design. The aim of these meetings was to get as many disciplines together to discuss requirements for the design before any requests for information were sent out.

The expectation setting meetings were mostly face-to face, either in person, or using digital tools and primarily involved just the leaders from the different disciplines. The expectation setting meetings were easy to set up because the team members were all local to the Pittsburgh area and were close enough to each other that the meetings could occur easily.

As reported by the architects:

"Meetings with everyone in the same room, including the owner, in person. Those are not the meetings where you get all the wrinkles ironed out, but those are the meetings where you get all the expectations ironed out" [12]

As reported by the MEP engineers:

"I think if everybody in the perfect world. Everybody who's a part of the project, design would be there at the design meetings and everybody who is on the design team should be at the construction meetings, for a vary of reasons but again it usually comes down to budget." [13]

Team members reported that the main advantage of the face-to-face meetings – both in-person and using digital tools – is that they could work side by side with the other disciplines and look at drawings and models with each other.

However, team members also reported that there were issues with the expectation setting meetings that were mainly connected to changes in project vision and project management. The inexperience of the project manager with the project location meant the information for the different disciplines was neither always available at the right time, nor when it was most critically needed. Expectations were also not defined clearly on and were changed in the middle of design when considerable progress had been made in a specific direction, and emphasis was not placed on the key critical path items which caused staging issues further along the project.

After the expectation setting meetings, information was distributed to team members in the form of CAD backgrounds and a description of changes to the project. The architects were primarily responsible for sending out this information to the different team members. Standard filing procedures were used to keep track of the changes to the project. And there were routine milestones for exchanging design documents were set up.

As the project moved though schematic design and into design development, the types of meetings and the individuals involved in the meetings began to change from goal setting to troubleshooting.

The troubleshooting meetings occurred to iron out kinks and involved more targeted, point-to-point meetings between specific individuals on the team. These targeted interactions were useful when it was necessary to obtain or clarify specific information from a specific discipline. Team members reported that this happened later in the project as members of the different disciplines became familiar with the project and with each other. Regardless, as much as possible, the architects were always formally aware of the interactions between the different disciplines. Unlike the goal setting meetings which involved mainly team leaders, the troubleshooting meetings could be initiated by any team member

An example that illustrates the transition from the goal/expectation setting meetings to the more targeted interaction is with the civil engineers. At the beginning of design during pre-design, the civil engineering leader attended most of the expectation setting meetings and played the role of a coordinator between the entire design team and the civil specific team. Further along during the design process, the civil leader moved out of this role as the civil team members then engage in more targeted interactions with the other design team members.

Team members reported that the main advantage of this targeted, troubleshooting interaction is that they could reach out to each other to iron out and resolve discipline specific issues. For instance, if one of the landscape architects needed information from one of the civil engineers, they could reach out to them without having to go through the architect, as they had built enough familiarity with the project and with the other team members. The limitation of this approach was that changes could occur that the other team members are not aware of, so for instance, if said landscape architect and the civil engineer made some changes without notifying the architect, the undocumented changes could lead to troubles further on.

The findings on meetings highlight the importance of meetings for multidisciplinary building design teams but also suggest modifications to the dual process model which will be described later on.

The Use of Communication Technology

Team members were asked to discuss the different digital tools and technology that supported information exchange between the disciplines. They reported that on this project, technology was used to facilitate the exchange of design information between disciplines in two ways: through the use of Building Information Models (BIM) and to share documents.

All the disciplines reported the use of Building Information Modelling tools on the project (BIM), such as Revit and ArchiCAD. The advantages of BIM tools to the design process are numerous and have been discussed by several scholars. However, team members mentioned that the advantages of BIM could only be achieved if the modeling was done accurately. Inaccuracies occurred either on the part of the modeler, or resulted from a lack of accurate translation between the software used by the different disciplines (Tekla for the structural engineers, Revit for the MEP engineers and ArchiCad for the architects).

As reported by the structural engineers:

"no, but… so for the most part yes, and this project we were the same Revit software but when that doesn't happen that can be a bit of a hindrance for us because their software does not translate to our very well" [14]

As reported by the landscape architects

"Even when you deal with tools and files in-house, quirky things come up" [15]

As discussed earlier, when sharing documents, email was primarily used, but when large files needed to be sent, that is files larger than the email capacity, FTP sites were used on this project to share them. Other file storage and sharing tools including Box and Dropbox were occasionally used. The advantages and limitations of the different tools used will be further discussed in Chapter 5. However, the different disciplines reported that the limitations of the document sharing tools was that they were mainly for file storage and it could be difficult to keep track of changes in the document, and the document sharing tools also did not communicate or interact with the BIM tools.

On this project, technology was also minimally used to facilitate meetings with tools like Skype and GoToMeeting that allowed team members share their screens with each other, simulating the effect of working together in-person.

These findings on communication technology suggest that the benefits of BIM can only be achieved with accurate models and the technology supporting document sharing between disciplines on the multidisciplinary building design team can be significantly improved on.

Multidisciplinary Building Design Team Outcomes

Team members were asked to report on two outcomes: things that they though worked well on the project which would form the 'positive' outcomes, and things that could be improved on the project which formed the 'negative' outcomes.

For the positive outcomes, there was the overall sense that the right team had been put in place and the team was able to work well together. Team members reported that they were all able to keep up with wild changes and the team members were all in it together with shared responsibilities resulting from the preexisting relationships between members of the same discipline. Team members also reported that when there were clear expectations set and there was a clear direction for the project, set goals were accomplished. Team members reported that even with the challenges the project faced, they could work well together and all members remained accessible.

As reported by the landscape architects:

"like when we go into the next phase, I will and hopefully that's worth this project is going, its been a really good team,

Yeah, I think that that language, like good team, great process can generally as well come from the product that we get to implement at the end of the day and the ease at which we get to do it" [16]

The second positive outcome discussed was the team's approach to the project. Team members believed that the project was efficient as there were limited redesigns and the task were stages well. A note about this report is that while all team members believed that the project was efficient, the sense of efficiency was more strongly felt by the disciplines who has the longest working relationship, for instance the structural engineers who has a very long and rich working history with the architects (since their inception) reported on the efficiency of the project and attributed it to receiving the right information at the right time.

Multiple team members reported that they expect the plans to survive through construction and that working on the team has been smooth as all team members have been accessible.

However, along with the positive outcomes, team members reported that given enough time and if clear expectations were established early on, they could have produced a perfect delivery package. Due to the project challenges – time pressure and scope changes – some information fell through the cracks and some shortcomings and were exposed during construction.

As reported by the MEP engineers:

"No. I think with this project, it was difficult because of the time frame. I know that early on, we were kind of going down the road in a certain direction and its not just a direction change at all, but the goal of like the time frame of whenever we had to have documents done from a preliminary standpoint and a final standpoint, that's kind of got cut in half, which is the mad scramble of getting information on drawings.

Like you try, you have standards, but when push comes to shove and you have to react, you just you do what you got to do to kind of keep your head above water" [17]

It is worth mentioning that because the project had multiple phases, team members reported their willingness to discuss and address the challenges faced in the phase one before moving on to the other phases.

discussion

From the study of team 1, findings show that team characteristics, the organization of the disciplines and their involvement on the project all influence the patterns and modes of information exchange between the disciplines. The organization of disciplines can, in turn, be influenced by both team and project characteristics including: the preexisting relationships between team members, the location of the team and the stage of the project. Findings also show that the project stage – driven by the tasks performed by team members – determined the kinds of meetings that occurred. Improving model accuracy and increasing the functionality of document sharing sites were suggested as changes to communication technology for multidisciplinary building design.

The findings contribute to several takeaways that have research and practice implications for multidisciplinary building design teams, and suggest modifications to the exploratory framework to account for additional input characteristics and the additional communication processes interaction that occur. The takeaways include:

- Interpersonal social and professional relationships between team members across disciplines can help address the challenges of working in a multidisciplinary building design team.
- The proximity of all the disciplines to the site can be beneficial to the multidisciplinary building design process.
- The early involvement of all the design disciplines is beneficial to multidisciplinary building design.
- Preexisting interpersonal relationship between team members from different disciplines can modify the communication patterns of the multidisciplinary building design team.
- The stage of the building design project influences the patterns of communication between disciplines.
- Meetings remain a critical aspect of multidisciplinary building design team communication, but the type of meeting depends on the stage of the project.
- The difference in the information exchange processes of different disciplines should be accounted for in multidisciplinary building design teams through management and coordination.
- Building Information Models are only as useful as they are accurate.
- With additional functionality, document sharing sites can be more useful to multidisciplinary building design.
- The team's ability to respond to multidisciplinary project challenges can influence the nature of team outcomes obtained.

The case findings and takeaways suggest that the inputs of the exploratory framework can be modified to include the team and project characteristics that, in addition to functional diversity, influence team communication and outcomes. The information processes of the framework can also be modified to reflect the findings on communication as an information process where functional diversity leads to three information processes: the information rich, divergent process which occurs early in the design process, the targeted convergent interactions which occur later in the design process and categorization processes that occur due to the presence of multiple disciplines.

CASE REPORT – TEAM 2

executive summary

The case study presents the analysis and results from the interview data of members of multidisciplinary building design team 2. Team members worked on an institutional building in Pittsburgh, PA. The team comprised ten disciplines: project managers, construction managers, architects, landscape architects, civil engineers, structural engineers, MEP engineers, lighting, acoustic and audio-visual designers. Data was obtained from ten team members – one from each of the disciplines – on completion of the schematic design stage of the project, and was analyzed using content analysis and value flow diagrams described in Chapter 3. Excerpts from the data collected and the analysis are shown in the appendices.

Guided by the exploratory framework to suggest a relationship between functional diversity, communication processes and team outcomes, this study provides descriptions of the multidisciplinary team, the teams' communication across three categories – as social behavior, as an information process, and communication technology – and the teams' outcomes.

The findings suggest that:

- Although, the contractual structure of the team forms the basis for how a team is organized, this structure is influenced by the preexisting relationships between the disciplines and the individual team members, and the role of the project managers.
- The early involvement of all disciplines and the facilitation of the project through meetings and workshops is beneficial to building design.
- Patterns of information flow that emerge in the project are a function of the disciplinary roles and tasks, and the stage of the project.
- An awareness of the benefits of project management tools is helpful for building design practice.

In addition,

- Rather than outcomes, the team processes are more relevant to design team members particularly in the schematic design stage.

In addition to the research and practice implications of these findings, the report finds that the exploratory framework needs to be modified to accurately represent multidisciplinary building design team practice. The framework should be expanded to include team and project characteristics – such as the project stage, facilitation and the involvement of disciplines – which contribute to the effects of functional diversity, and additional communication processes – such as targeted interactions that occur.

The findings from this case report will be compared against those from the other teams studied and presented in Chapter 4.

introduction

At the time of this report, the team comprised members across ten disciplines – each within a firm – including the project manager representing the owner. The design disciplines were the Project Managers, the Construction Managers, the Architects, the Landscape Architects, the Site Civil Engineers, the Structural Engineers, and the Mechanical Electrical and Plumbing (MEP) Engineers, the Lighting Designers, the Acoustic Designers and the Audio-Visual Designers.

Figure 1 The design disciplines in team 2 across different firms

The team worked on a 36,000sq ft. institutional building in Pittsburgh, Pennsylvania, containing classrooms, collaborative work spaces, simulation spaces, office and conferencing spaces.

Figure 2 Map of Pittsburgh highlighting the neighborhood of team 2's project

The project lies between two existing campus buildings and serves as a connector between the buildings. This unique location of the building and the spaces it contains poses several design challenges and accounts for the range of disciplines involved in the project.

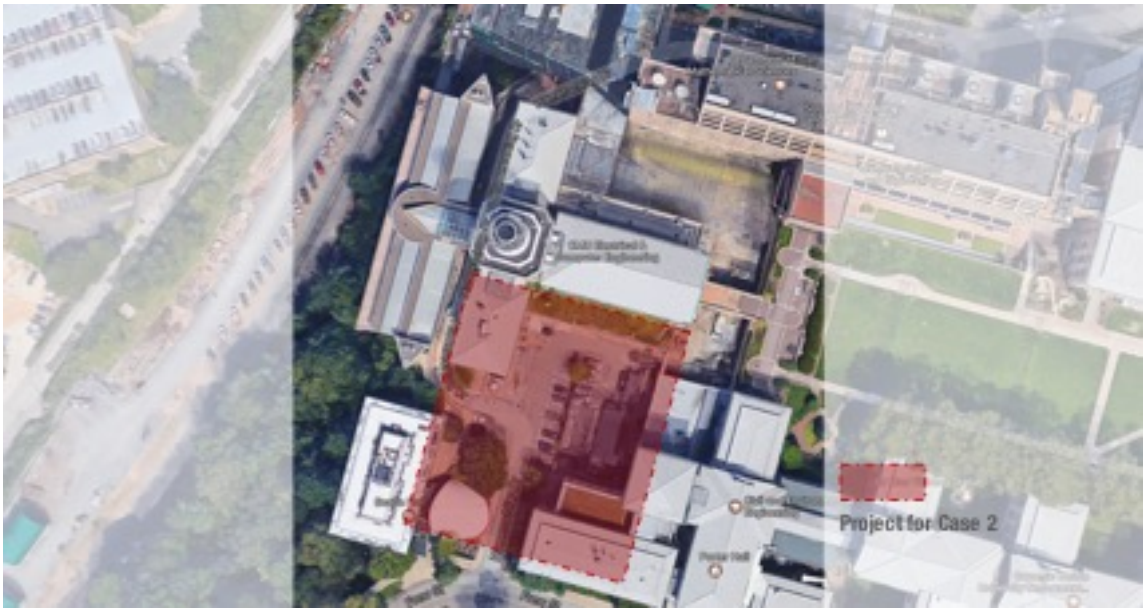


Figure 3 The team 2 project site

The project followed a CM at Risk process where the construction manager provided the owner with a guaranteed maximum price (GMP) contract and as such was involved with in the project from the start of design.

Data for the case study was collected on completion of schematic design and before the beginning of design development.

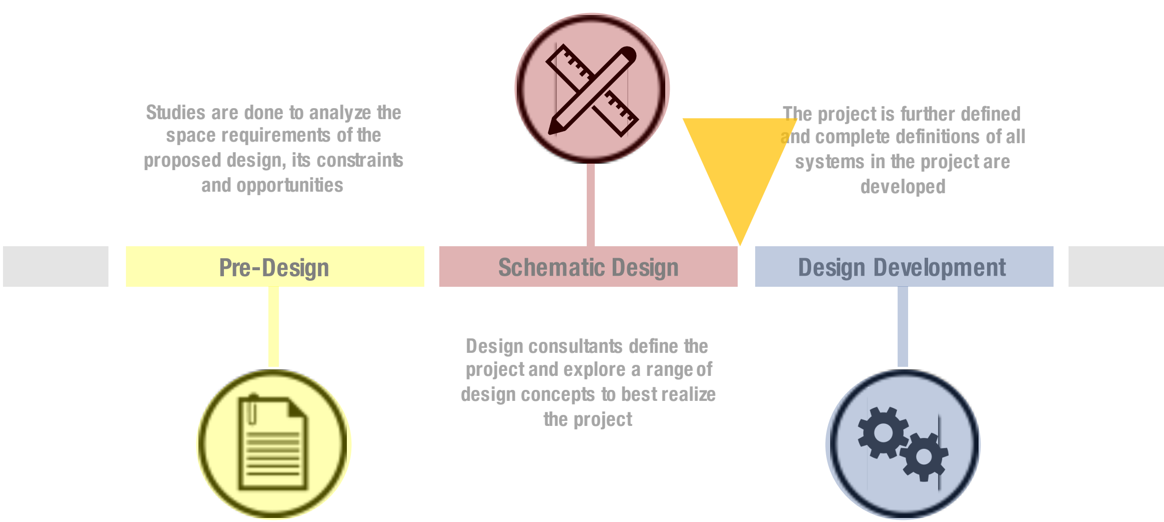


Figure 4 The stages of the building design process showing when the data for team 2 was obtained. Adapted from (UCOP, 2013)

To obtain the data for this case study, ten team members were interviewed, five were interviewed in person while the remaining five were interviewed over the phone. Table 1 summarizes the data collection for this case study.

Table 1 Summary of data collection

Disciplines	Number of Interviews	Mode of Interviews
Project Managers	1 team member	In-Person interviews
Construction Managers	1 team member	In-Person interviews
Architects	1 team member	Phone interviews
Landscape Architects	1 team members	In-Person interviews
Civil Engineers	1 team member	Phone interviews
Structural Engineers	1 team member	Phone interviews
MEP Engineers	1 team member	Phone interviews
Lighting Designer	1 team member	In-Person interviews
Acoustic Designer	1 team member	In-Person interviews
AV Designer	1 team member	Phone interviews

The interview data is coded according the coding protocol developed from the review of existing literature described in Chapter 2, and the research questions outlined earlier in Chapter 3. An excerpt of the coded data is shown in Table 2 while the coding protocol is shown in Case 1 (See Table 3 in Case 1). The findings from the data collected are presented in the following section.

Table 2 Excerpt from coded data for team 2

Person	Description	Code
Interviewee	So, we take care of all of the capital projects that's over a certain dollar amount, So, other groups take care of some smaller build-up projects, the things that don't require a building permit. So, anything that doesn't affect life safety or, things like that. But when it gets beyond that threshold then we get involved. Its not even so much of the dollar amount anymore when we get involved, I think its basically when anything needs a permit be built. Why do we take care of it? Well, that's what we do here. So, we have a lot of different disciplines within our office. We have engineers, architects, interior designers, but everybody with a project management background. Our role is to facilitate the project. So, we do the hiring of the consultants, the architects, the engineers, the construction managers and so forth. So, we get the expertise on the project and there is a process for that, which I can go over. And then, once we get basically again like we make sure that the process to make -- basically, to reach out to the end-users, to make sure we get the program documented and communication through all the disciplines is taken care of and in order to do that, there's a lot of meetings, which you can see that we did today. The condensed version of all these, the key is communication. I am a huge proponent of communication and setting expectations. I mean, that's pretty much it.	Tasks/Role Tasks/Role Disciplines
OA	Okay.	

results

The findings from this case study are presented in three sections, along each of the lines of inquiry discussed in Chapter 1: the multidisciplinary building design team, multidisciplinary design team communication and multidisciplinary design team outcomes. At the outset, it is important to mention some of the project challenges which provide some context for the findings and discussion that follows including the maker space, connections to existing buildings, the owner who was comprised of several end user groups, and a change in the project scope and budget.

The maker space – a large multi-story workshop/collaboration space – in particular presented several design challenges. As it was described as a relatively new type of space, the requirements for the space its surrounding classrooms and offices are to date previously undefined. The types of spaces in the building also required the involvement of several specialty design consultants including the lighting designer, the acoustic designer and the audio-visual designer.

The Multidisciplinary Building Design Team

Team members from the different disciplines were asked to describe their experience with the project design team, including its organization, its dynamics, their disciplinary roles on the team, the team strengths and its limitations.

The disciplines all reported that the uniqueness of the project introduced design challenges: the maker space and the connections between the new building and the existing building. However, the challenges made working on the project very interesting from a design standpoint.

As reported by the landscape architects:

"this project, it's a nice little project. It's one of the more design-focused ones. We really like the design-focused ones." [1]

The different disciplines also reported that several team characteristics such as the management of the project and the preexisting relationships between team members helped mitigate some of the project challenges. These characteristics are presented in two categories: the organization of the team and the involvement of the team on the project.

Team Organization

Findings on team organization suggest that the contractual structure of the team forms the basis for how the team was organized, where the project managers play an important role linking the team to the owner. Preexisting working relationships between the disciplinary firms also play a significant role in in determining the specific firms that worked on the project.

1. Contractual Structure

With the exception of the project managers who were the owner's representatives, and the construction managers, all the disciplines on the project were contracted to the architect. As a result, these disciplines provided services to support the architect's design and were organized around the architects. The organization of the team, based on the contractual structure is shown in Figure 5.

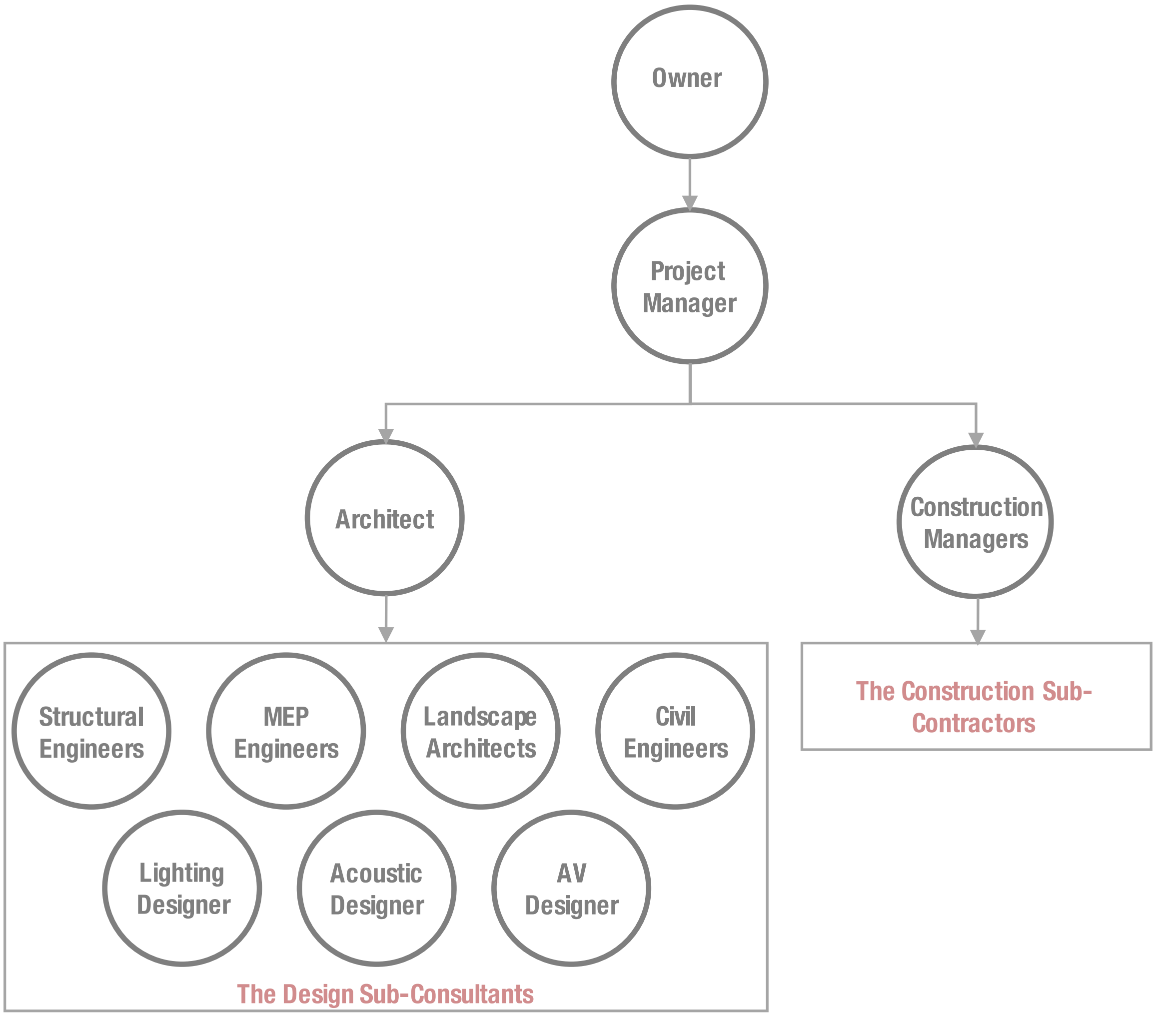


Figure 5 The organizational chart of the design team showing the hierarchy of the team members

The project managers were central to the team and served as the connection between design and construction. All the other design disciplines were linked directly to the architect.

This organization had an impact on the patterns of information exchange that occurred in the team and highlights the role of the project managers on this project.

2. *Facilitation and Project Management*

The project managers were responsible for facilitating the project by identifying the project goals and requirements, and selecting the architects and the construction managers for the project.

To identify the goals for the project, the project managers met with several end user groups. From these meetings and discussions, they were able to come up with very specific goals for the project. As a part of the goal identification process, the project managers also hired an architect and a CM firm to develop the initial project program and validate the budget.

As reported by the project managers:

"So, we did a quick study. It took care -- we did discuss possible program, square footage's, footprint, all those types of things, and then we also validated the budget. And for that, after the architect had some very quick schematics, we worked with another construction company which has done projects on site. So, they came in, we gave them the scope and they vetted the scope with the gift agreement. And from there, we were like, "Okay, this can happen, but we are limited to 25,000 square feet…" [2]

To select the project architects and construction managers, the project managers then held workshops where firms were invited to meet with the owners and end user groups. At these workshops, they held discussions regarding the project goals, its scope, and the participants ideas of how to address the project. From these workshops, the project architecture firm and CM firm were selected based on their presentations and responses.

As reported by the project managers:

"We just had a workshop and in that workshop, I did some slides and I showed with the program -- what we were anticipating the program to be. There were parts to those workshops. One was infrastructure. The other one was the master plan, so they understood the University's master plan and then the third one was the program which I sat in and I explained the program and the scope for each of those firms. We had slides and from there we asked for the proposals." [3]

Team members from several disciplines who attended the workshops reported that having such defined goals so early on, helped clarify the expectations for the project.

As reported by the structural engineers:

"I believe we had this meeting very early where they were also meeting with other consultants and the architects, it was mostly based on programming and, you know, things along those lines. The architects asked us to be there and that was helpful in developing our proposal…" [4]

This suggests that project managers as facilitators can significantly influence the building design process.

3. Preexisting Relationships

There were extensive preexisting working relationships between the disciplines and the owner, and also between the disciplines themselves. The specific firms involved on the project were selected as a result of these relationships. Two examples illustrate this: firm selection by the project managers, and consultant selection by the architects.

In selecting the design consultants and even the construction managers to participate in their workshops, the project managers invited architecture and construction management firms they had recently worked with or received proposals from.

As reported by the project managers:

"Some projects start out with like RFQs, Request for Qualifications. You send those out to a bunch of -- we kind of identify which architectural firms we're going to send them to. We send them out to those architectural firms and then they will send them back to us with their qualifications.

This particular project though, we didn't go through the RFQs. We went to five architectural firms that we've done work with recently or we've seen proposals from them recently." [5]

The architects then had to attend the workshops with their design sub-consultants. Most of the design sub-consultants had worked with the architects on previous projects or at previous firms.

As reported by the acoustic designer:

"So, one of the architects was in a different firm and we were introduced in a previous project. So, on this project, they reached out to me…" [6]

The architecture firm had worked previously with all the other except the audio-visual designers. One of their more recent projects was with the structural engineers. Some of the disciplines including the civil engineers, the landscape architects, the structural engineers, the lighting designers and MEP engineers had worked with the owner and project managers on past projects.

Team Involvement

Findings on team involvement suggest that regardless of the tasks performed by the different disciplines, all the disciplines were involved fairly early in the building design process.

4. *Disciplinary Involvement*

Due to the project managers approach to the team selection workshops where the architects had to attend the workshops with their design sub-consultants, most of the disciplines on the project were involved before pre-design. Figure 6 shows the timeline of the involvement of the different design disciplines on the project.

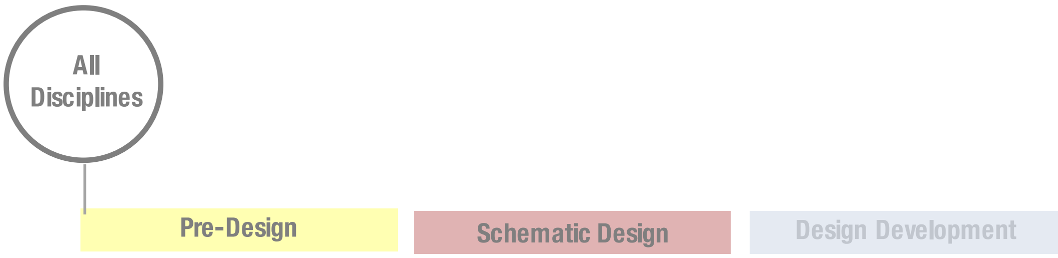


Figure 6 Timeline of involvement of the different disciplines in the design process

The project managers expressed that they preferred having the bulk of the disciplines on the design team be present at the selection workshops as it was helpful to have a clear sense of how each discipline would address the project.

As reported by the project managers:

"So, they presented to us and actually brought models in, so, they had time to think about how they would address this building. So, its kind of like, now we're not only looking at their fee, we are looking at - Hey, really how much do they really understand? And do they understand the scope? Do they understand the difficulties of the site? And how do we like some of their solutions?" [7]

5. *Disciplinary Tasks and Roles*

While the different disciplines performed tasks that were fairly standard within their areas, they were asked to perform these tasks earlier than they normally would.

As reported by the structural engineers:

"that's actually little earlier than we would typically meet for this project. I feel like we've done a little bit more from a structural standpoint than we normally would. We actually had a programming phase narrative which normally, we wouldn't be involved really at all, you know, throughout the programming phase just because that's so early" [8]

The project managers were the facilitators of the project. They hired the architects and the construction managers, and represented the owners' interests on the project. The construction managers provided pre-construction services during design that involved working with the project managers to develop the cost estimates for the project.

The architects were responsible for the initial spatial design and layouts and also coordinating the design sub-consultants. The landscape architects and the civil engineers worked closely on the site issues including surveying, site design, grading and so on. The structural engineers' the framing options for the building, the MEP engineers coordinated equipment sizes and calculated preliminary loads for cooling, heating and power. The acoustic designer developed a report exploring different acoustic treatments based on the architects and MEP engineers' information. The lighting designers provided the architects with preliminary lighting specifications while the AV designers worked with the MEP to IT and AV options.

Outside of the tasks performed, some of the firms offered multiple disciplinary services. For instance, the civil engineering could provide geotechnical, environmental and transportation engineering as well as landscape architecture services.

Team members within the disciplines also performed different roles. For instance, each discipline had a team leader whose role was primarily to coordinate with the other disciplines and the project managers.

A summary of the disciplinary tasks and roles is shown in Figure 7.

Figure 7 Summary of the tasks and roles of the different disciplines studied in team 2

These team findings describe the context and influencing factors of the multidisciplinary building design team in this case study. The implications of the findings are explored in the discussion section.

Multidisciplinary Building Design Team Communication

The findings on communication are discussed along the three categories – communication as social behavior, communication as information exchange, and the use of communication technology.

Communication as Social Behavior

Communication as social behavior, as discussed in Chapter 2, explores the patterns of interaction between the different disciplines on the team. Team members from the different disciplines were asked to describe the flow of information between the different team members on the project.

Figure 8 shows the flow of information between the different disciplines.

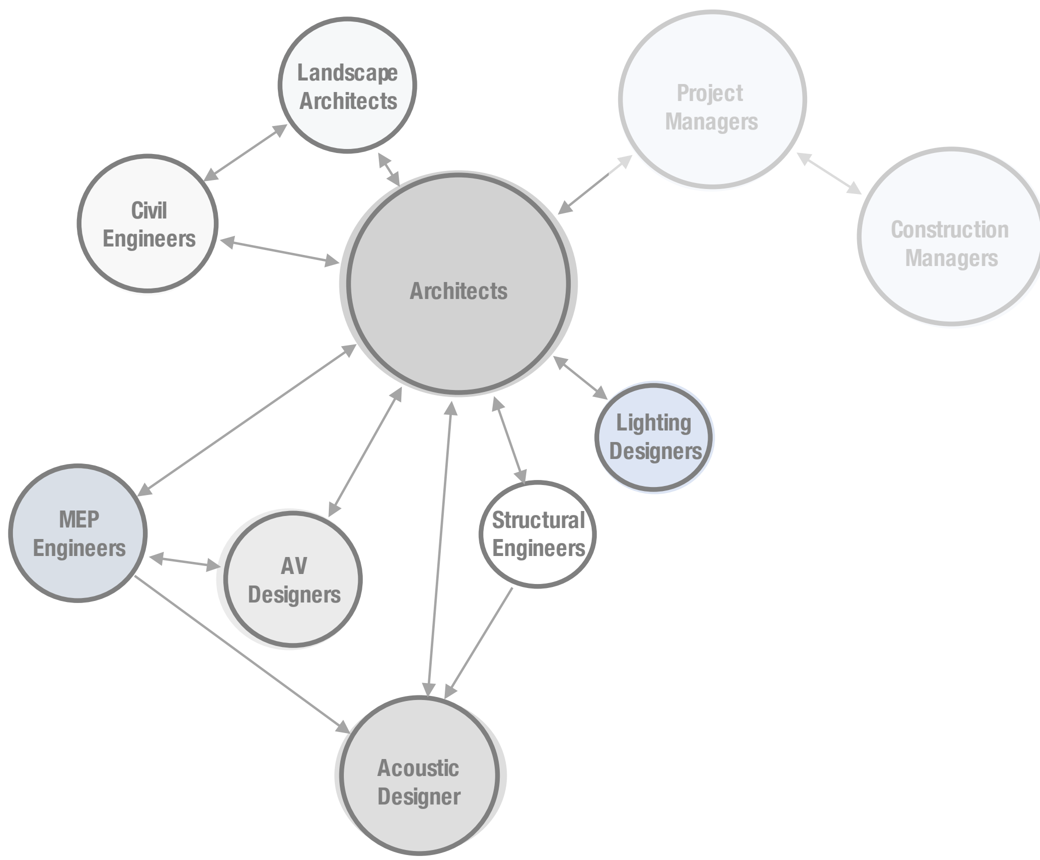


Figure 8 Flow of information between the different disciplines in team 2

The flow of information is represented using circles (or nodes) and arrows. The diagram uses color coded and labeled nodes to represent each discipline on the team. The size of the node – with the exception of the project managers and construction managers nodes – indicates the connections between other disciplines while the arrows indicate the flow of information between disciplines. Figure 9 shows a comparison of the architects and the structural engineers nodes.

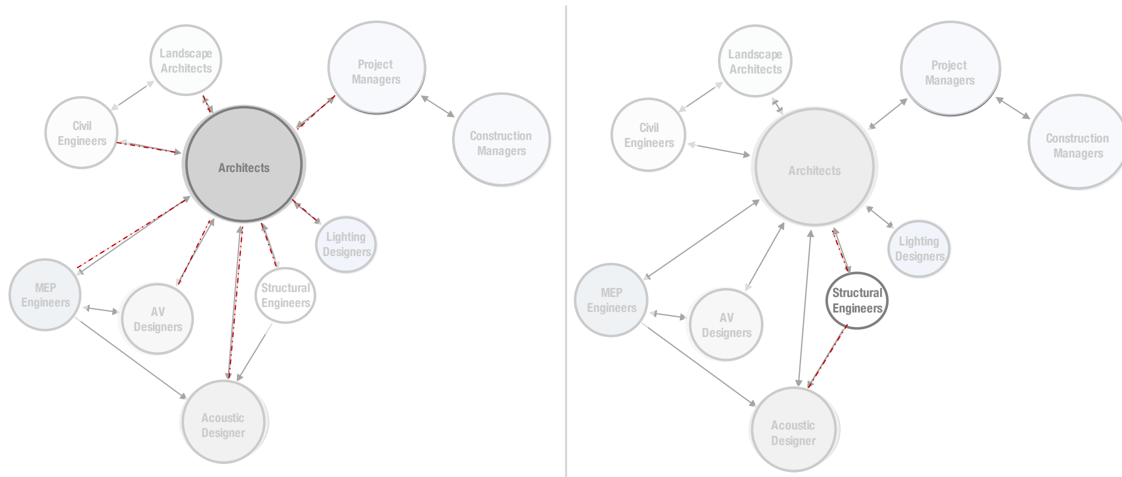


Figure 9 Comparison of architects' node and arrows with the structural engineers' node and arrows

The figure shows that the architects have the largest node as they have eight disciplines sharing information with them, compared with the structural engineers who have one discipline sharing information with them, and another they share with.

Two findings regarding information flow emerge from these diagrams: information flow as a function of disciplinary tasks, and information flow as a function of the stage of the project.

6. Information Flow as a function of Disciplinary Tasks

The disciplinary tasks performed influenced the flow of information. This can be seen from the two groups that appeared which are highlighted in Figure 10.

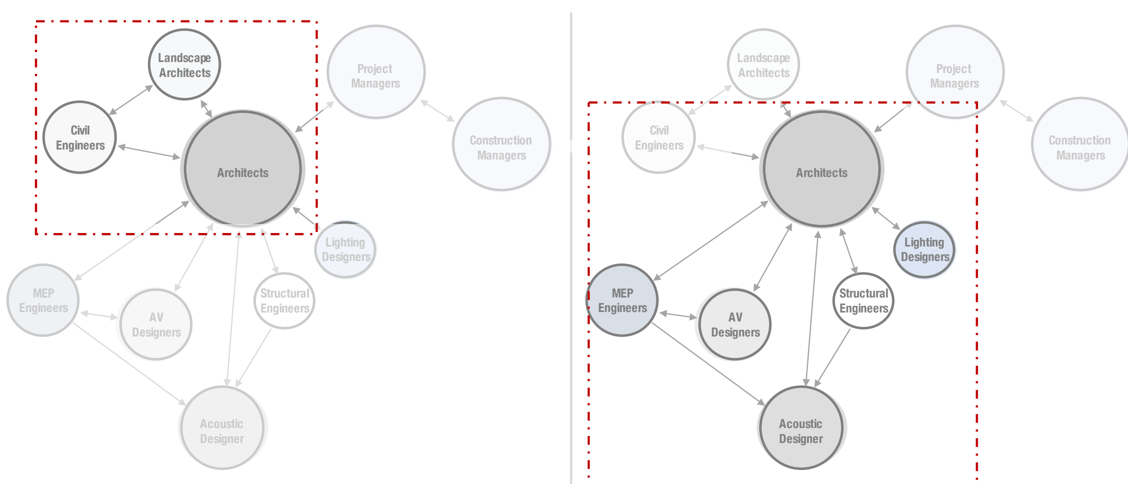


Figure 10 Comparison of the distinct task based groups in team 2

One of the groups comprised the architect, civil engineers and landscape architects, while the other group involved the architects, MEP engineers, AV designers, acoustic designer and structural engineers. These groups occur as a result of the overlap in the information requirements of the tasks performed by the disciplines.

For instance, the civil engineers and the landscape architects worked on site issues meaning there would be a lot of similarity in the information they would require and some overlap in the tasks they performed. On the other hand, the acoustic designer required information from the MEP engineers and the structural engineers to perform their tasks.

7. Information Flow as a function of Project Stage

The information flow between the different disciplines on the team was in part a result of the project being in the schematic design stage. Team members suggested that the flow of information between the disciplines would be different when the design development stage of the project began and more information was required from more disciplines.

As reported by the lighting designers:

"It's a bit early on the project, we've worked with just the architects for this one.

As it develops and we get into details, in addition, we interact with the electrical engineer, and the AV consultant, for our conferencing center or something like that..."[9]

The expectation was that there would be more two-way connections among all the disciplines rather than the distinct groups shown in Figure 10.

<u>Communication as an Information Process</u>

Communication as an information process, as discussed in Chapter 2, explores the forms of design information and the modes of information exchange. Team members from the different disciplines on the team were asked about the types of design information they sent to other disciplines and how they sent this information.

The results highlighted the importance of information delivery, managing expectations, and documenting meetings and design decisions.

8. Information Delivery and Timing

Design information at this preliminary stage was exchanged in the form of technical reports, programming budgets and narrative documents. The architects sent out the initial scope of the project to their consultants along with a request for information.

As reported by the AV designers:

"I mean, I have kind of a preliminary programming budget and we're starting to put in some stuff but we're not to the point now where I have questions for other consultants" [10]

As reported by the MEP engineers:

"it's in our contract to do is to complete the basis of design, and for schematic design some space planning in terms of land use. Schematic design's usually heavy on narrative." [11]

The narrative nature of the information on this project was a result of the project being in the schematic design stage, but changes to the scope and budget of the project meant the design disciplines were not as engaged during schematic.

As reported by the architects:

"At the end of programming, we had a hiccup regarding the scope and the budget, so we have not engaged our disciplines as much as we would like to in schematic design" [12]

The nature of the information sent also meant that there were no large files to transfer so the team members primarily used email to send information to each other.

Regarding information timing, team members reported that the project stages for all the disciplines did not always line up. For instance, schematic design and design development stages for the lighting designers proceeded at such an accelerated rate because their schematic information was required during the architects' design development stage as shown in Figure 11.

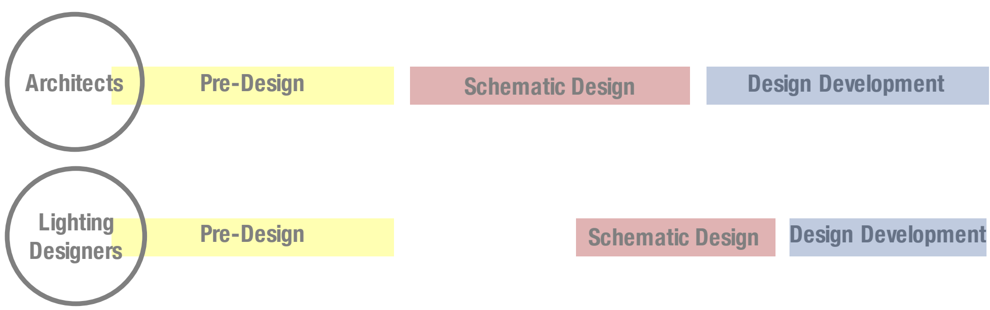


Figure 11 Comparison of the design stages for the architects and the lighting designers

As reported by the lighting designers:

"So, at schematic process we quickly kind of capture what the architect was trying to do in getting some sort of a sign off on that and then we quickly transition into our DD phase, in your DD phase, so we can catch up." [13]

Team members also reported asking the right questions early in the process was necessary to identify the connections between the disciplines tasks and providing the other disciplines with accurate information.

As reported by the acoustic designer:

"So, like I said, if I'm asking a few questions over and they kinda okay getting that sound power, do that early is important because the earlier I get that, the more I can just start doing my analysis on the mechanical systems to determine, especially the major pieces…" [14]

9. *Managing Expectations through Facilitation*

Team members across several disciplines discussed the importance of managing expectations in the building design process. While this was described in different ways, the consensus was that it was a necessary component of information exchange on this project as well managed expectations meant all the disciplines had a clear idea of what they were required to do. The project managers and landscape architects discussed managing expectations in terms of the project scope and budget, the acoustic designer discussed managing expectations in terms of getting clear requirements from and giving clear information to the architects.

As reported by the project managers:

"There's always a budget, you have to establish that budget and then you want to be able to basically manage the expectations of what that budget can actually do" [15]

As reported by the acoustic designers:

"I try not to do their job and maybe kidding what you need to do and what the expectations I need is really comes down to managing the expectation at the end of the day" [16]

Team members also reported that they perceived that the architects had been able to effectively manage the expectations of their clients (the owner) along with the information they received from the other disciplines.

As reported by the audio-visual designers:

"I don't know it's kinda really nice and it seems like they're really managing client expectations with requirements from sub-consultants very well. So that's been really good." [17]

Team members reported that expectations were managed in two ways: through the facilitation workshops held by the project managers and the kick-off meetings held by the architects.

As described earlier, the facilitation workshops were a part of the project manager's selection process. Team members reported that attending the facilitation meetings early on and getting a clear sense of the project, its different requirements, the various user groups for the building was useful in coming up with their proposals and understanding the project as a whole.

The architect led kick-off meetings were held individually with the different disciplines and will be discussed in the following section. Team members reported that having these meetings were useful as they could ask questions and clarify requirements specific to their discipline.

As reported by the MEP engineers:

"The architects have done a very good job at keeping everything managed pretty cleanly. We were able to set the parameters of what we need to get done. So, it's all very pretty clearly understood what our roles are" [18]

10. Meetings and Meeting Documentation

As discussed in the previous section, team members attended the project manager led facilitation workshops and meetings, and the architect led kick-off meetings. The main difference between the two was that the project manager led meetings included the construction managers while the architect led meetings were only between the design consultants (see Figure 5).

The kick-off meetings in particular were one-time, one-to-one meetings between the architects and each design consultant. This allowed the disciplines to address their concerns and questions regarding the project scope and requirements. This one-time nature of the kick-off again was a function of the project being in the schematic design stage. Team members reported that there were plans to have weekly meetings involving more disciplines together as the project moved into design development.

As reported by the acoustic designer:

"Well it sounds like there were gonna be communicating more often because they already requested those by weekly meetings" [19]

As reported by the structural engineers:

"I expect that those quick informal types of meetings will occur more often later in the project" [20]

Several team members mentioned that a key aspect of the meetings was documenting the discussions between the disciplines. This documentation was necessary to keep track of the various decisions and changes made to the building design. The meeting minutes on this project were specifically pointed out as being very effective in sharing information and requirements with the disciplines

As reported by the landscape architects:

"the architects are very good about recapping the meetings, like meeting minutes and keeping record, I would say that. We stepped in when they – like that building is kind of complicated because it's

really just an addition, sort of, so they had a lot of stuff already thought through and they were good at explaining it to us because it's really complicated" [21]

What was particularly effective about the minutes was that rather than providing the disciplines with all of the details of the meetings, the architects highlighted what was important to each discipline and provided action items for the disciplines.

As reported by the MEP engineers:

"They've kept good meeting minutes that have definitive actions, rather than a lot of commentaries. Sometimes we got lost in commentary notes. But you need an action and then some backup from that action as to why you're doing it. So actually, it's pretty good so far." [22]

<u>The Use of Communication Technology</u>

Team members were asked to discuss the different digital tools and technology that supported information exchange between the disciplines. They reported that on this project, technology was used to facilitate the exchange of design information between disciplines in several ways: through the use of Building Information Models (BIM), technology to facilitate meetings, and project management tools that track and share documents

Several disciplines reported the use of Building Information Modelling tools on the project (BIM), such as Revit and ArchiCAD. Team members specifically pointed out the benefits of working in 3D and being able to visualize the work of the other disciplines as most useful on this project.

As reported by the civil engineers:

"We use something similar, meaning we use standard AutoCAD but the program that's specific to us is actually called Civil 3D… those two entities that the surface features, the topography, and then the utility networks are 3D Features which in turn allows you to get that third dimension feel for the site." [23]

Technology was also used to facilitate face-to face interactions between the different disciplines which meant that team members could point out issues and mark up drawings or models. Tools like Skype for Business which allow screen sharing were described as being most useful to team members.

As reported by the structural engineers:

"I find that yeah, the further and further web conferencing technology progresses, it seems the less and less I'm actually really going into architect's offices." [24]

Project management applications were also discussed as they were used by a few disciplines within their firms but not on this project.

As reported by the construction manager:

"And then, so we're not using it to its full capability yet, but one of the things that we have starting to implement is a form of cloud-based project management software.

So, what I use is I have my iPad with the note taking app on it. Take all those notes, I saved each meeting has its own section inside of that. What I have been doing is that in the end of the meeting I can export that as a PDF and send it to the architect and the owner, for here's my thoughts on the meeting." [25]

These tools were useful as they provided a central storage site for all team documents but also allowed team members across disciplines review and modify the documents while keeping records of the changes being made.

Multidisciplinary Building Design Team Outcomes

Team members were asked to report on two outcomes: things that they though worked well on the project which would form 'positive' outcomes, and things that could be improved on the project which formed 'negative' outcomes.

For the positive outcomes, team members reported that all the disciplines were responsive to all requests for information and have been willing to share information with each other. Team members also the reported that among the disciplines there was a clear understanding of each other's processes and requirements.

As reported by the architects:

"I think there are ways that we are able to manage the project. And I also think that the consultants know their discipline well enough that they can kind of jump on board quickly and get caught up and still kind of feel comfortable.

And I think they understand the integrative process so going forward, I don't think there will be too many problems, but its going to be a matter of how we lead the process" [26]

Team members did not identify many things that could be improved on the project and reported that this was due to the stage of the project. The only outcome that was discussed that included room for improvement was the level of engagement of the disciplines discussed under information delivery and timing (see quote 12). This was attributed to changes to the project scope and budget.

discussion

From the study of team 2, findings show that team characteristics including the organization of the disciplines and their involvement on the project influence the patterns and modes of information exchange between the disciplines. This organization can be influenced by the preexisting relationships between team members, the location of the team and the stage of the project. Findings also show that the project stage and the disciplines involved determined the kinds of meetings that occurred. Improving model accuracy and increasing the functionality of document sharing sites were suggested as changes to communication technology for multidisciplinary building design.

The findings contribute to several takeaways that have research and practice implications for multidisciplinary building design teams, and suggest modifications to the exploratory framework to account for additional input characteristics and the additional communication processes interaction that occur. The takeaways include:

- Interpersonal social and professional relationships between team members across disciplines can contribute to the selection of disciplines on the multidisciplinary building design team.
- The early involvement of all design disciplines, regardless of tasks to perform, is beneficial to multidisciplinary building design.
- The connections between the tasks performed by the different disciplines guides the communication patterns that emerge from the multidisciplinary building design team.
- The stage of the building design project influences the patterns of communication between disciplines.
- Facilitation provides opportunities for discussion and questions among the disciplines which can help clarify project goals and requirements.
- The differences in the information requirements of the different disciplines should be accounted for through management and coordination.
- Meetings are an important aspect of building design, but documenting the meetings and decision making is even more important.
- Project management tools that can support documentation and the information processes of multidisciplinary building design teams are available but not used extensively.

The case findings and takeaways suggest that the inputs of the exploratory framework can be modified to include the team and project characteristics that, in addition to functional diversity, influence team communication and outcomes. The information processes of the framework can also be modified to reflect the findings on communication as an information process where functional diversity leads to three information processes: the information rich, divergent process which occurs early in the design process, the targeted convergent interactions which occur later in the design process and categorization processes that occur due to the presence of multiple disciplines.

CASE REPORT – TEAM 3

executive summary

The case study presents the analysis and results from the interview data of members of multidisciplinary building design team 3. Team members worked on an institutional building in Pittsburgh, PA. The team comprised ten disciplines from twelve firms: project managers, construction managers, architects – design architects and architects of record, landscape architects, civil engineers – site civil engineers and civil/geotechnical engineers, structural engineers, MEP engineers, transportation engineer, sustainability consultants, and commissioning agents. Data was obtained from twelve team members – one from each firm – on completion of the projects' design development stage, and was analyzed using content analysis and value flow diagrams described in Chapter 3. Excerpts from the data collected and the analysis are shown in the appendices.

Guided by the exploratory framework to suggest a relationship between functional diversity, communication processes and team outcomes, this study provides descriptions of the multidisciplinary team, the teams' communication across three categories – as social behavior, as an information process, and communication technology – and the teams' outcomes.

The findings suggest that:

- Although, the contractual structure of the team forms the basis for how a team is organized, this structure is influenced by the preexisting relationships between the disciplines and individual team members, and the location of the disciplines.
- Patterns of information flow that emerge in the project are a function of the organization of the team, the disciplinary roles and tasks, and the stage of the project.
- The information needs of each discipline is dependent on their specific range of involvement in the project where each discipline can either be narrowly or broadly involved.
- Outcomes that describe the process, rather than tangible outcomes are preferred by building design team members.

In addition to the research and practice implications of these findings, the report finds that the exploratory framework needs to be modified to accurately represent multidisciplinary building design team practice. The framework should be expanded to include the team and project characteristics – such as the location of the disciplines, and the involvement of disciplines – which contribute to the effects of functional diversity, communication processes, and the patterns of interaction that occur.

The findings from this case report will be compared against those from the other teams studied and presented in Chapter 4.

introduction

At the time of this report, the team comprised members across ten disciplines: The Project Managers, the Construction Managers, the Architects, the Landscape Architects, the Civil Engineers, the Structural Engineers, and the MEP Engineers, the Transportation Engineers, the Sustainability Consultant and the Commissioning Agent. Each discipline was represented by a specific firm except for the architects and the civil engineers who were represented by two firms each.

Figure 1 The design disciplines in team 3 across different firms

The team worked on a 40,000sq. ft. mixed-use, institutional building in Pittsburgh, Pennsylvania, containing administrative spaces, collaborative work spaces, simulation spaces, office and conferencing spaces.

Figure 2 Map of Pittsburgh highlighting the neighborhood of team 3's Project

The project site posed several design challenges that will be discussed later and accounts for the range of disciplines involved in the project.

Figure 3 The team 3 project site

The project followed a CM@risk process where the construction manager provided the owner with a guaranteed maximum price (GMP) contract and as such was involved with in the project from the start of design.

Data for the case study was collected immediately after the completion of design development.

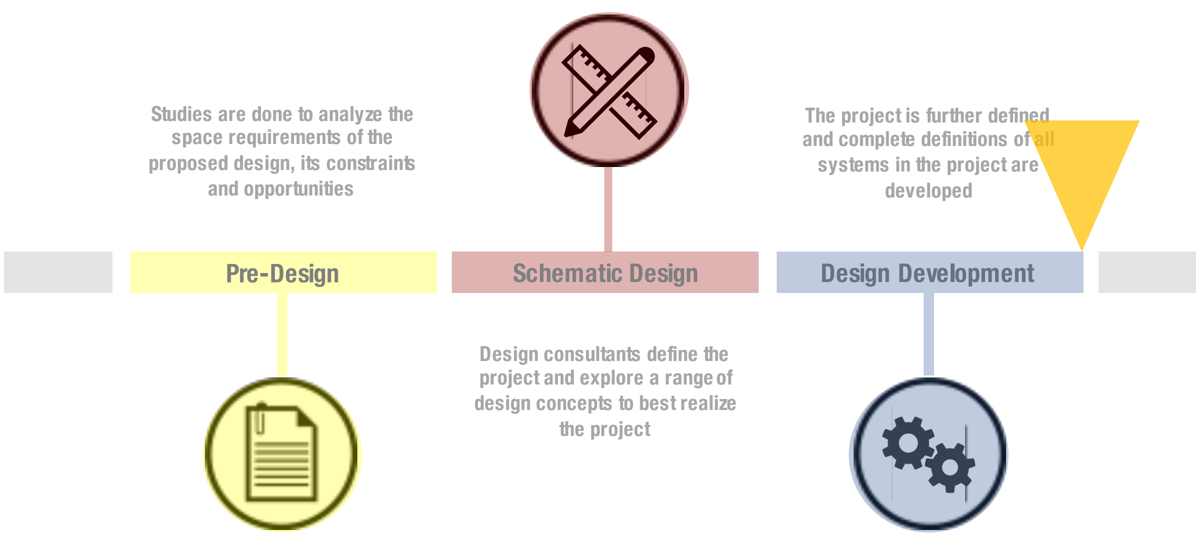


Figure 4 The stages of the building design process showing when the data for team 2 was obtained. Adapted from (UCOP, 2013)

To obtain the data for this case study, twelve team members – one from each firm – were interviewed. Two were interviewed in person while the remaining ten were interviewed over the phone. Table 1 summarizes the data collection for this case study.

Table 1 Summary of data collection

Disciplines	Number of Interviews	Mode of Interviews
Project Managers	1 team member	In-Person interviews
Construction Managers	1 team member	Phone interviews
Architects	1 team member (Design Architect) 1 team member (Architect of Record)	Phone interviews In-Person interviews
Landscape Architects	1 team members	Phone interviews
Civil Engineers	1 team member (Geotechnical consultant) 1 team member (Design engineer)	Phone interviews Phone interviews
Structural Engineers	1 team member	Phone interviews
MEP Engineers	1 team member	Phone interviews
Lighting Designer	1 team member	Phone interviews
Acoustic Designer	1 team member	Phone interviews
AV Designer	1 team member	Phone interviews

The interview data is coded according the coding protocol developed from the review of existing literature described in Chapter 2, and the research questions outlined earlier in Chapter 3. An excerpt of the coded data is shown in Table 2 while the coding protocol is shown in Case 1 (See Table 3 in Case 1). The findings from the data collected are presented in the following section.

Table 2 Excerpt from coded data for team 2

Person	Description	Code
Interviewee	Okay. Yes. We are a consulting civil engineering firm and we deal only with transportation issues.	Discipline Tasks/Role
OA	Okay.	
Interviewee	So, our role in this was to look at traffic, parking and pedestrian issues related to the project and related to its touchpoint with the transportation network around the building site.	Task/Role
Interviewee	Typically, we work on a wide variety of projects. You know, I do institutional master planning for medical centers and universities and their entirety. But we also do smaller or individual projects as well. So, its within our typical project range.	Prior Experience
OA	Okay. And then, is your -- so is your like timeline similar to the entire project's timeline? So, do you follow the same like schematic design of our land construction documentation stages or do you have a different process?	
Interviewee	Our process is different. Because in this case, we were engaged to do study and to provide documentation necessary to get approval through the city of Pittsburgh. And also to provide input to the design team for things that would be needed that were related to traffic parking loading pedestrian.	Tasks/Role Involvement
OA	Were you contracted by the owner directly or by the architects [?].	

results

The findings from this case study are presented in three sections, along each of the lines of inquiry discussed in Chapter 1: the multidisciplinary building design team, multidisciplinary design team communication and multidisciplinary design team outcomes. At the outset, it is important to mention some of the project challenges which provide some context for the findings and discussion that follows.

The project was described as high-profile with an 'out-of-town' architect. The project profile and scope meant there were significant master planning and neighborhood implications. In addition, there was a change in the project manager, an aggressive design schedule, and the owner comprised many interested stakeholder groups. There were design challenges as some of the spaces in the building were relatively new types with previously undefined requirements, for instance the robot garden.

The Multidisciplinary Building Design Team

Team members from the different disciplines were asked to describe their experience with the project design team, including its organization, its dynamics, their disciplinary roles on the team, the team strengths and its limitations.

The disciplines all reported that the project profile and its various challenges influenced team functioning. However, the disciplines were able to respond to the challenges and successfully perform their tasks.

As reported by the transportation engineers:

"In the end, that's the important thing. We get things approved and do it in a way that's responsible and correct" [1]

The different disciplines also reported that several team characteristics such as the management of the project and the preexisting relationships between team members helped mitigate some of the project challenges. These characteristics are presented in two categories: the organization of the team and the involvement of the team on the project.

<u>Team Organization</u>

Findings on team organization suggest that the contractual structure of the team forms the basis for how the team was organized, where the project managers linked the entire team to the owner. The preexisting working relationships between the disciplinary firms and the location of the disciplines also played a significant role in determining the team organization.

1. *Contractual Structure*

With the exception of the project managers who were the owner's representatives, the construction managers, the commissioning agent, and one of the civil engineering firms, all other disciplines on the project were contracted to the architect. As a result, these disciplines provided services to support the architect's design and were organized around the architects. The organization of the team, based on the contractual structure is shown in Figure 5.

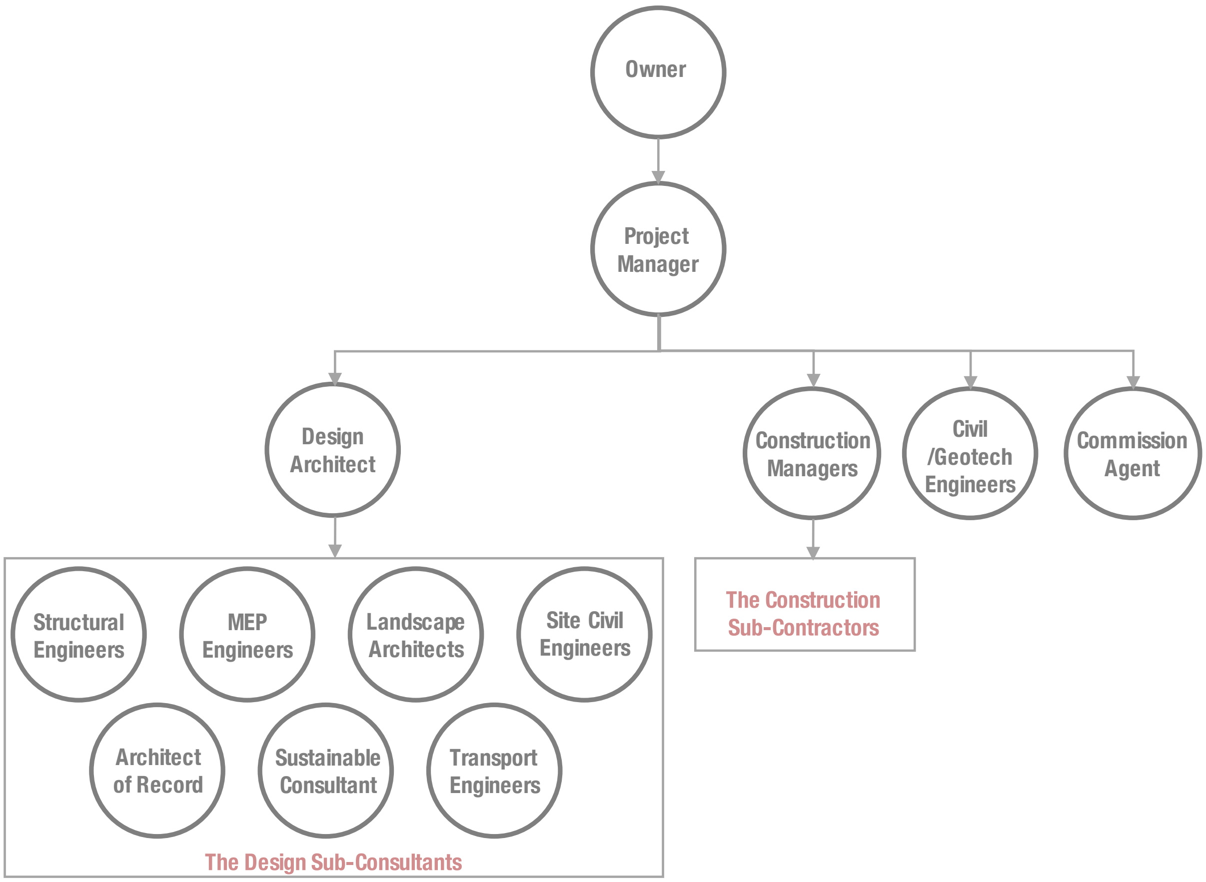


Figure 5 The organizational chart of the design team showing the hierarchy of the team members

The project managers were central to the entire team and served as the connection between design and construction. The civil/geotechnical engineers were contracted directly to the owners through the project managers as they were responsible for conducting a preliminary site study before the start of the project. Similarly, the commissioning agent was contracted directly to the owner as they provided performance validation services to the owner. All the other design disciplines were linked directly to the architect.

This organization had an impact on the patterns of information exchange that occurred in the team and will be discussed later, and highlights the role of the project managers and the architects regarding coordination on this project.

2. Preexisting Relationships

There were extensive preexisting working relationships between the disciplines and the owner and also between the disciplines themselves. The specific firms that were selected as the design sub-consultants were recommended based on these relationships.

As reported by the MEP engineers:

"The owners had recommended our services to the design architects because, that's helpful with them being an outside architecture company…" [2]

Some of the disciplines and firms had worked together on previous projects. For instance, the transportation engineers were familiar with the landscape architects and the site civil engineers, the site civil engineers had worked with the design architects as well as the architects of record, and the MEP engineers.

What was particularly interesting was that except for the design architects, most of the other disciplines on the project had at some point or another worked with the owners. Some firms including the transportation engineer and the civil/geotechnical engineers held (or previously held) term service agreements with the owner.

As reported by the transportation engineers:

"We had previously held a contract directly with the owner" [3]

As reported by the civil/geotechnical engineers:

"We held a term service contract with the owner since about 2010 where we were originally required to do a mobility and safety study" [4]

This can in part be attributed to the design architects being from 'out-of-town' and not local to the Pittsburgh area.

3. Location

The preexisting working relationships between the disciplines on the team and the owner existed partially because most of the disciplines were in the Pittsburgh area while the design architects were based in New York. While this was a challenge and led to increased coordination efforts between the disciplines, team members reported that this difference in location did not adversely affect design.

As reported by the site civil engineers:

"I think it would've helped to have them here. But that's really for the ease of access to them and convenience. I don't think it created any undue stress or issues as a result of it…" [5]

However, the location of the architects as being separate from the other design consultants had implications for the types and the frequency of meetings among the disciplines on the team and also for the communication technology which was used on the project.

Team Involvement

Findings on team involvement suggest that regardless of the tasks performed by the different disciplines, all the disciplines were involved fairly early in the building design process.

4. *Disciplinary Involvement*

Due to the approach to the team selecting firms, most of the disciplines on the project were involved before pre-design. Figure 6 shows the timeline of the involvement of the different design disciplines on the project.

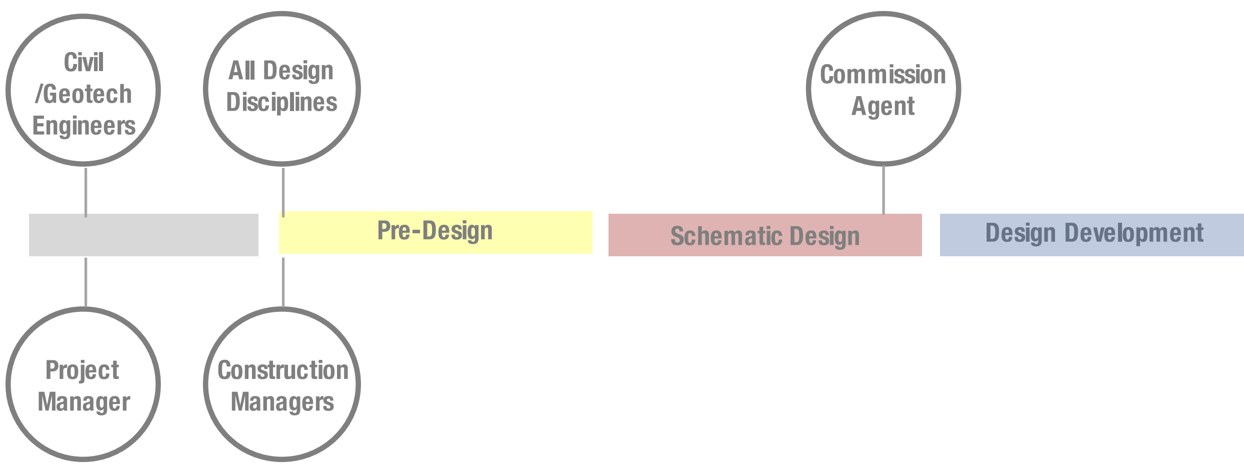


Figure 6 Timeline of involvement of the different disciplines in the design process

All the design disciplines (including the design architects and the design sub-consultants were involved as early as pre-design. This was because the design sub-consultants were a part of the selection process for the architects. The construction managers were also involved as early as predesign. It was reported that this was in part due to the project managers' approach, the construction managers' preference, and their familiarity with each other.

As reported by the construction manager:

"But kind of because of my relationship with CMU I participate probably a lot more on this front, front end design stuff than may be normally a project manager would or another for another client" [6]

The project managers were involved earlier that all the other disciplines as they represented the owner and were responsible for hiring the architects and the construction managers. Similarly, the civil/geotechnical engineers were involved prior to the start of the project as a result of the tasks they performed.

The commissioning agents were involved later than they would have preferred. They attributed this to the initial expectations of the tasks they performed.

As reported by the commissioning agent:

"So, we came on towards the end of schematic design. I think that was just that the project had started. Sometimes that happens when we're brought on as a commissioning agent. I think folks sometimes think of commissioning just as sort of – testing the system, as opposed to helping create the goals and targets for the project. This has not been the case in subsequent projects." [7]

5. Disciplinary Tasks and Roles

The project managers were the facilitators of the project. They hired the architects and the construction managers, the civil/geotechnical engineers, and the commissioning agent; and represented the owners' interests on the project regarding the scope and the budget. The construction managers provided pre-construction services that involved working with the project managers to develop the cost estimates after every stage of design. They were primarily concerned with the budget, the constructability of the design and the project schedule.

The design architects as the project design lead were responsible for designing the building but also coordinating between themselves, the consultants and the project managers. They set the schedule and determined the tasks and milestones for the design sub-consultants. The architects of record were responsible for providing local code information and local permitting but also held a sub-contract to design the laboratory spaces in the building.

The landscape architects and civil engineers worked on site issues. The landscape architects came up with the design for the site considering functional relationships between the proposed building features and circulation. The two civil engineering firms performed different tasks. While the civil/geotechnical engineers prepared an initial study and concept design to identify the conditions that would support or hinder the building from a site and an environmental perspective, the site civil did the actual site design. The site civil engineers were responsible for the design and permitting of site specific issues including geotechnical, sub-surface investigation and foundation design, surveying and environmental engineering.

The structural engineers designed the supports for the building core and ancillary structures. The MEP engineers were responsible for issues related to the HVAC, electrical, plumbing and fire protection for the building. The transportation engineers developed the documentation regarding traffic, parking, loading and pedestrian issues.

The commissioning agent developed the owners' project requirement (OPR) documents with specific project performance targets which they would eventually test the building for. The sustainability consultants developed a similar document that was focused on the requirements for LEED documentation.

Outside of the tasks performed, some of the firms offered multiple disciplinary services. For instance, the civil engineering firms could provide geotechnical, environmental and transportation engineering as well as landscape architecture services.

Team members within the disciplines also performed different roles. For instance, each discipline had a team leader whose role was primarily to coordinate with the other disciplines and the project managers.

A summary of the disciplinary tasks and roles is shown in Figure 7.

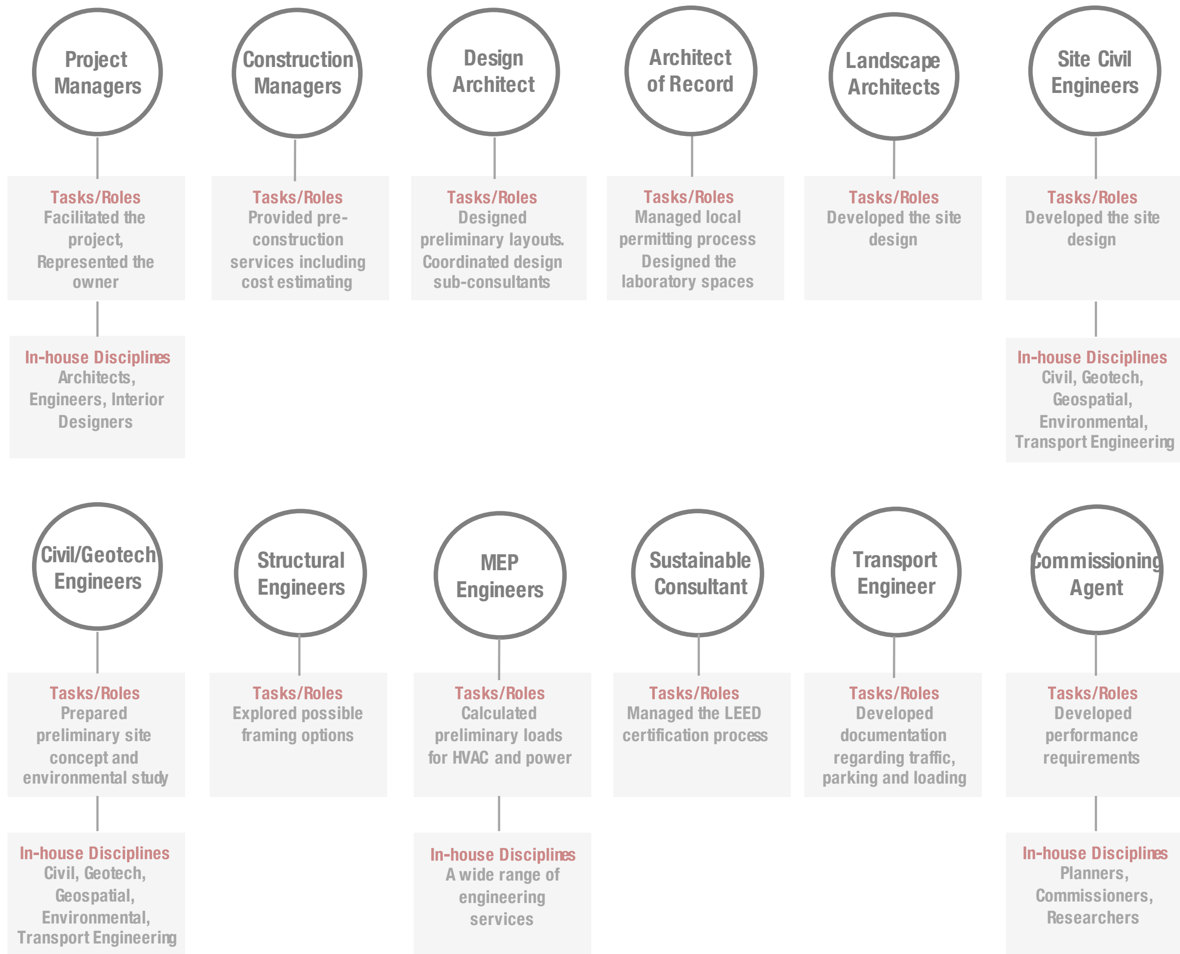


Figure 7 Summary of the tasks and roles of the different disciplines studied in team 3

These team findings describe the context and influencing factors of the multidisciplinary building design team in this case study. The implications of the findings are explored in the discussion section.

Multidisciplinary Building Design Team Communication

The findings on communication are discussed along the three categories – communication as social behavior, communication as information exchange, and the use of communication technology.

<u>Communication as Social Behavior</u>

Communication as social behavior, as discussed in Chapter 2, explores the patterns of interaction between the different disciplines on the team. Team members from the different disciplines were asked to describe the flow of information between the different team members on the project.

Figure 8 shows the flow of information between the different disciplines.

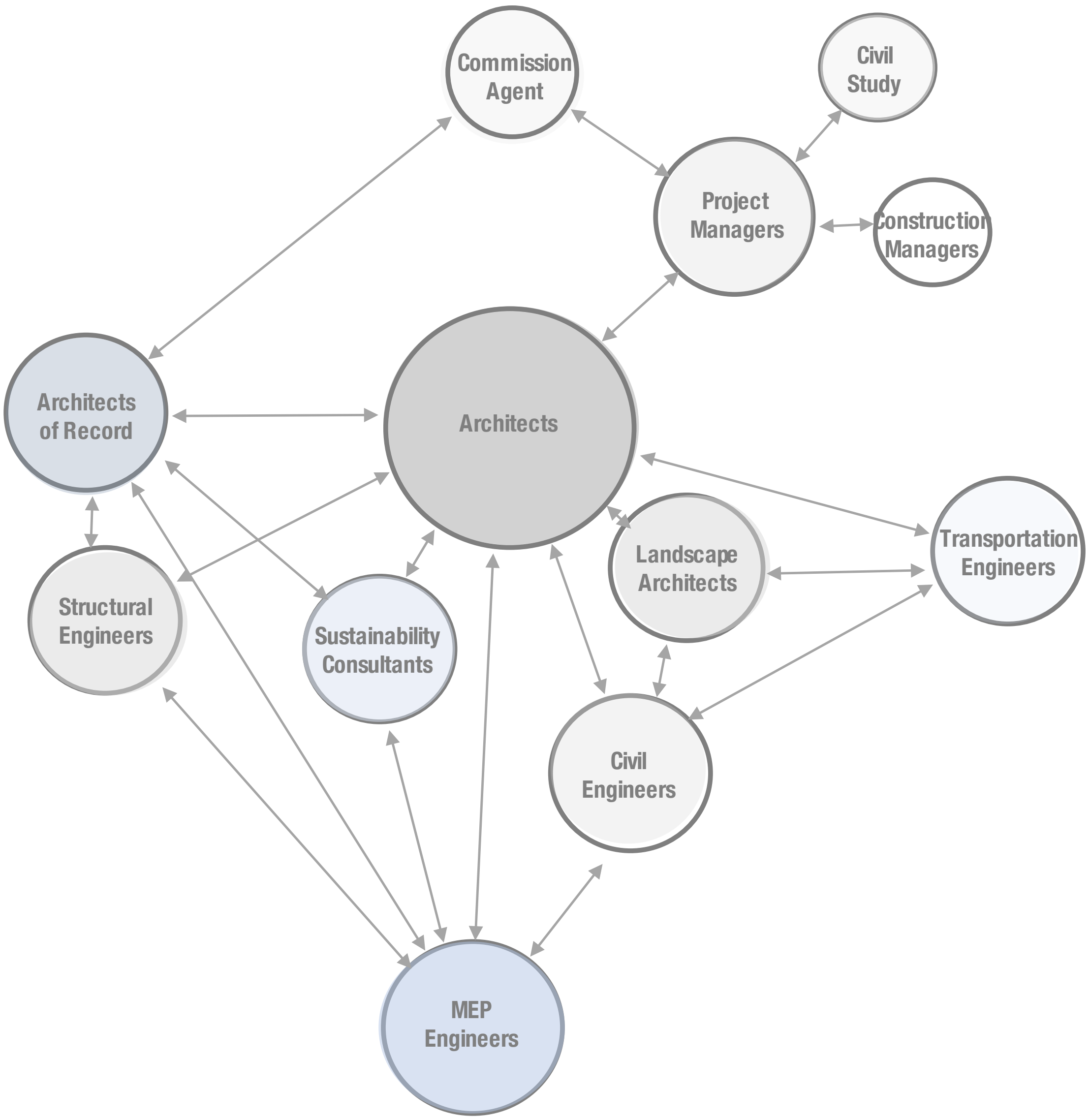


Figure 8 Flow of information between the different disciplines in team 3

The flow of information is represented using circles (or nodes) and arrows. The diagram uses color coded and labeled nodes to represent each discipline on the team. The size of the node – with the exception of the project managers and construction managers nodes – indicates the connections between other disciplines while the arrows indicate the flow of information between disciplines. Figure 9 shows a comparison of the architects and the project managers' nodes.

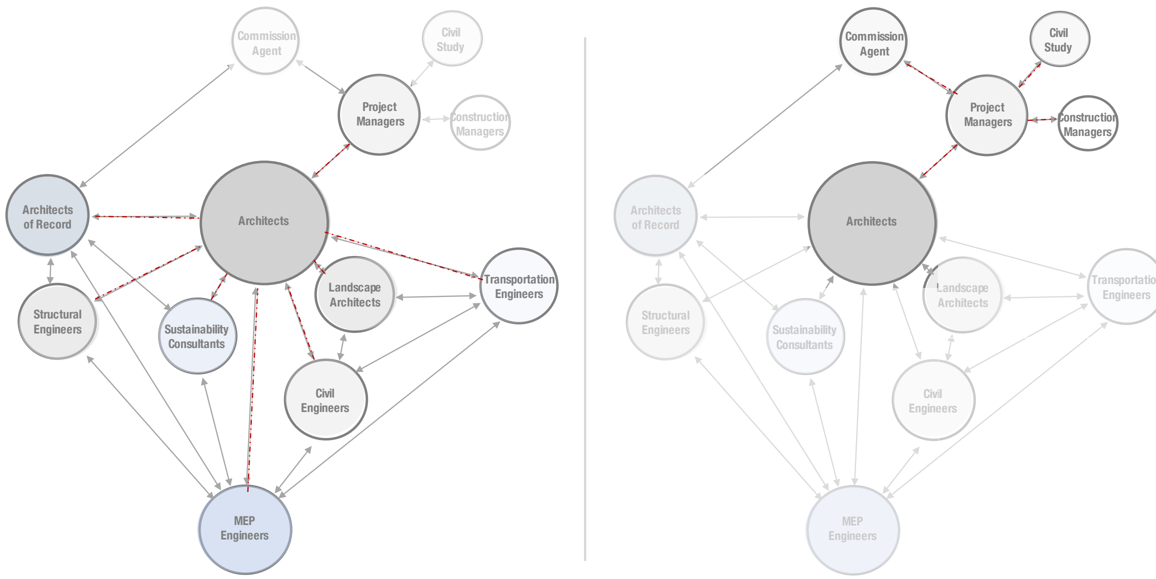


Figure 9 Comparison of architects' node and arrows with the structural engineers' node and arrows

The figure shows that the architects have the largest node as they have seven disciplines sharing information with them, compared with the project managers who have four disciplines sharing information with them.

Two findings regarding information flow emerge from these diagrams: information flow as a function of team organization, and information flow as a function of connections between disciplinary tasks

6. Information Flow as a function of Team Organization

The information flow between the different disciplines on the team was in part a result of the organization, specifically the contract structure of the team illustrated in Figure 5. As mentioned earlier, the design architects held contracts with the architects of record, the structural engineers, landscape architects, the sustainability consultants, the civil engineers, the transportation engineers, and MEP engineers. This meant that all communications and interactions among these disciplines went through the design architects shown in the central position of the architects in Figure 8.

7. Information Flow as a function of Connections between Disciplinary Tasks

The overlap in the information requirements of the disciplinary tasks performed influenced the flow of information. An example of a group that appeared is used to illustrate this and is highlighted in Figure 10.

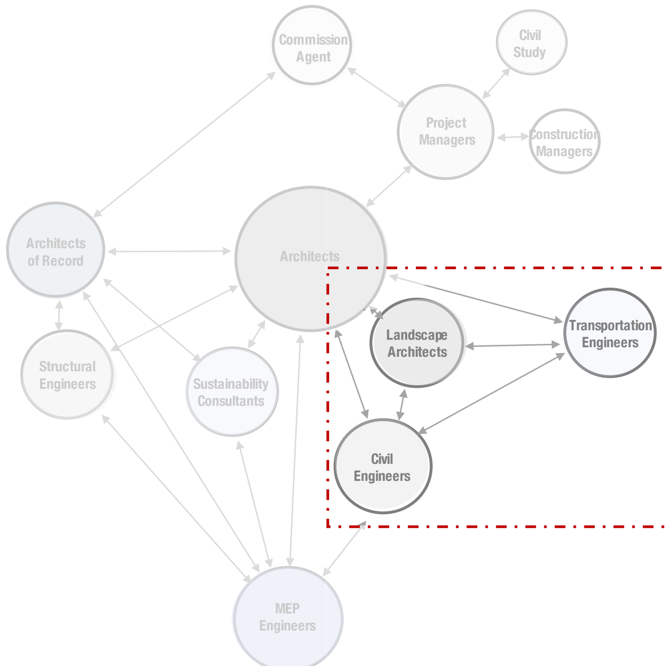


Figure 10 Group showing the connection between tasks performed by the disciplines

The group highlighted comprised the site civil engineers, the landscape architects and the transportation engineers. These three disciplines were directly or indirectly involved in site issues – site design for the civil, functional relationships and connections for the landscape, and parking layouts for the transportation engineers – and required information from each other to perform their tasks. This connection between their tasks and information requirements is shown through the bi-directional arrows connecting all three disciplines.

<u>Communication as an Information Process</u>

Communication as an information process, as discussed in Chapter 2, explores the forms of design information and the modes of information exchange. Team members from the different disciplines on the team were asked about the types of design information they sent to other disciplines and how they sent this information.

The results highlighted the importance of information delivery, meeting scheduling and documentation. In addition, the results indicated that there was a difference in the information needs of disciplines based on their range of involvement on the project. For instance, some disciplines like the transportation engineers and landscape engineers had narrow areas of involvement on the project while others like the sustainability consultants and the MEP engineers had wider areas of involvement.

8. Information Delivery and Timing

Since the project was through the design development stage, design information was exchanged primarily in the form of 2D CAD drawings, 3D BIM models, technical reports and meeting minutes.

Several modes were used to exchange design information. In this case, to deal with the architects working remotely, email and virtual meetings – over the phone or with video conferencing services – were the primary mode of information exchange.

As reported by the architects:

"we just will schedule around everyone's availability times to have a go-to meeting or something like that to talk through those issues, and we email sketches back and forth, and we do a lot of advancing of the documents through email actually." [8]

Regarding the timing of information, team members reported that in the earlier stages of the project, as the architectural definition of the design was being developed, disciplines with a narrow range of involvement were more involved in listening and understanding the project goals compared with later in the project when they were involved in design details.

As reported by the construction managers:

"Being involved early means taking a back seat and listening and just understanding what the end users are looking for in the building." [9]

As reported by the transportation engineers:

"During the architectural definition, there is so much back and forth, and it can take a while for the pieces to stop moving." [10]

As reported by the MEP engineers:

"Early on, whether it's the conceptual design or the schematic design, its more about what is the building going to look like? And then design development kind of focuses more on the details. We spend a lot of focus on actually sizing the main mechanical equipment... the shafts, the boiler room... planning out the boiler room, how we vent the boilers, how we vent the water heaters, how water service comes into the building…" [11]

While this suggests that it may be better for the narrowly engaged disciplines to be involved later in design, team members agreed that being involved and participating in generating information and design documents helped them understand the impacts of design and ask specific questions to influence the process.

As reported by the civil/geotechnical engineers:

"I think, once we get the specific details of a certain situation early, we ask very specific questions about doing further instigation or coming to conclusions about what to do and what not to do, and that's been pretty effective" [12]

9. Meetings, Meeting Documentation and Scheduling

Again, due to the design architects being remote, meetings were a big component of the information coordination process for this project. The meetings were designed to be inclusive, were scheduled ahead of time and integrated with team members calendars.

Team members attended weekly meetings, one initiated by the architects that involved all the design sub consultants, and one initiated by the project managers that included the construction managers, the commissioning agent and occasionally the civil/geotechnical engineers.

The frequency and inclusive nature of the meetings meant that all the disciplines got to know each other, and they were always aware of all major decisions that were made on each other's tasks.

As reported by the landscape architects:

I think the biggest advantage to having the pretty regular communications happening especially with the design architecture firm being remote is that we get regular updates on what's happening so I think that's good. [13]

As reported by the transportation engineers:

"like initially you need to get to know each other by phone or in person because we're human beings and not machines. It's really helpful to know with who you're speaking to and that you could recognize them in a crowd, so that's nice." [14]

As reported by the MEP engineers:

"Having everyone in the meetings was effective. If the architects just coordinated directly with us, we'd always talk about mechanical issues and I'd never hear about the structural side of things. For instance, where lateral bracing is gonna go, there's often mechanical conflict…" [15]

As reported by the site civil engineers:

"The group-wide, design team wide communication at times was very beneficial because it exposed you to more of the project and at a better understanding of other disciplines and what design is used that they were working towards" [16]

As reported by the structural engineers:

"Meeting with everyone is great in some respects because everyone knows what people's different concerns are or where the challenges that you work through" [17]

However, there were limitations to having these 'group-wide' meetings and discussions. The meetings took a lot of time, team members were not always certain if or when they were needed in the meetings, and there was a lot of information for team members to sift through.

Team members suggested that while agendas provided for the meetings were detailed and useful in understanding what was to come, a different approach to documentation after the meeting some of the challenges of information overload.

As reported by the project managers:

"I think we need to redouble our efforts on documentation other than just the drawings. So, in terms of capturing meetings and sharing information proactively, I think those are going to be the things that will help us get through CDs without a whole lot of pain, and even if there is pain at least we'll have a record" [18]

One thing about the meetings which was unique and that team members found effective was that they were scheduled in advance and were integrated with team member calendars. While team members reported that the only disadvantage to the integrated meeting and calendar schedule was that changes to the meeting schedule automatically changed in their calendars, they reported that having the meetings scheduled in advance with an agenda made clear what was required from the specific disciplines.

As reported by the architects:

"I think what has been effective is establishing a work plan that outlines every single meeting that we intend to have with the week kind of highlighted that allows us to pick the day that works best for everyone with a detailed agenda of what we're anticipating talking about so that the team is clear in terms of who are the appropriate people who need to be available. [19]

Team members also suggested that it would be worth having a schedule which accounted for multiple projects in especially in a situation with multiple projects involving the same team members and firms.

The findings on meetings highlight the importance of meetings for multidisciplinary building design teams but also suggest modifications to the dual process model which will be described later on.

The Use of Communication Technology

Team members were asked to discuss the different digital tools and technology that supported information exchange between the disciplines. They reported that on this project, technology was used to facilitate the exchange of design information between disciplines in three ways: through the use of Building Information Models (BIM), to facilitate virtual meetings and to share documents.

Several disciplines reported the use of Building Information Modelling tools on the project (BIM), such as Revit and ArchiCAD. Team members specifically pointed out the benefits of working in 3D and being able to visualize the work of the other disciplines as most useful on this project.

The advantages of BIM tools to the design process are numerous and have been discussed by several scholars. However, team members mentioned that the advantages of BIM could only be achieved if the modeling was done accurately. Inaccuracies occurred either on the part of the modeler, or resulted from a lack of accurate translation between the software used by the different disciplines.

As reported by the MEP engineers:

"if we are just getting a model, a Revit model to do our MEP design, we have a procedure that cleans it up because there's just a lot of extra information that comes from that model... we don't need that and it would slow ours down 'cause the file sizes are so large." [20]

It was also reported that not all the disciplines required BIM for their tasks and receiving the models meant they had to figure out how to translate it from one format to another. This meant that they either received information they could not use, or did not need.

Technology was also used to facilitate face-to face interactions between the different disciplines which meant that team members could point out issues and mark up drawings or models. Tools like WebEx and Skype for Business which allow screen sharing were described as being most useful to team members.

As discussed earlier, when sharing documents, email was primarily used, but when large files needed to be sent, that is files larger than the email capacity, Newforma was used. The advantages and limitations of the different document sharing tools used will be further discussed in Chapter 5.

Multidisciplinary Building Design Team Outcomes

Team members were asked to report on two outcomes: things that they though worked well on the project which would form 'positive' outcomes, and things that could be improved on the project which formed 'negative' outcomes.

For the positive outcomes, team members reported that all the disciplines were responsive to all requests for information and have been willing to share information with each other. Team members also the reported that among the disciplines there was a clear understanding of each other's processes and requirements, the design at this stage is functional, and the consultants were able to influence the design.

As reported by the transportation engineers:

"I think in the end, things have worked out okay. The design is something that's going to be functional and that's going to work.

I thought the we have listened to each other and the design architects team actually you know, listen to the consultants who are more familiar with local requirements and they took it seriously."[21]

Regarding the outcomes that could be improved, team members referred to the need for improved documentation (see quote 18) going forward in the project and the early involvement of more disciplines (see quote 7).

discussion

From the study of team 3, findings show that team characteristics including the organization and location of the disciplines influence the patterns and modes of information exchange between the disciplines. This organization can be influenced by the preexisting relationships between team members and the stage of the project. Findings also show that the due to the differences in location of the disciplines, team-wide meetings were favored rather than targeted interactions. While communication technology such as video conferencing and file sharing tools help address the challenges from having disciplines in different locations, improving BIM accuracy and increasing the functionality of document sharing sites could improve communication technology for multidisciplinary building design.

The findings contribute to several takeaways that have research and practice implications for multidisciplinary building design teams, and suggest modifications to the exploratory framework to account for additional input characteristics and the additional communication processes interaction that occur. The takeaways include:

- Interpersonal professional relationships can contribute to the selection of disciplines on the multidisciplinary building design team.
- The location of the lead disciplines can influence multidisciplinary building design team functioning.
- There is a strong preference for early involvement by all disciplines regardless of the tasks they perform.
- The connections between the tasks performed by the different disciplines guides the communication patterns that emerge from the multidisciplinary building design team.

- The stage of the building design project influences the patterns of communication between disciplines.
- Having all disciplines present for all team meetings may not be an efficient approach to multidisciplinary team communication.
- The information processes and needs of disciplines varies by their breadth of involvement and should be accounted for through management and coordination.
- Screen sharing and file sharing technology can help address the challenges of disciplines working remotely.
- Building Information Models are not useful to all design disciplines and are only as useful as they are accurate.

The case findings and takeaways suggest that the inputs of the exploratory framework can be modified to include the team and project characteristics that, in addition to functional diversity, influence team communication and outcomes.