Influence of Individual Perceptions on Engineering Team Performance within Design-build Infrastructure Projects

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Abstract

The successful delivery of large complex infrastructure projects continues to challenge the civil engineering profession, with a predominance of projects delivered late and over budget. Many researchers have investigated methods and means of improving the less-than-satisfactory record of the execution of these projects. One recent research direction suggests that improvements in project delivery may not be realized until the project setting is understood from the as-lived perspective of the participants. Following this direction, the research described in this dissertation explores the personal and interpersonal dynamics operating within projects, treating them as complex social processes. The social dimensions explored in this study involve team leaders and staff engineers in a matriced organization handling a large urban design-build infrastructure project. The interactions among the participants within and across units and levels had both positive and negative impacts.

The data for this exploratory case study comes from semi-structured interviews and online surveys collected at three points over eleven months when the project was in the design phase. Interviews were conducted with a limited number of individuals; the survey was collected from the larger engineering organization.

From the interview data, issues which impacted project delivery were identified as the relationship with supervision, the availability of information, an understanding of the larger project context, and the response to project constraints. The survey data was used primarily to understand the social dimensions affecting two engineering disciplines, one that performed well and one that performed poorly. Issues that aligned with the performance differences included frequency of contact with supervision, the ability to make decisions, and effective use of time available to complete design tasks. Data from the two modes of investigation demonstrated strong triangulation. Recommendations for both academia and industry are provided.

Dedication

To my wife, Kay whose love and
commitment has never wavered.
Thank you.

Acknowledgments

Like many who have tried to pen an acknowledgment, there are so many people that have supported me in this journey that I cannot name them all. I owe a debt of gratitude to all of you.

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Chapter 1: Introduction

1.1 Need for This Research

The practice of contemporary project management has seen significant development over the last 60 years, evolving from the early initiatives in the US defense/aerospace industries in the late 1950s/60s into a core competency that today is widely recognized across most industry sectors. To a significant extent, project management has grown out of practice and experience, expanding on those elements that proved most effective in actual situations. Project management practice has historically been predicated on rigid "centralized planning, decentralized execution, and centralized control" using detailed baseline schedules and reporting metrics established by experienced experts (Levitt, 2011, p. 198). These historical management practices continued to evolve and were formalized and codified. One widely recognized reference epitomizing this codification is the *Project Management Body of Knowledge* (PMBOK) *(Project Management Institute, 2008)*. At this point in time, project management is recognized as a profession in itself, with norms and operating procedures that have proved beneficial over the course of many projects.

However, despite the advances in project management practice, delivery issues persist, particularly for large complex projects. Delivery problems have been validated by separate investigations conducted by the Construction Industry Cost Effectiveness project (Forbes & Ahmed, 2011), the American Association of State Highway and Transportation Officials (Crossett & Hines, 2007), the National Institute of Science and Technology (Huang, Chapman, & Butry, 2009), Ernst and Young (Shyamal, Jalan, & Ajmera, 2011), and the Government Accountability Office (USGAO, 2013). The details of these studies will be reviewed in Chapter 2, but each agency studying projects under their purview found that large complex projects were typically delivered late and over cost.

Problematic delivery of large complex projects has prompted researchers to investigate the causes of this situation from several different perspectives. Priemus and Flyvbjerg (2008) articulated how the long time span required for these projects introduces complications. Initially, potential projects are identified, then begin to be directed by attempts to reduce risk and negotiate governance. By the time the projects become political reality, they may or may not resemble the initial conception. In this way, megaprojects projects are morphed and shaped, and megaprojects are described as "high stakes games characterized by substantial irreversible commitments…and high probabilities of failure" (Priemus & Flyvbjerg, 2008, p. 6). In addition, the impact of long development times for transformative projects are recounted in Miller and Lessard's book, *Strategic Management of Large Engineering Projects* (Miller &

Lessard, 2001. All projects experience difficulties, but increasingly complex and dynamic instabilities may occur over longer development horizons, resulting in difficulty predicting the project outcome. As Miller and Lessard explain, "The longer the development time, the higher the likelihood that the project will be affected by emergent events" (2001, p. 22).

Taking a somewhat different tack, Williams (2005) performed a post mortem on projects that were managed in "proper" PMBOK fashion and still badly overran their budgets. Williams argues that on large complex projects, two eventualities will likely occur: complex projects cannot be completely preplanned and impacts external to the project will have continuing effects on the project. Both of these eventualities contradict the assumptions inherent in traditional project methodologies such as the PMBOK.

Levitt's approach (2011) to the difficulties in large complex projects places project execution in a historical context. Like Williams, Levitt (2011) noted that the assumptions underpinning the traditional methods are frequently rendered invalid by unanticipated impacts from the world outside the project, rendering the assumptions implicit in the original project baseline invalid. But as Levitt (2011) explained, "Key project assumptions underlying project plans are changing … rapidly in every dimension…technically, financially, politically, socially…" (p. 198). In addition, today's internet-enabled workers resist implementing a plan with no changes or creativity and distance themselves from the planning intrinsic in the baseline (Levitt, 2011). Traditional project management is disciplined and rigid, not agile, and doesn't engage available knowledge. These weaknesses in the traditional approach reflect its inability to adapt to the changing project environment.

Despite huge investments in research and energy, "the performances of contemporary projects do not seem to have substantially improved … and problems in project management practice persist" (Cicmil, 2009, p. 4). In response to the continued difficulties with project delivery, researchers branched into two complementary directions. One direction investigates the processes involved with the conduct of large complex projects. This direction involves imposing modifications to the traditional methodologies and includes organizational changes as well as adjustments to the planning and scheduling approach advocated by the PMBOK. In this vein, Lean Construction represents an important departure from the traditional planning and scheduling methods by focusing on the flow of resources and materials.

The second branch of research examines the social dimension of the project environment, including network modeling, as well as virtual, global, and cross-cultural teaming issues. Over the last decade or so, this second branch of investigation has been advocated by scholars such as Stacey, Morris, Cicmil, Williams, and others, with an emphasis on projects as complex social phenomena. Years ago, Morris (2000) suggested that there seems to be wide agreement that the scope of project management issues should be broader than those currently incorporated in the PMBOK and that just as important are

the people issues. More specifically, Chinowsky, Diekmann, and Galotti (2008) posited "Although this [traditional approach] has been effective, this engineering focus [on processes] has reached the point of diminishing results...Specifically, the [traditional system centered] approach…has neglected to recognize the importance of the participants…" (p. 804).

Similarly, Stacey (2009) addressed collaborations and development of relationships within a project environment in the continuous evolution and interaction of the project and participants. He also explored the complex self-organizing nature of projects and their participants. Building on this direction, Cicmil (2006) stated that, in contrast to objective [traditional] models, viewing the project as a social process builds theories which consider the motivations and agendas of individuals and the interactions of these motivations, as well as the tensions, power, and patterns of communication among individuals and how they are negotiated. Insights into collaboration at the project level and understanding social interactions provides a potential key to deciphering the issues perplexing both researcher and professionals in project management.

Developing this argument, Chinowsky et al, (2008) suggested that project management research has neglected to recognize the importance of the participant perceptions to the success of the overall project. Cicmil, Williams, Thomas, and Hodgson (2006) asserted that current approaches in project management research "do not satisfactorily explain the richness of what actually occurs in project environments" (p. 684). Cicmil and Marshall (2005) argued further that to make gains in the conduct of projects, study of the situational interactions and social arrangements among project participants is needed to understand spatial and temporal dynamics within the project context. This belief was echoed by Stacey (2009) who suggested that rather than portraying social interaction as rational, linear, and predictable, alternative perspectives are necessary that explain the project environment as a web of human interactions predicated on the interdependencies of the actors.

The emphasis on social processes acknowledges the importance of traditional project management methodologies but shifts the investigative focus to the interactions and relationships among the people on the project. Traditional project management tools are necessary, but not sufficient. Further, future improvements in project execution are unlikely unless interactions at the individual level are considered.

1.2 Purpose of this Study

This dissertation addresses the need to understand human interactions and the social processes operating within the project environment by conducting an exploratory longitudinal case study of the interpersonal dynamics and interactions of participants on a large design-build infrastructure project. The project was in the design phase, with the study coinciding with the first year of detailed design.

The motivation for this investigation is to understand and describe the experiences of individuals within the project environment from the perspective of the project participant. It uses the theoretical development of Stacey (2009) and Cicmil (2006) as a lens to investigate individual perspectives to understand what issues are salient to the participants, how these issues interact, and how they contribute to a project's success or failure.

To do so, this exploratory mixed methods study has addressed the following research questions (RQs):

1. What factors are salient to individuals at multiple organizational levels as they experience team interactions within an urban infrastructure mega-project?
    a. What critical factors characterize participants' perceptions of the interactions and interpersonal dynamics on the project?
    b. What interactions occur among factors that affect participants' overall experience and performance?
    c. How did these perceptions and interactions change over the course of the study?
2. How do perceptions of project experience and interactions align with group performance?
    a. What differences exist between the group that performed well and the group that performed poorly at the beginning of the study?
    b. What differences exist between the group that performed well and the group that performed poorly at the end of the study?
    c. What changes occurred within the group that performed well from the beginning to the end of the study?
    d. What changes occurred within the group that performed poorly from the beginning to the end of the study?

The case study includes both semi-structured interviews and on-line surveys. Both modes of investigation focused on understanding the ontology of the as-lived experiences of the project participants as the project developed. Issues considered included the time available to perform work tasks, frequency of interaction with supervision, the ability to make independent decisions, reliability of information and products from other work groups, the understanding of the project outside the limited responsibilities of the specific discipline, and other interrogations of the as-lived experiences of the participant.

1.3 Overview of Methods

This exploratory longitudinal mixed methods investigation consisted of semi-structured interviews and on-line surveys, each conducted three times over the 11 month duration of the study. The

interviews lasted between 30 and 60 minutes and were conducted with a subset of the engineering staff, starting with 21 individuals initially, then 17 for the second round, and 12 for the final round. Each set of interviews were conducted with the same individuals, with the total number of interviews decreasing over time as individuals left the project.

The on-line surveys addressed essentially the same topics as the interviews using Likert-Type questions and were emailed to the entire engineering department. The surveys were intended to take 10-15 minutes to complete. The total engineering population was 153 individuals, and the returned responses for the three surveys totaled 58, 35, and 44 respectively.

Qualitative and quantitative data collection were performed in parallel, but analysis occurred sequentially. The results from the qualitative investigation strongly informed the direction of the quantitative analysis of the study. This sequencing and timing is provided in Figure 1. It was not until the analysis phase that the data and results from the qualitative and quantitative methods were compared.

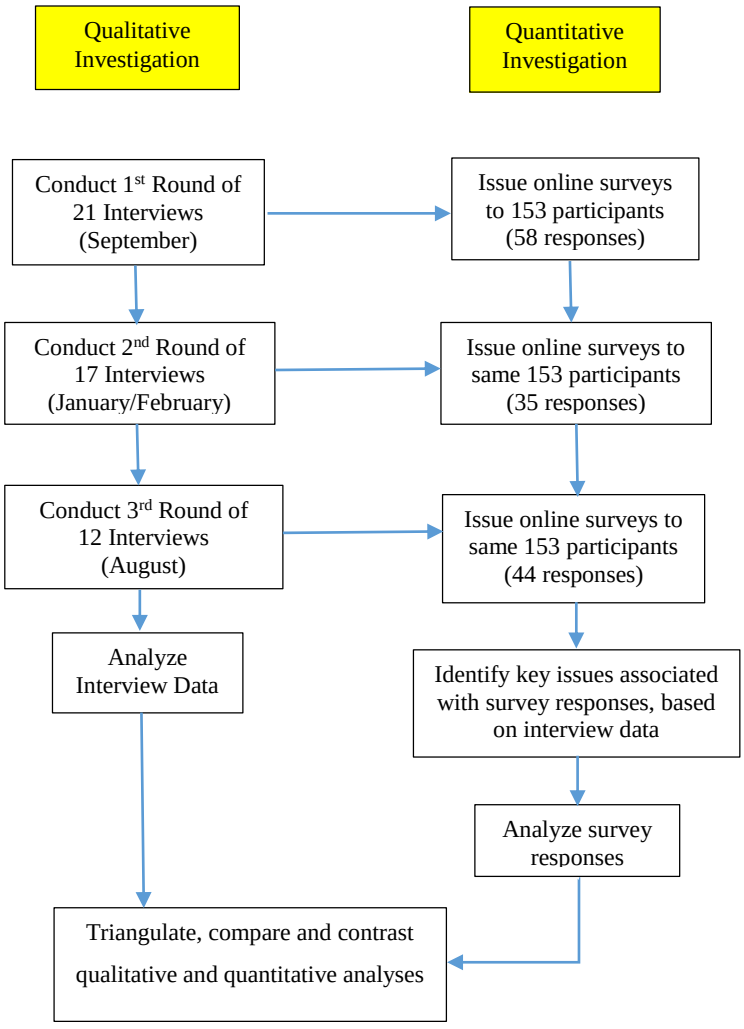

Figure 1 Sequencing and Timing of Data Collection and Analysis

1.4 Significance of the Study

Stacey, Cicmil, Chinowsky, Williams and other researchers point to the need to understand the project at the elemental level of the project participant, to perceive the day-to-day development of the project, and to begin to grasp the complexities and interpersonal dynamics that exist between the human players within the project. The findings and analysis of this case study identify these dynamics and complexities and suggest areas for future investigation. This is an exploratory case study; it represents an effort to begin to satisfy the need to further the understanding of the as-lived experiences of the project participants.

1.5 Limitations

This investigation describes a case study of the engineering development on a single large design-build infrastructure project. The characteristics of design-build projects are somewhat unique, since the immediacy of construction adds pressure to move the design along quickly. There are other types of design projects in which this is not the case. In addition, there exist other types of design-build projects that are not based on civil engineering, as is infrastructure. As an exploratory case study, the research in not designed to be generalizable, but rather to provide a rich description of one site and identify salient issues for further study and potential transfer to other sites. Limitations include self-selection of interview participants and survey respondents and the limited time period of the study relative to the whole project.

1.6 Overview of Remaining Chapters

Chapter 2 provides a literature review of pertinent developments in project research, tracing the evolution of project management research and discussing issues currently of interest within the project management field. Chapter 3 then develops the mixed methods design used in this study, including the approach, study populations for both the qualitative and quantitative methods, data collection, and analysis techniques. Chapter 4 and 5 address the findings resulting from the qualitative and quantitative investigations, respectively. Chapter 6 offers discussion relative to each investigative method and contrasts and integrates the two approaches. Chapter 7 then provides recommendations for academia and practice.

Chapter 2: Literature Review

To situate this investigation within the relevant literature, this chapter starts with a review of the current state of the performance of large complex construction projects. This discussion summarizes reports on large mega-projects from a number of industry and government sources. Following that, a brief historical development of current project management practices is included to establish the constructs that underlie the development of these practices. Finally, new directions and recommendations are reviewed, which provide the basis for this investigation and dissertation.

2.1 Large Complex Projects – Perceptions of Performance Issues

Contemporary project management has evolved from the early initiatives in the US defense/aerospace sectors in the late 1950s/60s into a core competency that is widely recognized across most industry sectors. The initial development of project management practice, led primarily by the US Department of Defense and NASA, consisted of internally promulgated policies, procedures and practices for managing the agencies' decades' long and geographically distributed projects (Morris, Jamieson, & Shepherd, 2006). To a significant extent, project management has grown out of practice and experience, expanding on those elements that proved most effective in live situations. At this point in time, project management is recognized as a profession in itself, with norms and operating procedures that have proved beneficial over the course of many projects.

However, despite the advances in project management practice, significant project delivery issues persist. Projects, particularly large complex construction projects, are not just sometimes, but typically, completed late and over budget. This problematic project performance is reflected in many examinations of project performance by clients, government, and industry organizations that rely on the design and construction industry to deliver assets vital to their operations. For example, the Business Roundtable launched the Construction Industry Cost Effectiveness (CICE) project to promote quality, efficiency, productivity, and cost effectiveness. Among other findings, the report suggests that more than half the time wasted in construction is attributable to poor management practices, including poor communication and self-interest imposed by contracting terms. Furthermore, the one-off nature of construction projects also contributes to this situation. Little seems to have changed in three decades, as Forbes and Ahmed state, "The observations of the CICE project in 1983 are still relevant in 2010 and beyond" (Forbes & Ahmed, 2011, p. 5).

More recent studies support that claim. A notable instance of poor performance is spotlighted in a 2005 study published by the American Association of State Highway and Transportation Officials (Crossett & Hines, 2007). In the AASHTO review, bid-build projects predominated, but still demonstrated that complications with large project delivery persists. This study analyzed the

performance of 20 states completing more than 26,500 projects over a five-year period between 2001 and 2005. For projects over $5 million, 82% were over-budget and 65% behind schedule. Among AASHTO's conclusions were that in every state participating in the study, overall cost and schedule performance needed improvement (Crossett & Hines, 2007). Similarly, a report sponsored by the National Institute of Science and Technology by Huang, et al. (2009) estimates that U.S. construction productivity over a 40-year period to 2007 averaged a decline of -0.6% per year, versus a positive nonfarm productivity growth of 1.8% per year. Construction productivity, in essence, is the quantity of output divided by the cost. A steady, consistent 40 year decline in construction productivity is alarming and indicates an increasing waste of financial, social, and technical resources. Moreover, this decline in productivity occurred despite significant improvements in construction equipment (Forbes & Ahmed, 2011).

As recently as 2013, the United States Government Accountability Office (GAO) described systemic concerns with the performance of projects falling under its purview. The GAO performed a number of in depth analyses of major construction projects sponsored by the U.S. government. In 2013, the GAO conducted a series of reviews of projects managed by the Office of Environmental Management (OEM) and the National Nuclear Security Administration (NNSA) that focused on design adequacy, understanding the supply base, changes in project scope, effectiveness of project reviews, and life cycle cost estimates for the program. The summary position of the GAO was that these projects continued to be at risk for "fraud, waste, abuse, and mismanagement" (U.S. Government Accountability Office, 2013).

Nor are challenges limited to the U.S. In a similar review of project performance, Shyamal et al., (2011) undertook an investigation of the performance of major infrastructure projects in India. The projects in India, while not mirroring the conditions found in the United States, suffered the same delivery issues. The study Shyamal et al. included roads and transportation, power, oil & gas, railways, urban infrastructure, coal, and several miscellaneous categories. The study results determined that as of February 2011, 52% of ongoing projects were behind schedule (293 of 559) and that only 24% were on schedule (Shyamal et al., 2011).

This multi-faceted commentary on project delivery is disturbing. Despite decades of effort and huge investments in research, project execution remains problematic. Project delivery continues to fail to meet expectations of clients in far too many instances. To understand the broader implication associated with this perplexing issue, the next section of this literature review discusses the evolution of project management as a profession, to understand the development and directions of the research investigations associated with this field of study.

2.2 Historical Development of Project Management Practices

As noted in the previous section, project management has developed from practice to provide guidance and direction in the provision of client facilities, products, and ideas. This evolution has consisted of the development of systems, codification and refinement of those systems, and finally investigation of issues emanating from those systems. Figure 2 below, describes the development of modern project management research.

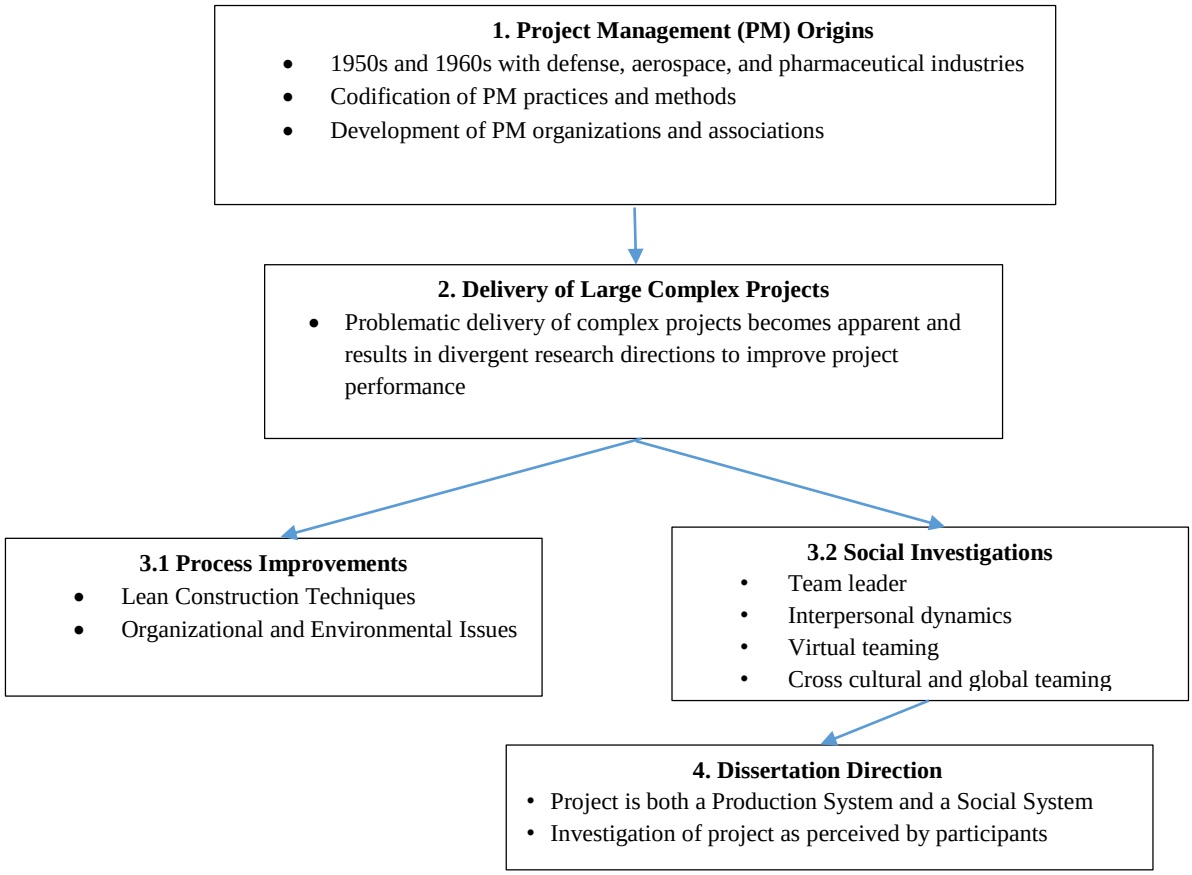

Figure 2 Development of Project Management Practices

*2.2.1 Project Manag*ement *Origins*

Project management, as a profession, has responded to needs associated with delivering engineering and construction projects (refer to Block 1 of Figure 2). The professional practice emerged during the 1950-1960s as an effort to control and manage the development of both the Department of Defense and pharmaceutical industry practices. Organizations such as the Project Management Institute codified and formalized generally accepted management practices in references such as the *Project Management Body of Knowledge* (Morris et al., 2006).

Levitt (2011) detailed the description of the development of project management processes in the 1950s as efforts used to integrate a complex group of participants on large projects (Levitt, 2011). The processes were based on the assumptions that financial, political, economic and technical conditions external to the project would be predictable and stable for the decades-long life of the project. To implement these projects, teams of experienced experts would develop detailed baseline plans as well as project mechanisms and metrics. The purpose of the metrics was, through regular reporting, to monitor deviation from the baseline plan, allowing project managers to correct direction and maintain the plan.

These management practices further developed and matured during the 1970s. The essence of the project management methodology was reliance on rigid centralized planning control and decentralized execution (Levitt, 2011). As these management techniques became increasingly detailed and prescriptive, they were codified into formal methodologies. Project management "bodies of knowledge" have been published by professional project management associations for ten to fifteen years. One widely recognized reference epitomizing this codification is the *Project Management Body of Knowledge (Project Management Institute, 2008)*. The Project Management Body of Knowledge (PMBOK) addresses five process groups (initiating, planning, executing, monitoring and controlling, and closing) and nine knowledge areas (management of integration, scope, time, cost, quality, human resources, communications, risk, and procurement), forming the axes of a management matrix, incorporating a total of 37 project elements. The development of Project Management Institute's PMBOK has been enormously influential (Morris et al., 2006).

Implicit in the philosophy underpinning the PMBOK approach is that experienced project practitioners, who are very knowledgeable in delivery needs and methods, define the baseline plan and the output metrics needed to maintain the plan. These metrics typically include a myriad of cost, schedule, financial, contract, and subcontract reports, each with variance analyses intended to alert senior management, clients, and agencies of deviations from the baseline. Reports contain measures being taken to correct and return to the plan. The project team then commits to meeting the deliverables in the baseline plan, executing the project following the plan, and reporting any variances to management to bring the project into compliance with the plan (Levitt, 2011). For the purposes of this paper, these techniques are termed the "traditional" approach. The assumption implicit in this traditional management approach is the belief that by properly controlling the baseline plan, output metrics, and variances, a successful project will be delivered.

2.2.2 Delivery of Large Complex Projects

Implementation of traditional project methodologies such as those codified by PMBOK are particularly problematic on large complex projects (refer to Block 2 of Figure 2). Despite the advantages

that the traditional methodologies provide, it is clear that essential elements are missing from the project management model. The understanding of project management issues appears to require more than a set of prescriptive processes and procedures, particularly for the delivery of large complex projects, as several studies have demonstrated.

To explore the difficulties associated with managing large complex projects, Williams (2005) studied large complex projects that were managed in "proper" text book fashion, but still overran their budgets badly. Williams maintains that there are at least two potential fallacies with the assumptions that underpin the PMBOK. The first is that the project can be completely preplanned, ahead of implementation, leaving the project management role that of simply implementing the well-thought-out plan. This assumption becomes problematic in situations in which the planning parameters change over the course of the project. Issues such as additional regulations, permits, and public comments can perturb the project plan, potentially causing considerable rework, forcing the project back through previous stages sometimes even after the design or construction has been completed. This scenario becomes increasingly likely as the duration of the project extends from months to years or even decades. The second potentially fallacious assumption identified by Williams is that elements of the plan can be broken down independently of each other, then integrated as discrete elements into an overall plan. Again, the permitting process provides an example that could invalidate this assumption. Frequently, to obtain the final permit, public comment is required. The public comment comes as a presentation of the conceptualized final design. Both the public and the local politicians often perceive the public comment process as an opportunity to pursue local agendas. The design is frequently subject to change as the public comment process evolves. In this example, the design and the public comment process may become iterative, as well as interdependent, necessitating replanning and reintegrating the elements of the plan while being continually subjected to external influences.

In another view on the evolution of projects, Priemus and Flyvbjerg (2008) investigated the difficulties associated with the delivery of megaprojects. They characterize megaproject as "high stakes games characterized by substantial irreversible commitments, skewed reward structures when they are successful, and high probabilities of failure" (Priemus & Flyvbjerg, 2008, p. 6). One key issue is the long time horizon of the project duration, typically exceeding 10 years. Megaprojects are shaped over time as the result of iterative changes to assumptions implicit in the projects. These waves of changes prevent the careful preplanning of the project in the manner that the traditional methodologies assume.

Taking a somewhat broader view, Levitt (2011) placed the evolution of project management in a larger historical context, and in so doing, identifies a number of weaknesses with the application of traditional project management methodologies in a contemporary setting. As Levitt noted, "Key project assumptions underlying project plans are changing … rapidly in every dimension—technically,

financially, politically, socially…" (p. 198). Changing financial conditions, such as oil and gas prices stability may drastically impact project's viability. Political and social norms can shift over the long development durations of large scale projects, upsetting the assumptions in the original baseline plan. Often today, those individuals planning the projects are not the thoroughly experienced experts assumed by the traditional methods, but rather newer additions to the project team, which in turn erodes the credibility of the baseline plan. Further, today's internet-enabled workers, when told to implement a plan but denied input, tend to distance themselves from the planning intrinsic in the baseline, rather than embracing it and working to steer the project back to the original plan (Levitt, 2011).

These recent changes in the development of projects renders traditional project delivery methods inappropriate for many large complex projects. Traditional project management is disciplined and rigid, and therefore may be appropriate in some settings for which changes to the plan cannot be tolerated, such as NASA missions or nuclear refueling operations. However, it is not agile, doesn't engage available participant knowledge, and cannot shift as changes external to the project are encountered (Levitt, 2011).

2.2.3 Process Improvements within Traditional Project Execution Framework

In addressing the limits of traditional project management, current research can be organized into two branches, the first of which investigates process changes to improve the traditional project model (refer to Block 3.1 of Figure 2). This set of investigations does not directly take issue with the assumptions implicit in the traditional approach to project management model, although nuanced changes are present. The fundamental assumption implicit in the branch associated with process improvements is that the traditional model remains useful, but structural issues need to be configured correctly.

Process improvement issues have considered such issues as the organizational structure and inter-organizational relationships. As early as 1977, for example, Youker described a potential conflict between departmental-based organizations and project teams that were matriced across the departments as a challenge to project managers. Organizations featuring strong department structures tended to invite conflict between the cross-departmental project teams and the departmental managers (Youker, 1977). Further, McDonough suggested that management support for the project team within a departmentally based organization is critical to the success of the project (McDonough, 2000). This support is necessary to overcome the departmental resistance to cross functional project tasks. Similarly, Miller and Guimaraes (2005) established that functional (departmental) managers play vital roles (both positive and negative) in the project teaming process. In many situations, hierarchical departments are driven to disable the focus on interdepartmental projects, which by their nature, attempt to cross departmental lines. Interestingly, this issue is also reflected into engineering student teams in academia. McNair, Newswander, Boden, and Borrego (2011) noted that structural boundaries within academia present

challenges to interdisciplinary collaboration. Such conflicts create a series of structural impediments to successful project management.

In addition to these intra-organizational issues, however, issues between organizations also present barriers to successful project execution. Frequently, these barriers are rooted in potentially adversarial contract relationships, particularly in the construction industry where projects involve multiple organizations. To reset the inter-organizational environment, a partnering process is frequently implemented. Partnering involves an attempt to promote collaboration and trust, typically through regular inter-organizational meetings and conversational forums between the contracting parties. Partnering evolved as the result of increasing project complexity and financial risk associated with large projects and is intended to facilitate understanding and discussion rather than legal action. In an article describing partnering Hartmann and Bresnen (2011), articulated the trial partnering process between a client and the maintenance contractor in a highway operation. Historically, the contractor and the client suffered through an entrenched adversarial relationship. The partnering approach was initiated by the client to improve this historically difficult condition. The result was increased awareness and improved willingness to communicate, and a general increase in the fluidity in the process of interacting. This represented a successful departure from the traditional adversarial contracting relationship.

In addition to the examination of organizational issues, research into process improvements is being undertaken in the form of revised project planning. Prominent among these improvements is the emergence of Lean Construction. Lean Construction employs adjustments to the methods associated with traditional planning and scheduling. Koskela (2003) suggested that the construction industry apply the revolutionary production management principles found in the Toyota Production System and establish a theoretical foundation for implementing lean construction applications. As a theoretical matter, lean construction methods focus on flow of materials and resources. These concepts are only now evolving in real world applications. The practical focus of the lean methodology is collaboration on all fronts: between the owner and the contractor, between the design and construction elements, and finally between the contractor and subcontractors. The objective of the collaboration supports to the theoretical basis: improving project flows to deliver the desired project with a minimum of waste and disruption.

Table1 below, articulates the contrasts between lean and traditional methodologies, adopted from Howell, Ballard, and Tommelein (2011).

Table 1 Domains of Project Delivery

Domains of Project Delivery	Operating System Focus	Commercial Terms	Organization
Tradition Management	Activity Centered – cost loaded schedule	Transactional	Command and Control
Lean Methods	Flow	Relational	Collaborative

While attention to organizational structures and relationships as well as adjustments to the management method processes has helped, challenges remain. These issues, although important, do not consider the social dimensions affecting individuals in the project environment.

2.2.4 Social Issues Impacting Project Delivery

As described in the previous section, studies of project management as a process subject to continuous refinement have led to a number of different procedural approaches that support improved performance, but many projects continue to come in late and over budget. Exploration of the social dimensions of project management represents a critical avenue of research designed to better understand these persistent performance issues and provide new insights to improve performance (refer to Block 3.2 of Figure 2). The realities of executing large complex projects and the problematic results have resulted in researchers examining the social dimensions of project delivery. The voices for perceiving the project as a social process has been in the academic background for decades. Before the recent critiques by Levitt (2011), Chinowsky et al. (2008), Williams (2005), and others, Bresnen (1990) argued for the case of construction to be brought into the mainstream of basic research to explore the full context governing project dealings and the interactions among project parties, and "to address those aspects of the complex nature of construction projects that cannot be captured by statistical or expert system models for estimating, planning, prediction and control" (p. 215). Bresnen's statements represented an early recognition that the conduct of construction projects required an understanding of complex social issues existing outside traditional project metrics. In 2000, Morris suggested that the scope of project management topics should be broader than those currently incorporated in the PMBOK and argued that "research evidence …shows that in order to deliver successful projects, managing scope, time, cost, resources, quality, risk, procurement, etc.... alone is not enough. Just as important – sometimes more important – are issues of …people matters, business and commercial issues, and so on" (2000, p. 6). Levitt and Chinowsky (2010) and Chinowsky, Diekmann, and O'Brien (2010) extend this thinking, suggesting that interactions and communication between project participants require accommodation and recognition of issues such as trust and reliability that must be key elements in factors that create a successful construction project team.

A number of subjects fall into this domain. The characteristics of the team leader, the individual centrally responsible for managing project, is a logical starting point for this social branch of investigation. Interpersonal dynamics and networking represent additional social dimensions investigated by researchers. Communication and knowledge transfer are layered into the social dimension of interpersonal dynamics. At the same time that pressures mount on the individuals managing large complex projects, the construction industry is being buffeted by transformational changing conditions

brought on by virtual and global project teams. Each of these various topics is developed in the following discussion.

Team Leader

Much of the research on these social dimensions began with studies of project leadership and the characteristics that enable individuals to successfully lead and manage teams. Over several decades, the characteristics of the team leader have provided a fertile objective for studying the social dimensions of project management. These investigations have taken several directions. For example, leadership characteristics were identified in a case study involving new product development by Maihotra, Majchrazak, Carman, and Lott (2001), who identified the importance of the team leaders handling of dissonance in a manner that developed trust and maintained respect for team members. The collective findings of several studies point to qualities such as engendering trust and communication (McDonough, 2000) and providing direction and a forum that is conducive to collaboration (Barczak, McDonough, & Athanassiou, 2006). In addition, the leader needs to be capable of managing the work of others that lie outside the leader's personal discipline (Maihotra et al., 2001). These results are reinforced by Bakar, Razak, & Karim's (2011) research in an investigations contrasting leadership styles on two large engineering projects (Bakar et al., 2011). Research methods included structured interviews, questionnaires, and review of the projects' reports. Bakar et al. established that the team leaders', as well as the projects' success depended on the leader's ability to facilitate trust and communication, establish a collaborative environment, as well as to understand the work of disciplines other than his or her own. Interpersonal dynamics of project managers were also addressed by Lloyd-Walker and Walker (2011) in the context of generational differences in leaders. In this study, the characteristics of baby-boomers, Generation X, and Generation Y leaders were examined, to characterize leadership attributes needed for 21st century projects; all generational characteristics were underpinned by trust and commitment.

Focusing more specifically on project management rather than more broadly on leadership Tessema (2010) characterized and quantified the traits of successful project managers, by correlating the leadership behaviors and emotional intelligence skills using responses from 578 project management professionals. The stepwise regression indicated that 8 of 15 emotional intelligence skills explained 44% of transformational leadership behaviors. Additional exploration of project management used a statistical correlation of survey data, and developed a characterization of team leader attributes by identifying indices to measure aspects of leadership characteristics (Muller & Turner, 2010). Muller and Turner developed a questionnaire that measured emotional, intellectual, and managerial competencies of managers of successful projects. The results indicate critical thinking (intellectual competency) and

influence, motivation, and conscientiousness (emotional competencies) were present in each of the successful project managers studied.

In summary, these investigations, using both qualitative and quantitative methods, attempted to characterize the successful project manager. The common findings of these investigations are that a project manager must be able to engender trust, communication, and commitment.

Interpersonal Dynamics

The project managers, however, account for only one among many individuals on a team. As a result, another strong branch of social dimension research explores the interpersonal dynamics among team members. Interpersonal dynamics is a broad and complex issue, layering into such diverse directions as knowledge transfer, global teaming, virtual, distributed, and multi-cultural collaboration, as well as social networking, all of which have been recently developed in research literature. At the core of all of these collaboration modes, however, is trust. Trust has a "direct positive effect on cooperation and performance" (Jarvenpaa, Shaw, & Staples, 2004, p. 251). In a study of relational space and trust, McNair, Paretti, and Davitt (2010) established that both affective and cognitive trust are important to collaboration. Affective trust is reflected in the confidence that others can and will follow through on their commitments. Cognitive trust represents the confidence that team members are capable of follow-up on complex tasks. Collaborators will tend "to expend effort in sharing their expertise if they are confident that the recipients are sincere people and that they have the expertise and competence to assimilate the new knowledge and apply it in creative ways" (McNair et al., 2010, p. 5).

In project teams, trust is essential for the core activity and knowledge sharing (McNair et al., 2010). Usoro, Sharratt, and Tsui (2007) describes knowledge transfer as a process in which a source shares knowledge with a recipient, who then localize, interpret, and adapt the knowledge in terms of their own experience. The knowledge is then passed back to the original source, who incorporates the localized, interpreted and adapted knowledge into their own experiences. This process occurs frequently in engineering and construction settings, when, for example, a group within the project discusses approaches to a particular problem. Differing ideas are considered by the group, with each individual recounting solutions used in such a situation previously. As the group considers solutions, each individual internalizes the others' ideas and in so doing, shares and transfers knowledge. An effort to understand how interpersonal dynamics weaves into knowledge sharing mechanisms was undertaken by Javernick-Will and Scott (2010). In a study consisting of 48 employees in 13 companies (engineering, construction, and real estate development), employee's motivations for sharing knowledge was examined. These motivations were categorized as resources, altruism, extrinsic incentives, and social motivations. Of the total, social motivations accounted for 61% of the total knowledge transfer effort, demonstrating

the importance of personal interactions. The critical importance of interpersonal contact to facilitate knowledge transfer is also highlighted in two case studies conducted by Senaratne and Sexton (2008) that investigated the knowledge exchange on projects during periods of change. The investigation supported the author's rejection of the concept that knowledge is transferred in the form of sketches, lessons learned, or other codified methodologies. Instead, knowledge flows during project evolution rely heavily on tacit knowledge and person-to-person contacts between project participants. In a similar vein, Stacey (2009) posited that knowledge is not contained in the written and codified records of an organization; these are only tools that may facilitate person-interactions. Instead, he argues that "Knowledge is continuously replicated and potentially transformed in the communicative interaction between people" (Stacey, 2009, p. 222).

Informal networks emphasize dynamic interaction and the free flow of knowledge between project participants and are an indicator of the efficiency of information transfer with a project (Chinowsky et al., 2010). Larsson (2007) again confirmed the importance of the personal contacts, when he investigated knowledge transfer and social networking mechanisms within distributed project design teams. His findings highlighted that "knowing who knows" and "knowing who to trust" are essential in obtaining critical information needed to complete project tasks. Knowing who to "know and trust" are essential elements of networking.

Expanding the investigation of interpersonal dynamics within the project environment, Dossick and Neff (2013) studied the ethnography of teaming practices during the adoption of Building Information Modeling (BIM) practices. BIM employs intelligent 3D modeling of structures to facilitate improved communication and decisions. In Dossick and Neff's case study, management was under pressure to use BIM design methodologies and was therefore required to implement BIM methods into existing projects. Using this technology, team members would be able to collaborate via a 3D software interface. Dossick and Neff observed considerable resistance to the new technology because it disrupted the existing practices of "messy talk," a Dossick and Neff term describing the problem-solving conversation that is needed to resolve conflicts. The Building Information Modeling technology disrupted the interpersonal communication that had been established on the project. The study emphasized that such adaption of technology must take account of the importance of interpersonal relationships and the introduction of potentially beneficial new technologies may be disruptive to the interpersonal dynamics needed for successful project development.

Another research direction focuses on the interpersonal dynamics associated with personality and emotional intelligence. For example, Macht, Nembhard, and Leicht (2013) developed correlations between elements of the Five Factor Model of personality (openness, conscientiousness, extraversion, agreeableness, neuroticism) and the Emotional Intelligence Inventory (interpersonal skills, stress

management, general mood). Extraversion (liveliness and sociability) and neuroticism (expecting bad things to happen) were the two Five Factor Model characteristics most closely related to Emotional Intelligence main scales. The study by Macht et al. (2013) represented an attempt to understand the specific correlated traits associated with personal dynamics that influenced performance.

Expanding the interpersonal dynamics perspective, Salas, Cooke, and Rosen (2008) investigated the concept of shared team cognition. Shared cognition provides the theoretical basis for understanding how teams adjust their performance under differing task conditions, interpret cues in a complimentary manner, and make compatible decisions and take coordinated action. Building shared models of the team environment, task, and interactions increases the team's ability to function (Salas et al., 2008). Lacking a shared understanding of the conditions facing a team leads to breakdown in communications and failures in performance. Van den Bossche, Gijselaers, Segers, and Kirschner (2006) addressed the need to integrate social and cognitive perspectives in developing a shared understanding of problems facing teams. The social and cognitive perspectives are integrated by examining the interactions that lead to shared cognitions and combining them with interpersonal social factors. Incorporation of both the social and cognitive perspectives are essential in developing the shared understanding of project issues.

As these studies suggests, interpersonal dynamics is intricately woven into collaboration, knowledge sharing, and networking and has its roots in the formation of trust between individuals living and working on the project. These issues are complex, interrelated, and need to be successfully negotiated to result in a successful project.

Virtual Teaming Issues

Most recently, characteristics of project managers and the interpersonal dynamics among team members have been complicated by the rise of virtual collaboration. Economic pressures encourage the use of virtual modes of communication for several reasons; eliminating the expense of face-to-face meetings, off-shoring of work to locations that are less expensive and more effective, and the formation of increasingly large diverse teams as the size and complexity of projects escalate. Issues associated with virtual collaborations are complex. For example, using Activity Theory and Speech Acts, McNair and Paretti (2010), investigated the interaction of language and technology in establishing virtual social relationships. Virtual work settings introduce a number of barriers to trust and collaboration by removing the relationship's physical context, as well as other contextual cues, with the result that language must bear an increased weight in facilitating trust and collaboration (McNair & Paretti, 2010). In addition to the absence of physical contextual cues, communication is mediated by various communication technologies. The particular mode of distributed communication will likely affect team interactions and effectiveness. The absence of physical and social contexts combined with the particular technology

employed can severely hamper collaboration by disrupting the formation of social networks and the establishment of trust among the team members (McNair & Paretti, 2010).

Similarly, Privman (2013) and Lee, Paretti, and Kleiner (2013) both investigated partially distributed teams to understand the effects of the differing modes of communication. Distributed teams represent those project task groups that are not collocated. Specifically, Privman studied the effects of unbalanced communication; differences between those enjoying direct communication with project management versus those forced to communicate remotely created an "us" versus "them" effect that negatively affected the success of the team.

In a related study, an investigation of virtual student engineering teams conducted by Paretti, McNair, and Holloway-Attaway (2007) consisted of two sets of teams from Sweden collaborated virtually with two sets of US teams. Two of three areas of core metaknowledge suggested by prior research, including the role of communication in supporting distributed collaboration and the nature of identity within virtual teams to establish roles and expertise in the virtual setting. This study was performed in an academic environment, but these issues also reflect into the virtual industry workspace and provide additional understanding of the social dimension of project delivery.

Cross Cultural and Global Teaming Issues

Global teams introduce another layer of complexity by adding cross-cultural dimensions to interpersonal dynamics. In addition to the issues associated with interpersonal dynamics, and virtual collaboration, globalization introduces cross cultural influences to the issues needing to be navigated by those responsible for successful project execution. Globalization is presenting projects in the construction industry with unique challenges dealing with sponsors, financiers, developers, designers, and contractors from different countries and backgrounds (Horii, Jin, & Levitt, 2005). This globalized cross-cultural phenomena is anticipated to grow as the emerging market countries develop clean water supplies, roads, power, telecommunications infrastructure, etc. (Javernick-Will & Scott, 2010).

Differences between a host country's and the entrant firm's cultures, represented by laws, norms, beliefs, values, and incentives, presents a host of risks and potential costs to global firms (Orr & Scott, 2005). Horii et al. (2005) constructed a model of cross-cultural virtual design teams, then conducted simulations, using inputs from four Japanese-American projects in the San Francisco Bay area. The objective was to investigate dissimilarities in communication practices and organizational structures. The American contingent associated with the study tended to favor individual-based communication and decision making; The Japanese contingent preferred group-based communication and consensual decision making. In terms of organizational structure, the American element tended to employ decentralized authority, a medium level of formalization, and flat organization structures. By contrast, the Japanese

culture selected for centralized authority, high levels of formalization, and multiple levels of hierarchy. Understanding and accounting for the differences in social-cultural values is essential to successfully execute cross cultural projects; failure to perceive, understand or recognize the differences can lead to misunderstanding, miscommunication, potentially delays, unnecessary disputes, and possibly personal offense. In fact, Chan (2003) identified cultural clashes as one of the most significant contributors to disputes on international projects.

One approach to facilitating the successful negotiation of cross cultural issues and interpersonal dynamics in the global setting involves the training of entrant contractor personnel (Choudhury, 2000). Beneficial cross cultural training includes physical, social, religious, linguistic, political, economic, and technological conditions within the host country. Recognizing that it may not be possible to provide training addressing this wide range of topics, Choudhury applied multiple regression to questionnaire responses from international contractors to prioritize the issues. He established that an in-depth understanding of the host country's physical environment and social-cultural values was the most valuable training for entrant contractors to receive. This theme of social-cultural training was also reflected by Chen and Messner (2010) in a study of global virtual teams that investigated techniques to improve engineering and design services at a competitive cost without sacrificing time and quality. Chen and Messner investigated survey responses from 19 owners and 27 contractors. His recommendations, intended for implementation by contractors, included such elements as obtaining some level of multilingual capability and training to orient project team members to the realities of the virtual work environment. This orientation to the virtual work setting was one of the steps employed by McNair et al. (2010) to implement language practices leading to successful collaboration.

In addition to training to understand and accommodate social and cultural differences, Di Marco and Taylor (2011) investigated the employment of cultural boundary spanners to improve multi-cultural project performance. A cultural boundary spanner is an individual, not necessarily the project manager, who's "understanding of the multiple cultures and languages … is sufficient to connect members in a global project network" (Di Marco & Taylor, 2011, p. 28). Di Marco and Taylor demonstrated that use of cultural boundary spanning improves both 1) the initial performance of multi-cultural project networks and 2) project performance that is statistically indistinct from mono-cultural projects. This represents one approach to ameliorating the complications that multi-cultural teams experience.

2.2.5 Dissertation Direction

Collectively, these studies point to the need to explore not only the processes at work in effective project management, but the human dynamics. As the previous review suggests, however, many of the studies to date focus on management across a range of product design and development industries, but

few have focused specifically on large mega-projects analyzed by GAO, AASHTO, NIST, or Ernst and Young. Within construction management, Stacey, Cicmil, and Williams have all argued strongly for such social analyses with the project management literature. From the perspective of successful project execution, this represents a significant altering of the focus and direction of management attention. Cicmil further argued the performances of contemporary projects have not been substantially improved and that problems in project management practice persist and the development of teaming and project management theory remains unstable and fragmented (Cicmil, 2006). This research project thus draws on the frameworks advocated by Stacey, Cicmil, and Williams, along with findings in other contexts, to explore the social dimensions of project management within a large-scale design-build infrastructure project. It thus explores issues addressed broadly in teamwork research (leadership characteristics, interpersonal dynamic, knowledge transfer, and virtual/cross-cultural collaboration) in the specific context of construction megaprojects.

In 2000, Morris suggested that wide agreement exists that the scope of project management topics should be broader than those currently incorporated in the traditional PMBOK and that sometimes more important are the issues of people matters (2000). The conduct of successful project teaming and management appears to entail significant elements that exist outside the focus of the traditional system. Cicmil and Williams amplify this criticism, doubting the assumptions of planned decision-making and control and the presumption that human team member responses can be prescribed, directed, and controlled, as if they were component parts of a mechanical apparatus (Cicmil, 2006). These assumptions express the doubt that individuals and their assembly into a cohesive team can be accomplished as one would assemble mechanical apparatus.

The developing view of the project is that it is a complex social process, in which project participants pragmatically interact, sharing and shifting power, decision making, learning, and communication, and balancing and rebalancing authority and structure (Stacey, 2009). In Stacey's model, the organization is constantly evolving as dynamic participant interactions become more complex, deepen, and develop a self-organizing character and states that a healthy vibrant organization must rely on these dynamics in order to grow and achieve its objectives (Stacey, 2009). Organizations are understood to be emergent, the results of interactions associated with language, conversation, and power.

Taking Stacey's and Cicmil's perspectives as a lens, this research project pursues the understanding of a large design-build infrastructure project from the perspective of the individual project participant. What are the critical issues to the individual participant, and how do those issues interact and evolve as the project develops and self organizes? In the words of Cicmil and Marshall (2005), "the situational…aspect is of interest in order to understand the nature of interaction among participating individuals, and the spatial and temporal dynamics of power relations in a specific project context" (p.

534). Unlike most studies cited in this review, this dissertation represents a longitudinal exploration of the participant's perspective within a design-build infrastructure project, using sets of semi-structured interviews and on line surveys.

The tenets of Stacey and Cicmil research provides the foundation for conceiving, understanding and analyzing the interview statements and survey data. The understanding of the project in the context of day-to-day personal interactions provides a potentially key missing element to understand the dramatic failures of large complex construction projects.

2.3 Summary

This literature review traced the development of contemporary project management from its inception in the 1950s which laid the groundwork for "traditional" project management practices to current research investigating process improvements as well as social dimensions affecting projects. In the last two decades, complexities with the execution of large complex projects have been documented by a number of organizations, including AASHTO, GAO, and NIST as well as private investigators such as Ernst and Young. Problems with the delivery of large projects continue to plague the engineering and construction industry. The problematic delivery of projects have prompted investigations into project process improvements and more extensively, the social dimension of project collaboration.

Process improvements included the investigation of organizational and environmental arrangements and structural changes within the traditional management project planning, represented by lean construction methods. Lean construction approaches challenge the traditional methods by adjustments to the development of the project baseline.

In the last decade, the drivers increasing the focus on social dimensions of project execution have strengthened. The research direction adapted by this dissertation posits that future improvements in project delivery will require understanding the "people" side of the equation, missing from the broader understanding of project development. Investigating teaming as it is actually experienced by the participant is advocated by Stacey (2009) and Cicmil et al. (2006). This dissertation extends this research direction by investigating the as-lived experiences and interpersonal dynamics of a large complex design-build infrastructure project and focuses on contextual elements: how the project is perceived by the participants; what motivates their decisions to interact with others; what is the nature of those interactions; what influences are felt and how those influences are handled.

This research in no way implies that traditional project management approaches are incorrect or misdirected. Traditional approaches have provided a wealth of information concerning methodology and metrics needed to successfully execute projects. These methods and metrics have enormously influenced

and benefited the conduct of project execution. The point here is that the traditional methods are essential but not in themselves sufficient. Further research is needed to understand project social dimensions.

Chapter 3: Methodology

This chapter addresses the design of this exploratory investigation, the development and collection of the data, and the data analysis. The overall goal of this project is to develop a richer understanding of the personal dynamics and interpersonal reactions in play within large complex design-build infrastructure project. The study uses an in-depth single case study that combines qualitative interview data and quantitative survey data collected over an 11 month period to address the following research questions:

1. What factors are salient to individuals at multiple organizational levels as they experience team interactions within an urban infrastructure mega-project?
    a. What critical factors characterize participants' perceptions of the interactions and interpersonal dynamics on the project?
    b. What interactions occur among factors that affect participants' overall experience and performance?
    c. How did these perceptions and interactions change over the course of the study?
2. How do perceptions of project experience and interactions align with group performance?
    a. What differences exist between the groups that performed well and the groups that performed poorly at the beginning of the study?
    b. What differences exist between the groups that performed well and the groups that performed poorly at the end of the study?
    c. What changes occurred within the group that performed well from the beginning to the end of the study?
    d. What changes occurred within the group that performed poorly from the beginning to the end of the study?

3.1 Research Design Overview

To address these research questions, this exploratory case study utilized a concurrent nested mixed methods design (Creswell, 2009) to collect multiple forms of data for a single case over an extended time period. The data collection was performed in parallel, while the analysis was performed sequentially, with the qualitative findings shaping the analysis of the quantitative data. That is, the findings from the series of interviews provided the key that informed the statistical analysis of the survey responses.

The algorithm describing the data collection and analysis process was illustrated previously in Figure 1. The qualitative element of the investigation consisted of semi structured interviews conducted three times over the 11 month study period. The interviews were each recorded and transcripts produced. Each set of interviews was conducted with the same interviewees; that is, the same people were

interviewed for each series, though interview participants did drop out as the study progressed, due largely to individuals leaving the project. There were 21 individuals in the first round of interviews, 17 in the second, and 13 in the third. The quantitative element consisted of on-line surveys that explored the same topics as the interviews, but were emailed to the entire engineering department, consisting of 153 individuals. The responses for the three surveys totaled 58, 35, and 44 participants, respectively. Figure 3 depicts the timing and sequencing of the three sets of interviews and surveys.

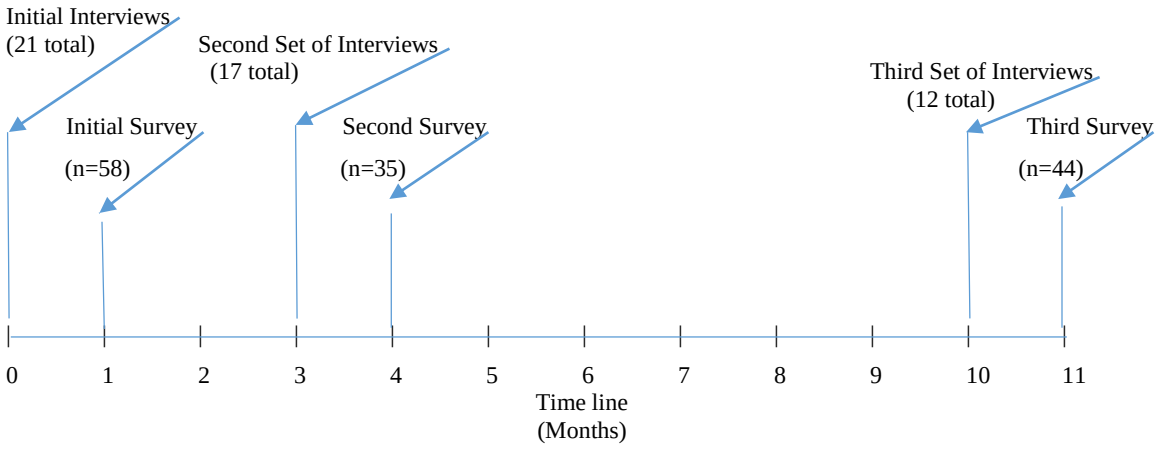

Figure 3 Timing of Interviews and Surveys

The balance of this chapter explains the approach and methodology of the research study in detail. The results of the qualitative investigation are presented in Chapter 4, with the quantitative investigation results in Chapter 5. The triangulation between the two approaches, as well as the discussion, is provided in Chapter 6.

The study was conducted with approval from the Institutional Review Board to insure appropriate ethical treatment of human subjects in research (IRB # 06-045). The interviews were confidential, and as a result, this study uses codes to identify participants. An informed consent agreement was signed by each participant. In addition, a Confidentiality Agreement was executed between Virginia Tech and the design-build firm.

3.2 Case Study Approach

This exploratory investigation was conducted as a longitudinal case study. The case study setting yielded a rich source of information relative to the investigation of participant interactions. Yin (2013) defined three conditions that merit case study research: 1) the nature of the research question is explanatory, exploratory, or descriptive, typically structured to address “how” or “why”; 2) the

investigator lacks methods to control the site and participants; and 3) the phenomenon being studied is contemporary and the context is real-life. Table 2 maps these conditions onto the present study.

Table 2 Case study criteria mapped to research conditions

Conditions	Research Setting
Nature of the research question	The research is an exploratory question to more fully understanding the personal interactions experienced by the design-build team members and their reaction to those interactions. There are few studies that address the personal interactions that evolve within a design-build team.
Lack of control	The researcher had no control over enrollment and outside factors that could influence professionals' behaviors in the design-build team.
Contemporary phenomenon in real-life context	Design-build teams are a contemporary phenomenon in industry and were studied *in situ* in a real industry context.

Case studies typically involve multiple data sources. Of the six sources identified by Yin, interviews are by far the most prevalent. Advantages of interview evidence are that it is "targeted … focusing directly on the case study topics … and insightful … explanations as well as personal views" (Yin, 2013, p. 106). Yin also notes the disadvantages of interview-based investigative methods, including questionnaire and interviewee bias and potential for reflexive interviewee responses. To mitigate this limitation in this study, multiple interviews were conducted with the same individual, and each set of interviews addressed essentially the same topics. In addition, survey data was collected to triangulate interview findings.

The three interview sequence also provided a longitudinal perspective on the case. Longitudinal studies are employed to track changes in the subject population over time and are used extensively in situations in which time is the primary variable, such as medical and treatment research. For this dissertation, although changes over time were not a primary focus, the use of a longitudinal approach is still applicable for two reasons. First, because teams evolve over time and perspectives change, multiple interviews were helpful in achieving a deeper understanding of individuals' perspectives, whether those perspectives changed or not. This interest in individual perceptions was the thrust of Stacey's (2009) and Cicmil's (2006) argument that understanding personal interactions and the as-lived perspective project participant is key to understanding the social dimensions of projects. The longitudinal approach thus mediates against catching someone on an off day and provides a more complete view of their thinking. Second, given the tight participants' time schedules and heavy workloads, the least intrusive approach was employed by using multiple shorter interviews.

3.3 Research Setting: Design-Build Infrastructure Project

Several aspects of the site will be provided in the section that follows. First, the overall nature of the project will be described, recognizing that naming or definitively identifying the project would violate the confidentiality agreements established with the design-build organization. Then, the approximate phase of the project during the study period will be established, and finally, the project organization will be reviewed, since that insight will provide an understanding of the results that follow in Chapters 4 & 5.

3.3.1 Project Description

The case study is set in a large design-build infrastructure project in a major metropolitan area. The study project is Phase I of a metro rail project spanning approximately a dozen miles, a tunnel, elevated and at-grade guideway, and multiple stations and costing over $2 billion. Currently, the project is over a year late and 20% over budget. The prime contractor is a joint venture between two large engineering and construction companies. The joint venture completed preliminary engineering on a cost plus basis, but converted to fixed price for the design-build contract.

3.3.2 Project Phasing during the Study Period

At the time of the study, preliminary engineering had been completed, bringing the engineering to approximately 25-30%. At the start of the study, the design-build contract had been in place for a few months. By the end of the study period, eleven months later, the engineering was perhaps 70% complete, based on observations only, without access to contractual or project controls documentation. During the study period, utility relocation started, as did the installation of temporary facilities, such as lay down yards, to support construction.

3.3.3 Project Organization

The project utilized a functional matrix to manage the engineering organization. This approach is not unusual in large complex projects. This structure is visualized schematically in Figure 4.

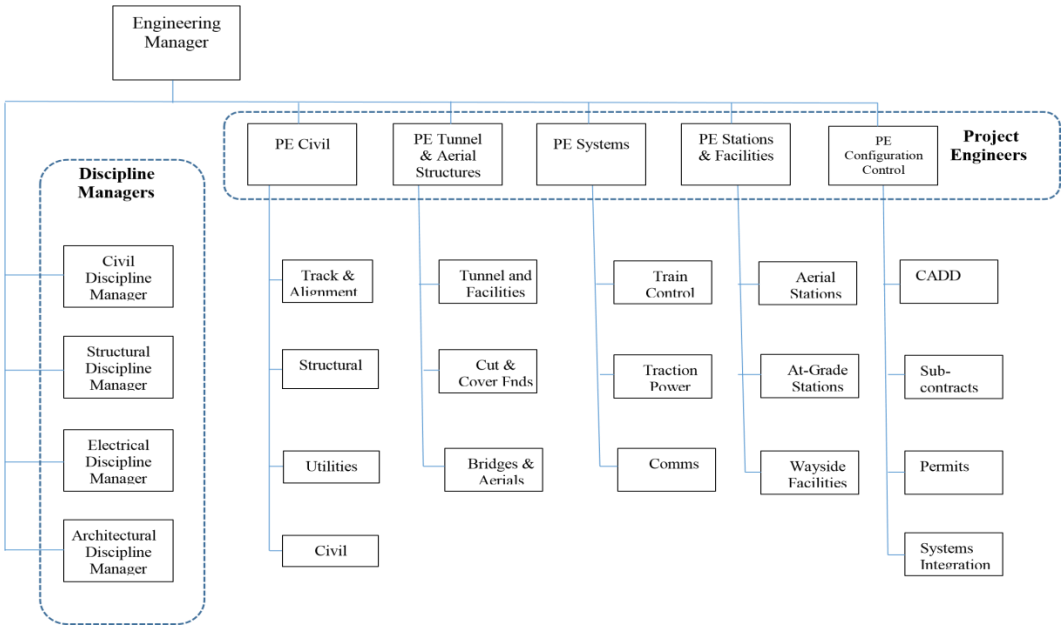

Figure 4 Organization Chart for Design-build Project

The matrix structure consists of two primary axes. The horizontal project engineering axis is responsible for work package production, and each Project Engineer is responsible for the areas falling under them in the matrix. Their focus is on meeting the design schedule and integrating the technical disciplines that are involved with their areas of the project. On the vertical axis, the discipline managers' are responsible for the design integrity and quality for their discipline. The staff engineers reside with the discipline managers and are assigned to particular project engineering tasks by their discipline manager, based on priorities and negotiation with pertinent project engineers. The discipline manager will eventually sign and seal the all design documents that their discipline organization generates. The project engineers and the discipline managers complement each other and need to collaborate frequently on priorities and sequencing. Each discipline manager may be working with several project engineers. For example, the Civil Discipline Manager may be generating road alignments and signalization modelling for the Civil Project Engineer and grading and drainage information for the Stations and Facilities Project Engineer. Similarly, the Structural Discipline Manager may coordinate architecture layout for the Stations and Facilities Project Engineer and aerial concept designs for the Tunnel and Aerial Structures Project Engineer.

Each staff engineer living inside the project thus has two individuals to report to: a project engineer and a discipline manager. For example, the Discipline Civil Engineer is the primary report for all civil engineers; each staff civil engineer will be seated in and collaborate daily with the Civil Discipline Manager and have an annual performance review performed by this discipline manager. Each

staff engineer will need to obtain the Civil Discipline Engineer's approval for the work produced, since the civil discipline manager eventually seals the work. However the staff engineer will attend weekly schedule meetings and answer to the Project Engineer for design delivery dates, thus experiencing pressure to produce the designs to a tight schedule.

As noted earlier, the surveys were sent to all members of the engineering organization, and interview participants were drawn from the same pool. Everyone who volunteered was interviewed and participants included two project engineers, two discipline managers, six lead engineers, and eleven staff engineers. The interview participants had varying reporting responsibilities and authority and ranged from those just out of school to those with more than 30 years' experience. In general, the responsibilities associated with these roles were as follows:

- Project engineers were responsible for particular aspects of the design, such as civil elements, stations and facilities, or tunnels and bridges and were focused on delivering their part of the project within the prescribed schedule.
- Discipline managers were matriced to one or more project engineers, as appropriate, and although they were aware of schedule issues, were primarily responsible for the technical content and quality of the drawings and calculations.
- Lead engineers supported either project or discipline engineers and were the first line supervision on the project.
- Staff engineers generally worked directly for the discipline managers and included a broad array of skills, from geotechnical, grading and drainage, profiles, civil (soil) structures, to rail alignment, roads and traffic studies.

3.4 Qualitative Overview

The qualitative data consisted of three semi-structured interviews that probed each participant's perceptions of the social dynamics and personal interactions within the project. The interviews explored issues that impacted the project participants and, as importantly, their reactions to those issues. Initially, 21 individuals were interviewed. The second and third series of interviews were conducted with 17, and 12 of the original 21 participants, respectively, as individuals left the project over the course of the 11 month study. Thus, 12 individuals participated in all three interviews. The research questions associated with the qualitative investigation are presented below:

1. What factors are salient to individuals at multiple organizational levels as they experience team interactions within an urban infrastructure mega-project?

a. What critical factors characterize participants' perceptions of the interactions and interpersonal dynamics on the project?
b. What interactions occur among factors that affect participants' overall experience and performance?
c. How did these perceptions and interactions change over the course of the study?

3.4.1 Qualitative Data Gathering

The qualitative investigation was conducted via three semi-structured, audio recorded interviews with each participant, and also included observational sketches, field notes, and sketches produced by the interviewees.

The interview regimen is provided in Table 3 below.

Table 3 Timing and Numbers for the Three Sets of Interviews

Interview Sequence	Timing	Total Number of Interviews	Project Engineers	Discipline Managers	Lead Engineers	Staff Engineers
1st	September	21	2	2	7	10
2nd	December/January	17	2	2	6	7
3rd	July/August	12	1	2	5	4

The interview questions were developed to investigate the project's participants' lived experiences (Stacey, 2009), which characterizes the lived experience from the perspective of individuals on the project. Cicmil and Marshall (2005) discussed understanding the project as a complex social process and gaining insights into the interactions that occur between participants. Using Cicmil's and Stacey's concepts as a lens, along with prior research on project management described in Chapter 2, the semi-structured interview questions were intended to elicit team member perceptions of their interactions on the project. Questions addressed a wide range of topics as appropriate:

- Nature and characteristics of interactions with the Project Engineer
- Nature and characteristics of interactions with the Discipline Manager
- Nature and characteristics of interactions with Lead Engineers
- Interactions between managers
- Frequency of interactions with managers
- Characteristics of interactions with fellow staff engineers
- Perspectives on the organization
- Communication within the individual's department

- Communication outside the individual's department
- How task assignments are established
- How performance reviews are conducted
- Time available to complete assignments
- Issues and challenges affecting the individual
- Ability to make decisions
- Nature of feedback from the organization

The actual interview protocol is provided in Appendix A.

Generally, each semi-structured interview began with the same set of initial questions, but individuals were encouraged to elaborate on specific experiences, perceptions, and ideas. The open ended nature of the discussion resulted in the discussion of a wide variety of topics and perceptions. In addition, the individual's role within the organizational structure tended to influence the direction of the discussion.

Each semi-structured interview typically lasted between 30 and 60 minutes. In addition, following each interview, written field notes were authored to highlight the key issues and particular responses to the interview questions. On several occasions, hand drawn sketches were utilized by some of the participants to make points, and these were also maintained in the interview files. On one occasion, a reflective memo was employed by the interviewer to document a development pertinent to the evolution of the organization. In this instance, the Discipline Lead Managers no longer met regularly with the Engineering Manager while the routine meeting with the Engineering Manager was reserved for the Project Engineers.

To protect the anonymity of the interviewees, pseudonyms were used in lieu of names. Examples included TM1*date*, SM2*date*, PE1*date*, or EGS1*date*. The quotations utilized in Chapter 4 employ the pseudonyms. Furthermore, to maintain confidentiality, location names which could identify the project have been modified.

3.4.2 Qualitative Data Analysis - Codes

The interviews were recorded, transcribed, checked, and then coded for analysis using the open coding approach advanced by Miles and Huberman (2013). Following the Miles and Huberman methodology, interview transcripts were systematically and repeatedly examined to categorize and then group information found in the data. This is termed "first cycle coding" by Miles and Huberman (2013).

To code the transcripts, highlighting was used within MS Word™ software application. Coding software was not used. Codes were assigned to the data to identify recurring patterns. These pattern codes were then grouped into categories that were refined as the analysis proceeded. As code definitions shifted and were refined, the process was repeated. By the third review cycle, emergent themes identified

what had become the central themes of the interview data, reflecting the participants perceptions associated with the interactions on the project. The relevant dominant themes were then used to recode all data. The final codes were validated by a second researcher, reviewing a subset of the interview transcript data. Any points of discrepancy were resolved by consensus.

Four sets of themes emerged as the interview data was reviewed, analyzed, recoded, and then reexamined. These four themes highlighted the salient perceptions of the project from the perspective of the participant and are presented in Table 4.

Table 4 Dominant Themes Developed from the Transcribed Interview Data

Theme	Code	Definition
Contextual Understanding	Understands larger context of work on project (Understands the "big picture")	Statements that explain the broader context of the project and how the individual's efforts fit into this larger perception.
	Does not understand larger context of work on project (doesn't understand the "big picture")	A statement indicating that the individual does not understand the integration of their efforts with others on the project.
Availability of Information	Fellow Employees	Statements indicating that information came from within the engineering discipline, from supervisors or other employees
	Other Departments (positive connotation)	Statements indicating that information came from outside the immediate engineering group and that the results were positive.
	Other Departments (negative connotation)	Statements indicating that information came from outside the immediate engineering group and that the results were negative.
Dealing with Constraints	Accepts constraints and integrates them into planning and activities	Statements that indicate that the individual understands their, as well as those of others work with them, and incorporates them into the work planning process.
	Puts up with constraints, but is irritated with them; fights them	Statements that indicate that the individual recognizes that the constraints will not go away, but tends to not accept them and fight them.
Response to Supervisors	Positive Impact	Statements that indicate that the individual is positively affected by supervisor's attitudes.
	Negative Impact	Statements that indicate that the individual is negatively affected by supervisor's attitudes.

These codes represent several iterations of analysis involving combing through the interview data, color coding statements made by the interviewees, then reexamining and recoding the data. At the

end of the analysis, these codes provided the best fit of the data, the perceptions of the participants and their stated reactions to the project.

3.4.3 Qualitative Data Analysis – Patterns Among and Across Codes

Following the identification of the themes that stated the participants' reactions to the project, an analysis of the interactions between the coded responses was conducted. The objective of this aspect of the investigation was to identify codes that appeared in combinations. That is, for example, to what extent did understanding the "big picture" align with participants' ability to positively (or negatively) deal with constraints.

The analysis of the data involved assigning either high, neutral, or low rankings to each of the four codes to each interview participant, then tabularizing the results. Each high, neutral, and low rankings were color coded and the results tabularized. Using Excel, the columns were sorted to visually identify color coded entries that aligned. This analysis considered all combinations of coded themes, and the results are presented in Chapter 4.

An additional analysis was performed to understand longitudinal changes in in the interview data. In this study, twelve individuals were interviewed at both the beginning and end of the study. Analyzing the statements made by the same individual over the life of the study established whether the responses had changed over time. The discussion of these results are also presented in Chapter 4.

3.4.4 Qualitative Investigation - Data Collection: Interview with Engineering Manager

The final interview was conducted with the Engineering Manager, initially as a courtesy prior to leaving the site. In that interview, a number of important facts emerged that shaped the final phase of analysis. The interview revealed a number of frustrations, particularly with the management of one of the groups under the Engineering Manager's purview. This group, including the Discipline Manager, responsible for leading this particular discipline engineering organization and the lead engineering supervisors were being replaced. On a project of this size, the staff could peak at perhaps 30 individuals over the 1-2 year course of the design work. The Engineering Manager made several statements that expressed frustration with this poorly performing department (SM2, 20090708):

"…the root cause is basically some gaps in competence and leadership…blind paths…wasted time and effort...excessive rework...inefficient...poor performance."

"Then it's my fault too…do I stop and reorganize or do I muddle through with what I've got because I don't have the time to start over?"

"So you make that judgment …and well, it turns out that it didn't get any better, so now we have to step in and fix it."

At the time of the interview, the Engineering Manager was demoting and replacing the Discipline Engineer and the Lead Engineers (SM2, 20090708). In contrast, the same Engineering Manager also stated that another engineering organization had performed well in that they had met the objectives of schedule, costs, and technical quality, a finding corroborated by the Discipline Manager, who noted:

> "We're good on our schedule performance…we've delivered our 60%, 90%, and IFC submittals on schedule…we're 4% over budget…(but) we'll get caught up when certain trends or change orders are approved and added to the budget (EGS2, 20090507).

Similarly, the Engineering Manager stated (referring to the Discipline Manager, whose organization performed well):

> "And of course, we get a boss who gives you that kind of trust, you'd walk through fire for him…And they do… their performance is great. They get the job done."

This frank discussion of the differing performances of these two engineering groups provided an opportunity to investigate differences between these two groups as reported in the survey responses. In other words, knowing the drastic differences in the relative performances of the two groups, in what surveyed areas did the two groups react differently to questions concerning the dynamics of the work environment and personal interactions?

3.5 Quantitative Investigation Overview

For the quantitative investigation, the study population was considerably broader and comprised most of the engineering population, including all groups in the organizational chart (Figure 4). The quantitative investigation used data responses received via an online survey tool. The survey questions were intended to elicit responses from the population that would indicate the nature of interactions on the project and their individual responses to those interactions.

3.5.1 Quantitative Data Collection

Requests to participate in an on-line surveys were emailed to the general engineering population that initially consisted of 153 individuals associated with the project. Survey links were sent following each interview session, in October, the following January, and then August. The surveys were housed on the Virginia Tech Survey site and all responses were anonymous. The questionnaires consisted of twenty-two questions, using primarily Likert type responses, but also background questions to understand each responder's role in the organization or explore details about non-scalable information, such as the group that they belonged to within the organization or the types of information they needed to perform work tasks. Fourteen of the twenty-two questions elicited responses for which statistical testing could be applied.

The survey questions were similar in nature to the semi-structured interview format and consisted of the following topics:

- Nature and characteristics of interactions with the Project Engineer
- Nature and characteristics of interactions with the Discipline Manager
- Nature and characteristics of interactions with Lead Engineers
- Interactions between managers
- Frequency of interactions with managers
- Characteristics of interactions with fellow staff engineers
- Perspectives on the organization
- Communication within the individual's department
- Communication outside the individual's department
- How task assignments are established
- How performance reviews are conducted
- Time available to complete assignments
- Issues and challenges affecting the individual
- Ability to make decisions
- Nature of feedback from the organization

A copy of the survey is included in Appendix B.

Responses to the emailed survey from the total population numbered 58 for the first, 35 for the second, and 44 for the third survey. Over the course of the 11 months, there was some natural attrition on the project; by the end of the study period, engineers were being taken off the project as the engineering deliverables were being completed. However, the primary responders at each point in time consisted of the group that performed well and the group that performed poorly, reinforcing the decision to compare responses for these groups. Roughly speaking, the responses consisted of equal parts well performing engineers, poorly performing engineers, and all others as summarized in Table 5:

Table 5 Frequencies and Categories of Survey Responders

Survey	Date of Survey	Group Performing Well	Group Performing Poorly	All Others	Total
1	October	19	22	17	58
2	January	12	11	12	35
3	August	16	12	16	44

The "All Other" category includes the balance of the responders, including the geotechnical, electrical, systems, and mechanical engineers, architects, configuration control specialists, and managers associated with the project.

3.5.2 Quantitative Data Analysis

Survey responses were downloaded into an Excel spread sheet. Given the findings from the qualitative analysis, the profile of the survey respondents, and the Engineering Manager's discussion of performance differences between the groups, the quantitative analysis focused on the differences between the group that performed well and the group that performed poorly.

2. How do perceptions of project experience and interactions align with group performance?
    a. What differences exist between the groups that performed well and the groups that performed poorly at the beginning of the study?
    b. What differences exist between the groups that performed well and the groups that performed poorly at the end of the study?
    c. What changes occurred within the group that performed well from the beginning to the end of the study?
    d. What changes occurred within the group that performed poorly from the beginning to the end of the study?

To address these questions, the survey data was examined to identify differences in the attitudes and perspectives that existed between the well and poorly performing engineering groups. In addition, a longitudinal examination of the survey responses allowed the changes within each group to be compared over time, which ties to RQ 1c, which examines changes in perception over time.

The sample sizes involved with this study are relatively small, varying initially between 19 well performing group personnel surveyed and 22 individuals that belonged to the group that performed poorly (see Table 5). Typically, minimum n values of 30 are used to represent a threshold for use of parametric statistics and, in fact, n values of hundreds and thousands are frequently seen. The small sample size renders the use of parametric methods problematic. In addition, many parametric statistical methods assume a normal distribution in the survey responses. While there are methods available to test and correct for normality, there are better non-parametric procedures for the analysis of potentially non-normal (and small) distributions (Hoskins, 2012).

A number of parametric and nonparametric tests are available for comparing the means of different data sets. The Wilcoxon, Mann-Whitney test, the Chi Square and the T-test are all potential candidates, each with its own set of conditions and limitations. The conditions of each test are summarized and presented in the Table 6 below.

Table 6 Potential Analysis Methods

Analysis Method	Conditions
Mann-Whitney Test (Conover, 1999)	• Independence • Distribution information not required • Random sample selection • Unequal sample sizes allowed
Wilcoxon Test (Conover, 1999)	• Independence • Normal Distribution not required • Random sample selection • Equal sample sizes
Chi Square (Lowry, 2013)	• Known (& uniform) distribution (so that expected values will be consistent) • Sufficient size (no expected values less than 5)
T test (Whitley, 2002)	• Normal distribution • Equal variances (or close)

The Wilcoxon Test was eliminated because the sample sizes are not equal, while the Chi Squared Test Student T Test were eliminated because the distribution is unknown. Given the capability of the Mann-Whitney analysis to deal with both small and unequal sample sizes and that understanding the underlying distribution is not required, this was the test selected to compare the two groups of engineers. The Mann-Whitney test is a form of the rank-sum test and is appropriate for determining if there is a statistically significant association between categorical survey responses and is suited to small sample sizes (Hollingsworth, Smith, & Nelson, 2011).

For the analyses listed in Table 6, the null hypothesis, H_0, typically states that there is no difference in the means between the two groups being compared. That is, there was no difference between the responses of the:

- Group of engineers performing well and the group performing poorly at the beginning of the project (reference RQ 2a)
- Group of engineers performing well and the group performing poorly at the end of the project (reference RQ 2b)
- Group that performed well from the beginning to the end of the project (reference RQ 2c)
- Group that performed poorly from the beginning to the end of the project (reference RQ 2d)

This null hypothesis is rejected if the Mann-Whitney tests indicate that differences between study populations do exist, for a given p-value. The definition of p value is "the smallest significance level at which the null hypothesis would be rejected for the given observation" (Conover, 1999). Often, in definitive statistical research, a threshold p-value of 0.05 is used. However, the selection of p-values

needs to consider the context of the study (Gelman, 2013). For this investigation, the objective is not to definitively establish a specific statistic as conclusive; rather it is to develop a general understanding of the as-lived conditions on the project. As Frongillo (2004) expressed the concept, when screening for possible interactions, a useful procedure is to screen using a p-value of 0.15 or 0.20 (2004).

For this study, a p-value of 0.20 was used to identify statistically significant results. This is the value adopted by Gelman (2013) and Frongillo (2004) in the sample studies they employed in their respective articles. This range of p-values was utilized with domains for which the development of definitive conclusions is not possible.

To analyze these data sets, the publically available VASSARSTATS (Lowry, 2013) software was employed. This website provides a broad range of both text information and data entry sites for the analysis of statistical data. For this analysis, the survey results were entered directly into the webpage provided by VASSARSTATS site. The results of this analysis are presented in Chapter 5.

3.6 Researcher Bias and Limitations

At this point in the discussion, researcher bias needs to be addressed. Rossman and Rallis' argument (2010), what "makes the inquiry systematic and scholarly" is transparency on the part of the researcher. In this section, I will discuss my background and the biases that may have been present during the investigation, and most importantly, how these biases were handled.

Prior to conducting the research detailed in this dissertation, my professional experience consisted of more than 30 years working on heavy industrial engineering and construction projects. My career began as a field engineer and progressed through construction and engineering management, and on several projects, my position was project manager. The topic of teaming and interactions among project participants represents a strong personal interest to me. Of the various types of problems that I have had to confront over the course of my career, personal interaction issues were the most intractable; the most difficult to resolve.

So, how might biases have been introduced to the investigation? As Rossman and Rallis (2010) state, bias may become an element of the research at any of the stages of development:

- design
- data collection
- analysis, interpretation, reporting
- limitations

Each of these potential areas for the potential biasing of the study will be discussed next.

3.6.1 Research Design

The design of the research, in this case, could include several steps. First, the development of the questions as the template for both the semi-structured interviews and the on-line survey (see Appendices A & B) presented an opportunity for the introduction of bias. Bias here was obviated by two mechanisms. This is an exploratory investigation, so the questions were developed as broadly as possible, including topics as coworkers, supervisors, time available, level of independent action, performance reviews, management interaction, quality of work products, sources of information, communication, and assignment of tasks. Second, the questions were reviewed with another researcher ahead of the interview process, to check for completeness and appropriateness.

3.6.2 Data Collection

The individual interviews employed for the qualitative investigation provide some opportunity for entry of bias into the data. The interviewee may react to the interviewer's tone or sense agreement or disagreement. In reference to the data collection associated with this dissertation, having many years of experience potentially introduced bias during the interview process in several ways. During the interview, my experience with the design-build project setting could lead me to identify with the interviewees' statements, assuming that I understood them, interpreting them in the light of my experience, rather than probing more deeply with additional questions. A positive aspect of this experience, is that I had an insider's understanding of the design-build environment, which might result in interviewees opening up more so than with an individual that had not had similar experiences to themselves.

Several steps were taken to address these potential biases. First, multiple interviews were conducted with each interviewee, each addressing essentially the same topics, avoiding a one-off misconnection between the interviewer and interviewee. Second, all the interviews were recorded and transcribed, which reduces the opportunity for selective memory and provided the basis for the follow-on analysis (Creswell, 2009). Finally, the protocols and intermediate findings were discussed at length with other researchers to solicit their feedback and take advantage of more dispassionate perspectives not directly involved in the interviews. This step introduces what Rossman and Rallis (2010) term a critical friend and provides the opportunity to reconsider conclusions reached prematurely. The data collection associated with the online surveys was more straightforward with less chance for biasing the results.

3.6.3 Analysis, Interpretation and Reporting

The analysis, interpretation, and reporting of the data also presents an opportunity for biased manipulation. The potential exists for bias to be introduced in the analysis of the data, based on previous researcher experience. For the qualitative element of the study, analysis consisted of coding the

transcribed data. First, using transcripts, rather than memory, eliminates the tendency to recall only those discussions that support the researcher's previously developed ideas. These coded transcripts became the basis for establishing the themes and issues important to the interviewees. The themes were developed by highlighting quotes within the transcripts across the interviewee pool. Using highlighted transcripts removed bias opportunity by introducing accountability into the analysis process. Importantly, other researchers (Rossman and Rallis, 2010) reviewed the coded and highlighted transcripts and themes as they were emerging, further reducing the opportunity for introducing bias into the analysis. As with the data collection phase, the quantitative analysis was less subject to bias, in that the raw data became the direct input for the statistical analysis.

It is important to note that strong evidence of triangulation exists in the analysis and findings of the data (Creswell, 2009). At least three issues emerged in both the qualitative and quantitative analysis, including the importance of supervisory contact, the response to constraints, such as deadlines, and a contextual understanding of the larger project. These common results in both the interview/coding phase and the online survey/statistical analysis phase provides strong support that the data and analysis did not incorporate substantial bias. It is also important to note that the data sources for the qualitative and quantitative analyses were collected from different populations, although, due to confidentiality, it cannot be determined whether the interviewees also participated in the surveys.

3.6.4 Limitations

The limitations associated with the data collection and analyses are particularly salient in the qualitative phase of the investigation. One of the conditions of a case study (Yin, 2013) is that the researcher has no control over the research enrollment or other outside factors that may influence participant behaviors. For the qualitative study, the interviewees were self-selected, volunteering to participate in the series of interviews. In addition, transferability of the findings and results from a case study may be difficult, since the case study is deliberately targeted at a particular situation. This specific research population was the engineering staff of a large design-build project. Permutations to this specific population are endless, even for design-build projects. For example, the construction organization or the subcontracting community could have been the subject of the study, possibly with much different results. Within the engineering community, other project types exist, including feasibility studies, conceptual designs and final design. Expanding the possibilities still further, product development teams could undergo study, or for teams within commercial rather than technical orientation, again with potentially very different results. For the same reason, case study results are not predictive. However, recognizing these limitations, the personal reactions and interactions between project participants arguably may not

change from site to site. The individuals involved may experience similar site settings and sets of interactions, regardless of the specific project.

3.7 Summary

The research site afforded an opportunity to investigate the design-build project teaming issues from two fundamentally different perspectives. The first, the qualitative investigation yielded rich data in the form of interviews that permitted project participants to develop their concerns and reactions to the as-lived project experience. This aspect of the investigation consisted three set of interviews conducted with a limited number of interviewees, several months apart. The interviews were recorded and transcribed. The transcripts, then, were iteratively coded using guidelines originally developed by Glaser and Strauss (1998) and more specific techniques developed by Miles and Huberman (2013). Following the analytical development of the primary codes, the interaction between the codes, was examined by identifying recurring groups of codes. Finally, the longitudinal perspectives were examined to detect changes that occurred in attitudes over time.

The quantitative investigation involved emailed surveys that were sent to the entire engineering staff. This yielded survey responses that, while lacking the depth of the interview data, provided much broader insights into the reactions of the general engineering staff. The surveys were sent to the larger engineering staff at three points over the 11 month study. This aspect of the study focused on the differing reactions of the well and poorly performing engineers to the project environment. The focus for this analysis was to compare 1) the responses of the well performing and poorly performing engineers at the beginning and 2) at the end of the study, 3) the changes in the responses of the group performing well, from the beginning to the end of the study, and 4) the parallel changes in the responses of the group performing poorly, from the beginning to the end of the study. This information provided insights into the very different ontology of the two groups.

A comparison of the qualitative and quantitative investigations will be provided in Chapter 6 of this dissertation.

Chapter 4: Results of Qualitative Investigation

This chapter presents the results of the qualitative component of the investigation. As described in Chapter 3, the qualitative component uses data from semi-structured interviews to address the following Research Question:

1. What factors are salient to individuals at multiple organizational levels as they experience team interactions within an urban infrastructure mega-project?
    a. What critical factors characterize participants' perceptions of the interactions and interpersonal dynamics on the project?
    b. What interactions occur among factors that affect participants' overall experience and performance?
    c. How did these perceptions and interactions change over the course of the study?

4.1 Research Question #1a – Salient Perception Themes

The analysis of the qualitative data resulted in the emergence of four themes in the statements made by project participants during the semi-structured interviews. As discussed in Chapter 3, these themes were develop by iteratively analyzing interview transcripts to identify issues expressed repeatedly across participants and over time. These factors included both positive and negative statements regarding issues that directly aligned with the participant's perception of their work environment. These included: 1) understanding of the larger project context, 2) the ability to obtain needed information, 3) response to challenges and constraints, and 4) interpersonal interactions with supervisors. The specific themes associated with this study are identified and defined in Table 7.

Table 7 Participant Perceptions Themes Emerging from Interview Data

Theme	Definition	Sample Statements
Contextual Understanding	Statements indicating understanding of the larger context of work on project and how the individual's efforts fit into this broader perception. (Understands the big picture)	"Ah...the biggest constraint I think we have right now as a team...as a whole...is we're downsizing. Just the nature of the job… we all knew going in to it that it was part of the plan" (TM4, 20081119).
	Statements indicating that the individual does not understand the integration of their efforts with others on the project. (Doesn't understand the big picture)	"...in a project like this...there's a lot of departments that I don't really understand what they do..." (TM7, 20080917).

Theme	Definition	Sample Statements
Availability of Information	Statements indicating that sufficient information is available to perform work activities, from either intragroup sources or outside the immediate engineering organization.	"But, ah he's always helpful; like in answering questions, he'll take the time to sit down and explain something or show us how to look it up in manuals." (TM7, 20080917)
	Statements indicating that insufficient information is available to perform work activities.	"So I was assigned...the cross discipline (task, by his manager). So I call a meeting with all these guys…and say no, we're not doing it… [but the manager]…tells me... "Take the ball…get it done" (TM11, 20080917).
Responses to Challenges and Constraints	Statements that indicate that the individual understands their constraints, as well as those of others who work with them, and incorporates them into the work planning process.	"One [issue] is we had some staffing problems...it's very competitive because there's a lot of other engineering work going on right now…[other projects] are taking a lot of people…we attract people from our parent organizations…and had 3 if not 4 jobs fairs" (EGS2, 20080924).
	Statements that indicate that the individual recognizes that the constraints will not go away, but tends to not accept them and fight them.	"Whenever I have emergencies from this lady [the lead for this individual's group], which happens a lot... I've seen people do things 5 times [its] absurd…" (TM6, 20080917).
Relationship with Supervisors	Statements that indicate that the individual is positively affected by supervisor's or fellow employee's interactions.	"He's actually wonderful to work for…He's always open-minded to your opinions. He'll always work through an issue with you" (TM9, 20080923)
	Statements that indicate that the individual is negatively affected by supervisor's or fellow employee's interactions.	"We had some issues… when she was lead in group. She had issues with us going directly to the folks outside of our group…[like] we were circumventing her …in my previous jobs, I was always able to go to whomever I needed to talk to…so I could move forward" (TM9, 20080923).

The following sections illustrate each of the four themes.

4.1.1 Theme 1 – Contextual Understanding

The first theme associated with participants' overall perception of the project is their contextual understanding of their work and the integration into the larger project. To what extent does the individual

understand the functioning of the larger project? Some individuals demonstrated a fairly mature perspective associated with the functioning of the project, as indicated in the following comment:

> …the biggest constraint I think we have right now [during this phase of the project]...is … we're downsizing. Just the nature of the job… (TM4, 20081119).

Here, the participant has a strong sense of the larger movement of project phases ("right now") and relegates the resulting challenges to "just the nature of the job." Similarly, the same participant stated:

> …basically what my manager needs to see is the end product…at the end of the day… what really matters…the execution. (TM4, 20081119).

In this case, the participant is able to accurately assess the needs of the manager and position his work accordingly. These statements indicate an experienced understanding and a relatively broad perspective.

Another engineer, displaying similar breadth and depth of understanding, worked with both the environmental compliance group and the construction group, developing erosion and sedimentation control plans. Her reflections on her approach to others:

> …we have our own environmental inspector…our own cop who looks at the [legal] requirements. So that is one department…then I also work with the construction department...and that was most interesting because the construction people think…in terms of actual implementation in the field…I found it extremely helpful to talk with them (TM8, 20090513, p. 4/14).

Here, the engineer understood the sometimes conflicting needs of legal requirements and practical implementation and armed with this breadth of knowledge was able to craft designs that would satisfy both needs of other departments.

In contrast, others didn't understand the broader project context. The individual making the following statement clearly had not developed a holistic understanding of the project elements:

> ...in a project like this...there's a lot of departments that I don't really understand… (TM7, 20080917).

Another participant talked about missing important information as to what was occurring on the projects:

> …we need more communication…we need to have meetings…why do we wait until something...some conflict or miscommunication happens and then have the meeting…we need regular meetings (TM12 20080923).

These examples illustrate the types of comments that indicate either perceptions of a broader project context or failure to grasp the functioning and integration of their work within the larger project.

4.1.2 Theme 2 – Availability of Information

The second theme that emerged from the analysis of the interview transcripts was the availability of information need to perform the work. Again, sources for information could originate either within or outside the engineering department, or not be available at all. The ability to obtain needed information is clearly important, and this was identified by the interviewees.

A positive indication concerning this theme occurred when the interviewee had access to information required to perform work tasks. Instances of information being available within the engineering department included the following statement:

> She's [the Project Engineer] a good person to go to for more information about how things are progressing or...for direction… (TM9, 20090506).

In this case, the individual has established sources of information within the engineering organization for determining the direction for their efforts. A similar situation existed for the following project participant, who regularly received information from his discipline manager:

> Mostly [I talk to my Discipline Manager] about scheduling and…what package I am responsible for…sometimes stuff that is not really clear about how we go…depending on what we are supposed to do. (TM14, 20081126).

Other individuals obtained information outside the engineering organization, reaching out to the construction to work out schedule priorities:

> So by communicating with him, I make sure that he knows exactly what I can do…He can say, "Yes, this plan will be done." Or he can say, "No, we need to add another two weeks of delay for this particular package because of certain reasons." That's crucial. I find that extremely helpful (TM8, 20080917).

This positive response was not always the case. Some individuals reflected on the difficulty of getting information and decisions, particularly when the issues crossed discipline boundaries. This difficulty is reflected in comments such as the following, where the participant expresses frustration with unresolved problems:

> …you have a vent fan…that has a sensor... has to be controlled by central control mechanism...who's in charge of making sure that [the multidisciplinary integration] is done?...[This] came up...probably back in December of last year and I don't know if it's been resolved yet. (TM15, 20080923)

This individual has been experiencing difficulty in resolving the design conflict and getting the information needed to move forward. Another person experienced difficulty in obtaining information schedule integration from management:

> … I need your design by x number of days. But [they're] not scheduled to complete that until y days in the future. But I need it right [by x]...there's conflict, problems or whatever (TM11, 20080917).

An interesting variant to responses to information availability was represented by the following statement from an individual who did not want to participate in unnecessary dialogue with others:

> …impromptu...somebody comes to your desk and asks questions. I get that a lot. That's probably my biggest time waster---time eater. I hate to say that, but... (TM9, 20080923).

Clearly, this individual did not want to be a source of information and resented the imposition. Information sources, whether positive or negative, whether giving or receiving, proved to be a significant factor affecting the interviewees.

4.1.3 – Theme 3 - Challenges and Constraints

Challenges and constraints in the work place are ubiquitous. Almost all individuals discussed issues that were beyond their control, but that they were still forced to negotiate with these on a daily basis. Challenges and constraints took on a variety of forms, including:

- Shifting priorities
- Deadlines
- Lack of communication
- Indecision
- Lack of clear instructions
- Delegation without authority

A central issue that emerged in the interviews and subsequent analysis concerned not the type of challenge, but the individual's reaction to those challenges. Individuals made statements that reflected one of two reactions. The individual both accepted the constraints and integrated the pertinent issues into their planning or, they resisted the constraint, fighting and grousing about them continually. Individuals displayed either generally positive or negative reactions to challenges and constraints. That is, this was the one theme that all interviewees discussed.

An example of statements reflecting the acceptance of the constraints and incorporation into the plans and actions are the statements concerning the adjustment of planning to accommodate the construction organization. For example, the following statements represent a positive response to challenges associated with shifting priorities and changing deadlines; the individuals responded by accepting the challenges and incorporating the changes into their work flow:

> So sometimes...[the schedule] might say they are going to … drive piles [at a particular location] in October, but in reality the piles are here and they can jump on it in let's say June. So I'll speed up my plans to support that. (TM4, 20090505).

Another individual, reflecting on the need to maintain flexibility in their personal planning stated:

> On a weekly basis, [we have] at least two [permits]…and sometimes we get daily requests. I mean this could be an emergency today. So we have to drop everything and make sure that package gets to the regulators (TM8, 20090506).

Another engineer talked about needing to shift to changing priorities as conditions in the field developed:

> My primary priority was the Route "X" Submittal…there are some changes coming from utility relocation...they need immediate attention. So when those come in, we drop everything and start to address those changes because…construction [will need it] (TM13, 20081120).

This positive means of dealing with constraints is contrasted with other individuals who adopted a more negative tone. For example, one individual resented the interdepartmental conflict that is a facet of all large organizations.

> …but … the construction folks kind of crap on the engineering folks a lot. Engineers [are] there to support construction only…they [always] … point the finger a lot and say, "Engineering screwed up again" (TM9, 20080923).

Evidently, this participant did not deal positively or constructively with the challenges presented by conflicts with the construction department. Similarly, this same individual, at a different point in time, fought against on-going regulatory reviews, as evidenced in the following statement:

> The first submission through final approval is ridiculous. And then they keep asking...they got new players involved… [with] different concept[s]…so he asks for something completely different… [You] can't get approval until you satisfy my comments... (TM9, 20080923).

The mechanism for dealing with the constraint in this instance did not provide a solution; rather it was repeatedly mentioned as an issue that created concern.

As the analysis of the data progressed, it became clear that an individual's mode of responding to constraints proved key in the ongoing daily life of the project participant; it also became important in establishing codes and identifying the relationships between them.

4.1.4 Theme 4 – Responses to Supervisors

The last theme reflected in the data focused on responses to workplace supervisors. Strong visceral reactions to both good and poorly perceived managers and supervisors were recorded in the interviewee statements. One employee, describing her supervisor stated:

> …he's always helpful; like in answering questions, he'll take the time to sit down and explain something or show us how to look it up in manuals… (TM7, 20080917).

In this case, the participant described their reaction to the supervisor's attitude and relationship in positive terms. This contrasts with the statements made by another individual:

> Well the previous EGS...I think it has to do with management style…It's a lot easier to get things done now than it was before. And the main reason for that is because our current EGS lets us coordinate amongst ourselves and not…be present for every single issue…I guess he trusts us a little bit more…he doesn't micromanage (TM4, 20090505).

In this instance, the individual contrasted the previous "micromanaging" supervisor with his current supervisor whom he perceives as more trusting and allowing of independent actions. Continuing to discuss the new supervisor, the participant elaborated on statements and attitudes received:

> I think its attitude of, you know, "Let's get this thing done." That's probably the biggest thing. … I just notice that personally when I look up to a manager...a lot of how I do my work is dependent on...him (TM4, 20090505).

And

> I'd say like...like every couple of weeks or so....you know, I hear, "Thanks for putting in the effort." …that kind of stuff…and… "This stuff got approved. Thanks a lot" (TM4, 20090505).

These quotations provide a vivid indication of the impact that work place personalities can have on individual participants. Another individual discussing his supervisor describes attributes that he finds appealing:

> And he's very professional...wonderful to work for…he's always open-minded to your opinions. He'll always work through an issue with you...he has patience and he'll take the time to listen to what the issue is, try to identify all the pros and cons of the issue, and then he'll try to make a decision if he can or he'll elevate it and get an answer for you (TM9, 20080923, p.3/18).

Another individuals, discussing different supervisor, addressed her lack of involvement with people on the engineering floor:

> But she's much less involved in people compared to EGS...not as good with people, not as interested in the people (TM13, 20080924, p. 5/17).

This individual addressed a previous supervisor with a perspective that connotes frustration with the supervisor:

> …the previous [supervisor]... has to do with management style and personality… having to double-check, triple-check every single step of the way…micromanage (TM4, 20090505, p 11/25).

So the attributes and characteristics of individuals in the working environment becomes an element of the social dynamics as they play out day-to-day.

4.2 Research Question #1b - Participant Perceptions--Interactions between Codes

As described in Section 4.1, four factors consistently emerged across the interviews as critical to participants' perceptions and attitudes toward the project. While such descriptive work is a critical first step, as important from a project management perspective is understanding how the factors interact and thus how interventions can and should be prioritized. The second research question addresses this issue.

At a summary level, four patterns among the codes were established in the data. These interactions were developed by examining the coded transcripts and then tabularizing the summary "Positive" or "Negative" responses of each interviewee to the interactions on the project. The interactions between the codes are listed in Table 8.

Table 8 Interactions between the Codes

Interaction	Interacting Factors	
1	Response to Constraints	Contextual Understanding
2	Response to Constraints	Relationship with Supervisor
3	Response to Constraints	Information Availability
4	Relationship with Supervisor	Information Availability

These issues will be developed in the discussion that follows.

4.2.1 Establishing the Code Pattern Interactions

To understand the code interactions, the characteristics of each individual relative to the potential code references was tabularized and examined for patterns between the codes. Definitions of Positive, Neutral (labelled Not Applicable), and Negative were established for each code reference as defined in Table 9.

Table 9 Definitions of Positive-Neutral-Negative for Code References

Position	Definition
Positive	Statements made by the individual established strong positive position relative to the code. This may have included bringing up the topic frequently or detailed discussions concerning the code.
Neutral (Not Applicable)	Statements made by the individual indicated the lack of a strong positions one way or the other, were balanced, or statements were made only in passing.
Negative	Statements made by the individual reflect a strongly negative reaction to the code. Statements were made frequently or contained detailed negative discussion concerning the code.

Then, the eight potential code references were mapped onto each individual's space, based on their statements recorded during the interviews. The initial table of code references is provided in Table 10.

Table 10 Code References for each Participant (sorted by positive response to constraints)

Pseudonym	Information Availability	Relationship with Supervisor	Understands Big Picture	Response to Constraints
PE2	NA	NA	P	P
EGS1	P	NA	P	P
EGS2	P	NA	P	P
TM13	N	NA	P	P
TM3	N	NA	P	P
TM4	P	P	P	P
TM5	P	P	NA	P
TM7	P	P	N	P
TM8	P	P	P	P
TM1	P	NA	P	NA
TM10	N	NA	P	NA
TM11	N	N	P	N
TM14	P	NA	NA	N
TM15	N	NA	P	NA
TM16	N	NA	N	N
TM17	N	NA	N	N
TM2	N	NA	N	N
TM6	P	N	N	N
TM9	NA	P	NA	N

At the center of participants' experiences was their response to constraints. The response to constraints tended evoke strong statements. As a result of the coding, the acceptance of constraints became the key determinant from which other factors were conditioned.

Patterns among the codes are visible in the highlighting of combinations of codes. For example, the strongest alignment between the codes between a positive response to constraints and a positive

contextual understanding of the environment (the big picture). Table 10 also indicates the inverse of this relationship; those individuals that expressed lacking a perception of the big picture also tended to consistently report concerns with constraints.

Another alignment between codes occurs between the response to constraints and the relationship with the supervisor. Individuals expressing a positive relationship with their supervisor also responded positively to constraints. Again, the inverse of this situation is also represented in Table 10. Individuals with a negative relationship with their supervisor, reacted negatively to constraints.

Finally, the alignment between the response to constraints and the availability of information is also evident in Table 10. Both positive and negative alignments between these two codes is demonstrated in Table 10.

One other alignment becomes apparent with a resorting of the data, presented in Table 11: the alignment between information availability and the relationship with the supervisor. This is not surprising; individuals identified other people as the source of information, most often the supervisor. Individuals that felt comfortable with their supervisor would likely also feel free to ask for information from the supervisor. Unlike the code alignments discussed above, the alignment between relationship with the supervisor and the availability of information was only evident in the positive sense. The inverse of this alignment (negative relationship with the supervisor and lack of information availability) was not apparent in the data.

Table 11 Reordered Code References (sorted by relationship with the supervisor)

Pseudonym	Information Availability	Relationship with Supervisor	Understands Big Picture	Response to Constraints
TM9	NA	P	NA	N
TM4	P	P	P	P
TM5	P	P	NA	P
TM7	P	P	N	P
TM8	P	P	P	P
TM6	P	N	N	N
TM11	N	N	P	N
TM14	P	NA	NA	N
TM16	N	NA	N	N
TM17	N	NA	N	N
TM2	N	NA	N	N
PE2	NA	NA	P	P
EGS1	P	NA	P	P
EGS2	P	NA	P	P
TM1	P	NA	P	NA
TM10	N	NA	P	NA
TM13	N	NA	P	P
TM15	N	NA	P	NA
TM3	N	NA	P	P

4.2.2 Evidence of Code Interactions

Each of the five codes interactions presented in Table 8 and highlighted in Tables 10 and 11 merits explanation and is discussed in this section.

Response to Constraints – Contextual Understanding

The relationship between the response to constraints and contextual understanding can be demonstrated by reviewing an individual who exhibited both traits. TM8 initially worked in the environmental group developing plans for protection of the environment during construction. Typically, construction personnel tend to not be strong in either the belief or need for some environmental protective measures. To negotiate with construction on this topic can be difficult and requires a broad approach to be successful. TM8's statement concerning this negotiation follows:

> And then I have to work with the construction department. And that was one of the most interesting type of work relationship because construction people think differently than the engineers. And when I say that, I'm referring to the fact that they actually implement in the field what they envision. And I found it extremely helpful to talk to them to make sure that something that I thought was practical and useful and helpful was going to be along the lines that they implement in the field. And sure enough, it wasn't…Initially, they wanted to eliminate the

> majority of the measures. And then I explained to them, "Here's what the book says." I managed to establish a relationship…they gained confidence that I am here to make sure that our construction department does not get fined (TM8, 20080917).

In this example, TM8 demonstrated the understanding of the big picture (implementation of environmental requirements in a manner that will gain construction's support) and the ability to deal with constraints, (another, potentially adversarial department). This same individual dealt successfully with another person that did not want to accept the current method of handling a particular procedure. The mode used to approach this person indicates a particularly adept and positive dealing with constraints:

> He first resisted us, and…kept thinking that things are not done the right way. And it took us a little bit of education...it took a little bit of time from us to show him our ways and for him to understand…we had to give (him) a little background…we had to educate him to understand (TM8, 20080917).

The inverse of this alignment between response to constraints and contextual understanding also was evident in the statements made by the participants, which connected negatively dealing with constraints and lack of contextual understanding. In the statement below, TM17 expressed a negative response to work deadlines as a constraint, because he could not understand what was coming up next, and was on a short fuse to produce his work:

> I was going to say...when something's due, I've gotta release all the drawings, and then that's where the schedule issue comes, because usually I find out drawings need to go out a lot of times the morning of...sometimes I get a day. … I haven't figured it… (TM17, 20080924).

Extending this example, this same individual could not understand how the change process worked and why he was repeatedly getting new changes appearing in his drawing work. He was working in the right-of-way group, his boundaries kept changing, and he was perplexed by it:

> ...sometimes we were… waiting...they realized the grading wasn't working...and because of that, the drainage people need to....they don't know how to set their stuff, necessarily…both of them together can change what I'm doing in right-of way. So...I have to wait… (20080924).

As will be demonstrated with several other code interactions, the connection between response to constraints and contextual understanding was a direct relationship, working both positively and negatively.

Response to Constraints - Relationship with the Supervisor

Another influence associated with the response to constraints was the relationship with the supervisor. In a discussion with TM4, the subject of rechecking assumptions came up. The well performing group, because they were typically first to complete their work, were forced to make assumptions about how other disciplines would complete their designs and then later, after other disciplines designs had been completed, go back and check the assumptions. This was a source of aggravation to some engineers, but TM4's approach to handling this constraint was expressed as follows:

> It lined up pretty well. I mean their design is actually a little bit wider than what I anticipated. So it will add, let's say, a hundred feet of guardrail or something. That's something that I didn't anticipate, for example. It's just that minor stuff that you've got to go back and double check and tweak it (TM4, 20081119).

The same individual compared his current supervisor to a previous individual, clearly preferring the current manager and on other occasions expressing strong positive statements about this same supervisor:

> Well the previous EGS...I think it has to do with management style and personality and that kind of stuff. It's a lot easier to get things done now than it was before. And the main reason for that is because our current EGS lets us coordinate amongst ourselves and not so much to be present for every single issue…I guess he trusts our judgment. But he doesn't micromanage…having to double-check, triple-check every single ...every single step of the way… you know, like I said, gives us more trust, gives us more flexibility...I think it's a...easier way of communicating.

The converse relationship also existed, with a negative response to constraints aligning with a negative relationship with the supervisor. In the statements below, TM2 describes a constraint, the frustration in operating under schedule pressure, with unclear direction:

> …if the coordination manager tells something to my supervisor, that needs to get done, my supervisor … tells me something it's not entirely what the other guy said. So I have to like a rework it a couple times…I shouldn't be saying this... I don't think I get clear directions from my supervisor (TM2, 20080909).

The same individual stating a reaction to her supervisor, because that supervisor places this individual in an awkward position:

> We have a civil PE that I know my EGSs has a problem with… a personality conflict. It's just like spite sometimes... I mean he wouldn't go talk to her. So he would send me to talk to her... but yea, I do get caught in the middle (TM2, 20080909).

In summary, the connection between response to constraints and the relationship with the supervisor worked in both positive and negative directions.

Response to Constraints – Availability of Information

The relationship between response to constraints and the information availability is also readily demonstrated in the statements made by the interview participants. EGS2 was a discipline manager and unusually adept at negotiating constraints on the project. In the statement below, this individual addresses conflicting priorities which was one type of constraint experienced on the project:

> …weekly meetings with the project engineers and the engineering group supervisors. So that kind of outlines the priorities and hot issues for the week ahead. So to some extent (competing priorities) gets worked out in those meetings. And then to the extent it doesn't or something pops up during the week between those meetings, then we then bring it to the project engineers to sort out (EGS2, 20080924).

This statement also demonstrates how this individual seeks resolution to problems, as well as obtains additional information (resolution of conflicting priorities). And, the same individual demonstrates another means of obtaining information, this time from a different source:

> But...ah...we also...probably once every two weeks on an average, [the Project Engineer]will organize a meeting with someone from the construction group so that we stay flanged up with where they're going, what their priorities are, what we owe them, and if it's all fitting together (EGS2, 20081126).

The interaction between positive response to constraints and availability of information was demonstrated by another project participant in the following sets of statements, the first discussing information sources:

> So instead, I'll go to the EGS; I'll raise specific examples with them whether they're technical or regarding specifications…Um...how often? I would probably say ...I probably run into every EGS once a day, for one reason or another. Yesterday I had a two-hour meeting with the Structural. After work, I had a three-hour meeting with Architectural. During the day, I had about a 1 1/2 hour session with the Mechanical EGS regarding elevators and some of the other work we were doing... (PE2, 20081112).

In addition to extensive communication to enable communication with other project members, the same individual discussed design productivity, as one of the issues the project faced and offered his perception of a means of dealing with the constraint (working in parallel):

> But our production just isn't what it should be. So I've struggled with how to influence that productivity and how to...influencing productivity, having the teams interact and communicate better… trying to enable them to work in parallel rather than only in series on a given facility (EGS2, 20090505).

This individual had established the ability to negotiate constraints and obtain needed information.

These pairs of quotes demonstrate the connection between a positive response to constraints and availability of information. However, the reverse was also apparent in the statements made by the participants, who at times connected a negative response to constraint and a lack of available information. TM7 talked about a constraint in the form of shifting priorities, while being under schedule pressure:

> There is lot of jumping around, back and forth, like juggling. Ah, I'm not going to say that it's a constraint that I can't finish it, [but]...getting it done in 40 hours a week... (TM7, 20090505).

In the statement below this same individual expressed confusion as to who he should address to obtain design information:

> Architects do it a little differently, it seems. Whereas if I'm in [one station], they'll direct me to one person. If I'm in [another], they might send me to someone else. Like, they must each have their own station. Cause they seem to direct me to different people (TM7, 20090505).

In summary, the connection between response to constraints and the availability of information work both positively and negatively on the individuals within the project.

Relationship with Supervisor – Information Availability

One of the younger engineers expressed his relationship with his supervisor in the following terms:

> Even at times when, like when I can tell he's under pressure...like to get things done...he's still can, like, spare a minute, to like...guide me in the right direction cause he's, like, a decision that maybe I'm not comfortable making...I want to just double check. He would always stop for a minute and help me out…working with him is definitely helps a lot…you learn, get more experience, build your confidence.

In terms of information availability, the same engineer stated that the source of his information originated within the department and per this individual's statements, was readily available:

> He coordinates and does a lot through e-mail to keep us all up to date on just the general status of the group, forecasting upcoming submittals, dates, and also notifying us on the previous submissions, that went through successfully, like if we got something permitted, or...just to let us know things are going well and that our work is moving along. So once it's gone, we still do hear about it. Yea, so it's good for us. So at least we know that the hard work is paying off.

This individual expressed a strong connection between the relationship with the supervisor and the availability of information. Unlike other code interactions, the statements in the interviews indicated that there was no negative corollary (no evidence of a negative relationship with the supervisor and a lack of information availability).

4.3 Research Question #1c - Longitudinal Perspectives

To examine the longitudinal changes over the course of the study, several assumptions were made. First, the longitudinal comparison was limited to those individuals that participated in the interviews at the beginning and end of the study. Analyzing responses on the extreme ends of the eleven month study provided a more meaningful time horizon for the longitudinal analysis. Periods between the last of one set of interviews and the beginning of the next set of interviews were sometimes as short as a few months, rendering meaningful evaluation of change for this short a duration questionable.

The data associated with the longitudinal analysis is presented in Table 12. The vertical axis lists the twelve participants that were interviewed at the beginning and end of the study period and the horizontal axis provided the four codes and the summary response of each interviewee. The twelve participants and the four codes provides a total of 48 points that are subject to the longitudinal analysis. In 44 instances, there was no change in the individual's response to a code over the course of the study. These entries are marked "N/C" for No Change.

The descriptors associated with the Table 12 are identified in the table key, located below Table 12.

Table 12 Longitudinal Responses of Interview Participants

Pseudonym	Date	Information Sources	Change	Supervisor Interactions	Change	Big Picture	Change	Challenges & Constraints	Change
EGS1	Aug	M	N/C	L	N/C	H	N/C	L	N/C
	May	M		L		H		L	
EGS2	Aug	H	N/C	M	N/C	H	N/C	H	N/C
	May	H		M		H		H	
PE2	Aug	H	N/C	M	N/C	H	N/C	H	N/C
	May	H		M		H		H	
TM1	Aug	L	N/C	L	N/C	H	N/C	H	N/C
	May	L		L		H		H	
TM2	Aug	M	N/C	L	N/C	L	N/C	L	N/C
	May	M		L		L		L	
TM3	Aug	L	N/C	L	N/C	H	N/C	H	N/C
	May	L		L		H		H	
TM4	Aug	M	M to H	M	M to H	H	N/C	H	N/C
	May	H		H		H		H	
TM7	Aug	M	N/C	H	N/C	L	N/C	M	N/C
	May	M		H		L		M	
TM8	Aug	H	N/C	H	N/C	H	N/C	H	N/C
	May	H		H		H		H	
TM9	Aug	M	N/C	H	N/C	H	H to L	L	N/C
	May	M		H		L		L	
TM12	Aug	L	N/C	M	N/C	L	N/C	L	N/C
	May	L		M		L		L	
TM13	Aug	L	N/C	H	N/C	H	N/C	M	N/C
	May	L		H		H		M	

Table Key: N/C – No Change in Statement Codes H to L – High to Low Change in Statement Codes
M to H – Medium to High Change in Statement Codes

Of the total 48 potential longitudinal changes over the course of the study, three instances were noted and are highlighted in yellow on Table 12. The first two occur with TM4 and indicates a negative to positive change in perception of "Information Sources" and "Personalities". This individual had transitioned from dependence on an offsite functional manager to becoming thoroughly involved with site personnel and in fact, was transferring to construction for the follow-on phase of the project. This reflects his improved perception of both information sources and personalities (his new supervisor). The third occurrence of longitudinal change involved TM9, whose responses shifted from positive to negative concerning understanding the "Big Picture." This appeared to be the result of increasingly being forced

to deal with technical changes resulting from agency reviews and impositions resulting from construction as the project progressed.

For most individuals, the data indicates that no changes in the individual's basic attitude over the course of the eleven month interview period. These individuals represented both inexperienced and seasoned individuals, both male and female, both anticipation with staying with the project or imminently leaving. Their perceptions associated with variously big picture, information sources, constraints, or working relationships, simply did not change.

There are several conclusions that can be drawn from this data:

- First, changes in positive or negative perceptions do not occur spontaneously; they happened only when external structural drivers of change played into the project. For the one individual experiencing a positive change in perspective, this coincided with a job change that he had anticipated. For the individual experiencing a negative change, dealing with late impositions from reviewing agencies or construction prompted statements reflecting an increasing negative attitude.
- The project itself evolved and changed significantly; design was completing, some work activities were shifted as assignments drew to a close, and characteristics of deadlines shifted. For most individuals, this project evolution had little effect.

Limitations are associated with this longitudinal analysis. The results depicted in Table 12 may have been partially a function of time scales. The duration of the study was eleven months; the engineering activities for this project had at least another 9 months to completion. Had the study duration equaled the duration of the engineering effort, perhaps more evidence of perception change would have been apparent.

4.4 Summary

Based on the recorded and transcribed interviews, this verbal data was analyzed, using the work of previous researchers (Stacey, Cicmil, Levitt, and Chinowsky et al.) as a lens. The specific methodology employed was articulated by Miles and Huberman (2013, p. 84). This method directs the researcher to analyze for initial codes, then reformat these initial codes into pattern codes to find the best fit to explain the factors residing in the data.

Following three increasingly focused iterations of refining the potential codes from the data, the four codes were identified in Table 7. These included Contextual Understanding, Availability of Information, Responses to Challenges and Constraints, and Relationship with Supervisor.

The interaction of these codes is also important, and there were several, including the response to constraints and the contextual understanding of the project environment, the response to constraints and the relationship with the supervisor, the response to constraints and the availability of information, and finally, the relationship with the supervisor and information availability. The first three code alignments identified in Table 8 worked together in both the positive and negative sense that is a positive response to constraints accompanied the contextual understanding of the project and a negative response to constraints aligned with a lack of a contextual understanding. The evidence available for the last code interaction, the relationship with the supervisor and the availability of information only identified the positive aspect of the alignment.

Longitudinal changes in perspective, from this relatively small sample, indicated that change in attitudes resulted only from external changes imposed from outside the particular department.

The discussion of these Chapter 4 results, as well as, the Chapter 5 results will be provided in Chapter 6.

Chapter 5: Results - Quantitative Investigation

This chapter presents the results of the data analysis associated with the online surveys. As described in Chapter 3, the surveys were emailed to the study population, encompassing the entire engineering department, including all disciplines on the project, a total of three times over the duration of the field study, generally corresponding to the completion of each of the three sets of interviews. Based on performance differences identified by the Engineering Manager (Section 3.4.4), the quantitative analysis explored significant differences in the survey responses between the group that performed well and the group that performed poorly that could help account for the performance differences. Specifically the quantitative analysis addresses RQ2:

2. How do perceptions of project experience and interactions align with group performance?
    a. What differences exist between the group that performed well and the group that performed poorly at the beginning of the study?
    b. What differences exist between the group that performed well and the group that performed poorly at the end of the study?
    c. What changes occurred within the group that performed well from the beginning to the end of the study?
    d. What changes occurred within the group that performed poorly from the beginning to the end of the study?

To improve the clarity of the discussion, the group that performed well will be referred to as Group A. This is the group that met schedule, cost, and technical quality objectives. Similarly, the group that performed poorly will be referred to as Group B. This is the group that failed to meet schedule, cost, and technical objectives and whose managers and lead engineers were being replaced at the end of the study. These designations are summarized in the Table 13.

Table 13 Designation of Engineering Groups

Designation	Description
Group A	Performed well, meeting all schedule, cost, and technical quality requirements
Group B	Performed poorly, failing to meet schedule, cost, and technical quality requirements

5.1 Differences in Responses between the Group A and Group B

The results comparing the responses of the two groups of engineers for the first survey are presented in Table 14 and, for the final survey, in Table 15. There are several points to bear in mind when reviewing the tables:

- The primary evaluation for comparing the two sets of data was the Mann-Whitney Test and the associated p-value. Given that this is an exploratory investigation, the significance threshold utilized was a p-value of ≤ 0.20 (Frongillo, 2004), assuming a non-directional or single tailed analysis. Questions that yielded significant results from the Mann-Whitney tests are highlighted (pale yellow).
- The difference in mean values for each question are based on the mean score of the group that performed well minus the mean score of the group that performed poorly. This information is provided to indicate the direction of the changes between the two groups. For example, should the mean score of the Group A – mean score of the Group B be positive, this indicates that the mean score of the Group A was higher. Similarly, a negative difference would indicate that the mean score of the Group B was higher. The mean scores and the differences are absolute differences, taken directly from the raw survey data.
- Mann-Whitney tests were conducted on the original data set, so the p-values are independent of the mean score values in Table 14 and Table 15.
- Fourteen questions provided Likert-Type responses, with scores ranging from 5, indicating best condition to 1, indicating the worst condition.

Table 14 Comparison of the Group A and Group B Responses - Initial Survey

Survey Question	Topic	P-Value from Mann-Whitney Test	Group A Mean Score (n=19)	Group B Mean Score (n=22)	Difference in Mean Values (Group A - Group B)
3	Understanding of other disciplines functions and responsibilities	0.345	3.810	3.739	0.070
4	Understanding of other disciplines the constraints, resource needs, and information needs	0.352	3.300	3.478	-0.178
6	Level of preparation for meetings	0.009	3.429	4.087	-0.658
7	Extent to which other disciplines provide needed information	0.436	3.333	3.318	0.015
8	Quality of the information from other disciplines	0.271	3.333	3.522	-0.188
9	Timeliness of the information received	0.496	3.476	3.478	-0.002
10	Time available for work tasks	0.085	2.714	3.087	-0.373
12	Other team members attitudes	0.330	3.762	3.826	-0.064
15	Frequency of contact with Discipline Manager	0.405	3.500	3.545	-0.045
16	Decision making authority without input from Discipline Manager	0.181	3.500	3.250	0.250
17	Nature of the feedback do you get from Discipline Manager	0.363	3.450	3.636	-0.186
18	Characterization of interactions between Discipline Manager and Project Engineer	0.496	4.000	4.095	-0.095
21	Characterization of feedback on performance	0.421	3.737	3.864	-0.127
22	Degree of challenge by work	0.251	3.952	4.273	-0.320

Table 15 Comparison of the Group A and Group B Responses - Final Survey

Survey Question	**Topic**	P-Value from Mann-Whitney Test	**Group A Mean Score** (n=16)	**Group B Mean Score** (n=12)	**Difference in Mean Values (Group A – Group B)**
3	Understanding of other disciplines functions and responsibilities	0.227	4.235	4.500	-0.265
4	Understanding of other disciplines the constraints, resource needs, and information needs	0.071	3.647	4.214	-0.567
6	Level of preparation for meetings	0.413	3.412	3.429	-0.017
7	Extent to which other disciplines provide needed information	0.176	3.353	3.571	-0.218
8	Quality of the information from other disciplines	0.187	3.353	3.643	-0.289
9	Timeliness of the information received	0.436	3.353	3.357	-0.004
10	Time available for work tasks	0.492	2.706	2.714	-0.008
12	Other team members attitudes	0.345	3.706	3.500	0.206
15	Frequency of contact with Discipline Manager	0.095	4.400	4.231	0.169
16	Decision making authority without input from Discipline Manager	0.323	3.643	3.429	0.214
17	Nature of the feedback do you get from Discipline Manager	0.480	3.500	3.500	0.000
18	Characterization of interactions between Discipline Manager and Project Engineer	0.215	4.125	3.928	0.197
21	Characterization of feedback on performance	0.245	3.875	3.571	0.304
22	Degree of challenge by work	0.409	4.125	4.071	0.054

The following sections discuss the results of the survey analysis in more detail.

5.2 Differences between Groups - Significant Issues

This discussion focuses on the differences between Group A and Group B, comparing survey responses at the start and end of the eleven month study period and addresses RQ2a and b:

a. What differences exist between the group that performed well and the group that performed poorly at the beginning of the study?

b. What differences exist between the group that performed well and the group that performed poorly at the end of the study?

5.2.1 Initial Survey

At the time of the initial survey, the engineering on the project had been in progress for only a few months, so the start of the study almost coincided with the start of the engineering work. Three issues indicated statistical significance in the first survey, as indicated in Table 14.

The first of these three issues (Question 6) pertained to the extent of meeting preparation. Participants were asked, "How would you characterize the level of preparation for meetings?" This issue can potentially be an indicator of the early orientation of the organization. The differences in the mean scores shows that Group B felt that they were better prepared for their meetings. The responses selected for this question ranged from 5 = "All team members are always well prepared" to 1 = "Most team members are generally not prepared." There was a significant difference in the responses of the two groups at a p = 0.009 level. The mean score for Group A was 3.429 and for Group B, 4.087, indicating that Group B perceived that they were better prepared for meetings.

The second issue (Question 10) addressed the time available to perform work activities and reflects the perceptions of production and schedule pressures early in the project. The participants were asked "How would you characterize the time available for you to meet your own deliverables?" Group B felt that they had more time to complete their work than did Group A. Responses were scaled from 5 = "I always have plenty of time to complete my work," to 1 = "I rarely have enough time…" and resulted in a significance at a p = 0.085 level. During the initial survey, the perceptions of Group B (mean score = 3.087), relative to Group A (mean score = 2.714), indicated that they believed they had more time to complete their work tasks.

Finally, perceptions concerning the ability and authority to make decisions (Question 16) differed between the two groups at the beginning of the project. Participants were asked "How would you characterize your ability to make decisions or commitments in the drawing package development meetings without input from your EGS? Responses were scaled from 5 = "I am free to make all decisions at the team level." to 2 = "I need to defer most decisions/commitments to my functional manager and was significant at a p = 0.181 level. The mean score of Group A = 3.500 and Group B mean score = 3.250, indicating that Group A sensed that they had a broader remit to make decisions concerning design issues than did Group B. The ability to make decisions at the beginning of the study period represented a significant difference between the groups, indicating that Group A sensed greater decision making authority.

By the end of the study period none of these three areas remained a significant as a difference between the two groups.

5.2.2 Final Survey

By the end of the study period, 11 months later, the engineering stage of the project was well along and the organization had matured, producing design and beginning to issue the initial design packages to the field. At this point in time, four issues, indicated in Table 15, now separated the well and poorly performing groups' perceptions none of which coincide with the areas of difference in the initial survey.

The first of these issues had to do with the understanding of the constraints and needs of other disciplines within the engineering organization (Question 4). Participants were asked "How well do you feel you understand the constraints, resource needs, and information needs of the other disciplines?" Responses varied from 5 = I understand the constraints and needs of all team members very well to 1 = I'm not at all familiar with the constraints and needs of other team members. By the end of the study period, Group B felt that they had a better understanding of the constraints and needs of other organizations. These responses reflect a significant difference in the two groups at a level of $p = 0.071$. The mean score for Group A was 3.647 and for Group B, 4.214, meaning that Group B felt that they had a better understanding of other disciplines' constraints. In general, it is reasonable that an improved understanding of the larger organization would develop, having interacted with the larger organization for the previous eleven months. What is not clear is that this effect would be focused on Group B differentially from Group A.

The second difference in perceptions had to do with the extent to which other disciplines supplied needed information (Question 7). Participants were asked "To what extent do other disciplines provide you with the information you need?" By the end of the study period, Group B believed that they were supplied needed information more so than Group A, significant at a level of $p = 0.176$. Responses were scaled from 5 = Always to 1 = Infrequently. Group A raw score was 3.353 and the corresponding Group B score 3.571, indicating that Group B of engineers believed that they received better information from other disciplines.

The third difference in perceptions concerned the quality of information from other disciplines. Participants were asked "How would you describe the quality of the information you receive from other disciplines?" Responses were scaled from 5 = Highly reliable; I can use it immediately and trust its accuracy to 1 = Generally unreliable; I do not use the information obtains from team members but instead seek it elsewhere or work without it. At the end of the study, Group B perceived that they received higher quality of information that did Group A, significant at a level of $p = 0.187$. Group A raw

score was 3.353 and the corresponding Group B score 3.643, indicating that Group B believed that they received better information from other disciplines.

The final difference between the Group A and Group B at the end of the survey had to do with the frequency of contact with their supervisor (Question 15). The participants were asked, "How frequently do you interact with your EGS regarding the drawing package development? Responses varied from 5 = Daily to 1 = Occasionally or sporadically. Group A mean score was 4.400 and Group B mean score was 4.231, indicating that Group A believed that they experienced more frequent contact with their supervisor.

Note that none of the significant differences between the two teams at the end of the study were significant at the beginning of the study.

5.2.3 Summary: Differences between Groups

In summary, Group A started the engineering phase reporting that relatively, they were well aware of schedule pressure, had more decision making authority and importantly, and by the end of the study, experienced significantly more frequent contact with their supervision than did Group B. Group B, on the other hand, initially believed that they had time to complete their work and were better prepared for meetings. By the end of the study, Group B met with their supervision less than weekly, but reported that they understood other disciplines and received more and higher quality information from other disciplines than did Group A.

5.3 Intra-Group Differences

In addition to a comparison between the Group A and Group B against each other, the survey responses of each group was compared with itself, contrasting the responses at the beginning and end of the survey period. This addresses RQ2c and d:

c. What changes occurred within the group that performed well from the beginning to the end of the study?
d. What changes occurred within the group that performed poorly from the beginning to the end of the study?

The comparison of Group A responses at the beginning and end of the study period is presented in Table 16, with the same comparison for Group B presented in Table 17. The points to bear in mind when reviewing these tables are reiterated here for clarity:

- The primary evaluation for comparing the two sets of data was the Mann-Whitney Test and the associated p-value ≤ 0.20 (Frongillo, 2004). Questions which yielded significant differences are highlighted (pale yellow).

- The mean values for each question are based on the final survey mean score – initial survey mean score. This information is provided to indicate the direction of the changes between the initial and final time period. The mean scores and the differences are absolute differences, taken directly from the raw survey data.
- Mann-Whitney tests were conducted on the original data set, so the p-values are independent of the mean score values.
- Fifteen questions provided Likert-Type responses, with scores ranging from 1, indicating the worst of least strenuous condition to 5, indicating best or most strenuous condition.

5.3.1 Group A

Presented in Table 16 is a comparison of Group A responses between the first and third surveys.

Table 16 Significant Differences in Group A between the First and Third Surveys

Survey Question	Topic	P-Value from Mann-Whitney Test	Group A Mean Score – First Survey (n=19)	Group A Mean Score– Last Survey (n=16)	Difference in Mean Values (Last – First Score)
3	Understanding of other disciplines functions and responsibilities	0.075	3.810	4.235	0.426
4	Understanding of other disciplines the constraints, resource needs, and information needs	0.181	3.300	3.647	0.347
6	Level of preparation for meetings	0.488	3.429	3.412	-0.017
7	Extent to which other disciplines provide needed information	0.440	3.333	3.353	0.020
8	Quality of the information from other disciplines	0.429	3.333	3.353	0.020
9	Timeliness of the information received	0.429	3.476	3.353	-0.123
10	Time available for work tasks	0.496	2.714	2.706	-0.008
12	Other team members attitudes	0.417	3.762	3.706	-0.056
15	Frequency of contact with Discipline Manager	0.048	3.500	4.400	0.900
16	Decision making authority without input from Discipline Manager	0.356	3.500	3.643	0.143
17	Nature of the feedback do you get from Discipline Manager	0.460	3.450	3.500	0.050

Survey Question	Topic	P-Value from Mann-Whitney Test	Group A Mean Score – First Survey (n=19)	Group A Mean Score– Last Survey (n=16)	Difference in Mean Values (Last – First Score)
18	Characterization of interactions between Discipline Manager and Project Engineer	0.382	4.000	4.125	0.125
21	Characterization of feedback on performance	0.488	3.737	3.875	0.138
22	Degree of challenge by work	0.227	3.952	4.125	0.173

As Table 16 indicates, significant differences between the initial and final surveys occurred in three areas. The first and second issues has to do with Group As' understanding of other disciplines (Questions 3 & 4). In Question 3, the participants were asked "How well do you feel you understand the functions and responsibilities of the other engineering groups and in Question 4, "How well do you feel you understand the constraints, resource needs, and information needs of other engineering groups?" As indicated in the responses to both questions, Group A increased their understanding of other disciplines' functions and responsibilities as well as the understanding of the constraints, resource needs, and information. Changes in Questions 3 & 4 were significant to a p =0.075 and p = 0.181 level respectively. The scores ranged from 5 = very well, to 1 = I am not at all familiar. The positive mean score differences, 0.426 and 0.347, for Questions 3 & 4 indicate that Group A reported an increase in their understanding. This is reasonable; having spent the previous eleven months working and interacting with other disciplines within the organization, their familiarity and understanding of their interfacing groups would have been expected to increase.

The third issue that indicated significant change was the frequency of contact with their supervisor (Question 15). The participants were asked "How frequently do you interact with your EGS regarding the drawing package development?" Responses were scaled from 5 = Daily to 1 = Occasionally or sporadically. This issue was significant to a level of p = 0.048 and indicated a positive difference in the mean scores of 0.900, which indicates that the frequency increased over the course of the study.

Bearing in mind the differing performances of the well and poorly performing groups, this issue is strongly aligned with the successful execution of Group A. Not only did Group A start the study with more frequent contact with their supervisor, than did Group B, but the frequency of contact between Group A and their manager significantly increased over the course of the survey.

5.3.2 Group B

Table 17 presents the comparison of Group B between the first and third surveys. As Table 16 indicates, Group B responses indicated significant differences between the initial and final surveys occurred in seven areas.

Table 17 Significant Differences in Group B between the First and Third Surveys

Survey Question	Topic	P-Value from Mann-Whitney Test	Group B Mean Score – First Survey (n=22)	Group B Mean Score – Last Survey (n=12)	Difference in Mean Values (Last - First Score)
3	Understanding of other disciplines functions and responsibilities	0.016	3.739	4.500	0.761
4	Understanding of other disciplines the constraints, resource needs, and information needs	0.037	3.478	4.214	0.736
6	Level of preparation for meetings	0.087	4.087	3.429	-0.658
7	Extent to which other disciplines provide needed information	0.145	3.318	3.571	0.253
8	Quality of the information from other disciplines	0.448	3.522	3.643	0.121
9	Timeliness of the information received	0.425	3.478	3.357	-0.121
10	Time available for work tasks	0.054	3.087	2.714	-0.373
12	Other team members attitudes	0.166	3.826	3.500	-0.326
15	Frequency of contact with Discipline Manager	0.348	3.545	4.231	0.686
16	Decision making authority without input from Discipline Manager	0.291	3.643	3.429	-0.214
17	Nature of the feedback do you get from Discipline Manager	0.345	3.500	3.500	0.000
18	Characterization of interactions between Discipline Manager and Project Engineer	0.093	4.095	3.928	-0.167
21	Characterization of feedback on performance	0.375	3.864	3.571	-0.293
22	Degree of challenge by work	0.274	4.273	4.071	-0.202

The first and second of these areas were about the depth of understanding of other disciplines and their response parallels the experience reported by Group A, in that both increased. In Questions 3 and 4, the participants were asked "How well do you feel you understand the functions and responsibilities of the other engineering groups?" and "How well do you feel you understand the constraints, resource needs, and information needs of other engineering groups?" The responses were scaled from 5 = I understand…very well to 1 = I am not at all familiar… These responses were significant to a level of p = 0.016 and 0.037 for Questions 3 & 4. The positive difference in mean scores, 0.761 for Question 3 and 0.736 for Question 4 indicate that Group B increased their understanding of the other disciplines over the course of the study. This is reasonable and reflects the eleven month period of working and interfacing with other disciplines and learning how the other organizations function.

The third area that indicated change reported by Group B was meeting preparations (Question 6). The question was "How would you characterize the level of preparation for meetings?" and responses varied from 5 = "All team members are always well prepared" to 1 = "Most team members are generally not well-prepared" with the change significant, at a level of p = 0.087. However, the direction of the change is interesting. Group B felt that they were better prepared at the beginning of the study than at the end (negative difference in mean scores = -0.658). By the end of the study, Group B reported spending no more time than Group A on meeting preparations.

Another area in which Group B reported a changes had to do with the information they received from other disciplines (Question 7). The survey question was phrased "To what extent do other engineering groups provide you with the information you need?" with responses ranging from 5 = Always to 1 = Infrequently and were significant at a p = 0.145 level. The direction of the change was positive (0.253) indicating that by the end of the survey, Group B engineers felt that information provided by others was improving.

Group B reported a change in their perceptions about time available for work tasks (Question 10). The participants were asked "How would you characterize the time available for you to meet your own deliverables?" The changes in Group B responses from the first to the third survey for this issue were significant to a level of p = 0.054. Scoring varied from 5 = "I always have plenty of time to complete my work" to 1 = "I rarely have enough time to meet the deadlines on my deliverables without extensive overtime." The direction of the change is negative (-0.373), indicating that Group B sensed that they had less time for producing their work at the end of the study period. This sense of increasing time pressure is also reasonable given that by the last survey, this group was well behind in the development of the design documents, under increasing pressure to produce the design.

The sixth area in which Group B reported change reflected their perception of their team's attitudes (Question 12). The question asked was "How would you characterize team members' attitudes?" and the responses indicated that these attitudes deteriorated over the course of the study. Reponses ranged from 5 = "Everyone has a strong positive attitude" to 1 = "No one has a positive attitude." The differences in the responses were significant to a level of $p = 0.166$, with a negative direction (-0.326), indicating that the perceptions of Group B were becoming increasingly negative. This may be a reflection of the pressure and tensions mounting as design progress continued to flag.

The final issue in which Group B reported a significant change addressed the relationship between the managers in the matriced organization (Question 18). The participants were asked "How would you characterize interactions between your Drawing Package Team Leader (Project Engineer) and your EGS (Discipline Manager)?" As described in Chapter 3, the engineering population existed inside a matrix organization. Each engineer had two supervisors. The primary supervisor, the Discipline Manager, represented the discipline expertise and technical acceptability. This individual directed and monitored the individual engineer, as tasks were assigned, worked, and then approved. The Discipline Manager sealed the design and was responsible for its technical content. The Project Engineer was responsible for integrating designs across groups, schedule, and reporting design completion dates to construction. The relationship between these two individuals provides a window (via Questions18 responses) into how well the two interests of the discipline design production and schedule integration aligned.

Responses to this question were scaled from 5 = "Smooth, no conflicts" to 1 = "Frequent conflict". By the end of the study, Group B of engineers reported a significant change ($p = 0.093$) in their perceptions of the interactions between their two matriced supervisors. The negative direction of the change (-0.167) indicated that Group B perceived a deterioration of the matriced managers' relationship over the course of the study. This deterioration very likely reflected the increasing strain between the Discipline Manager and the Project Engineer.

This significant difference in responses at the end of the study period provides an insight into the performance variation between the two groups. At the beginning of the project, no history had developed between the Discipline Manager and the Project Engineer. By the end of the study, the Project Engineer relying on the Group B Discipline Manager would have been in a difficult position. He would have been responsible for design production, in a situation where the design was badly behind schedule and portended potential delays to construction. Group B, in the matriced organization, witnessed and reported the deteriorating nature of their managers' interactions.

5.3.3 Summary: Intra Group Differences

Both groups reported that their understanding of other disciplines increased over the course of the study (Questions 3 & 4). This change would be expected, given the eleven months of working with other disciplines that occurred between the survey time periods.

The most significant change to the Group A environment over the course of the study is the increase in contact with supervision (Question 15) and reflects a step change both within Group A and in comparison with Group B. Recall that over the course of the study, one significant difference between the two groups was that by the end of the study period, Group A experienced more contact with their supervision than did Group B.

At the same time, there is minimal change in the perceptions of Group A concerning the time available to perform work tasks (Question 10). Group A initially reported and then, maintained scores indicating that they were well aware of the production and time pressures.

The responses of Group B indicate several changes that appear to align with performance. Their sense of time and schedule pressure increased over the course of the study (Question 10) and their reported decrease in overall team attitude over the course of the study (Question 12). At the same time, Group B also reported increasing tensions and a deteriorating relationship between the Group B Discipline Manager and the Project Engineer (Question 18).

5.4 Summary

The research questions associated with the quantitative study were designed to identify differences in the survey responses differentiating Group A and Group B. Knowing the differences in the Group A and Group B, how might the differences in their respective responses inform this study about issues that were important to them and impacted their performance?

To analyze the survey data, four Mann-Whitney nonparametric analyses were performed, each addressing one of the research questions. In addition to comparing the differences in the responses between the Group A and Group B at the beginning and end of the study, each group was examined individually for changes from the start to the end of the study. The results of the analyses indicate that Group A started their engineering work feeling more schedule and production pressure, than did Group B. They also reported experiencing more frequent contact with their supervision. Not only did Group A start the study experiencing more frequent contact with their supervision, the level of contact increased over the study period, shifting from weekly to several times a week, as the design was maturing. In addition, Group A reported more empowerment to make design decisions. This may reflect the relatively frequent contact with supervision, during which, such decisions, as well as general direction would be discussed.

Group B reported a somewhat different picture. They indicated that they initially had more time to complete design tasks than did Group A and met less frequently with their supervision, between weekly and occasionally. Significant changes over the course of the study included a decrease in reported time to complete tasks and degradation of the attitudes of the team. These two changes coincided with Group B falling increasingly behind in their deliverable schedule and experiencing increasing pressure to produce. An additional significant change to Group B perceptions was their reporting of the degradation of the relationship between the Group B Discipline Manager and the Project Engineer. These two managers are complementary and rely heavily on each other. Group Bs' failure to produce designs in a timely manner would have aggravated the relationship between these two managers. This aggravation was noted and reported by Group B in their survey responses.

It should be noted that both groups significantly increased their understanding of other disciplines responsibilities, constraints and needs. This is reasonable given that both groups had spent the previous eleven months interfacing with other elements of the organization; their understanding of the big picture, a qualitative issue, had improved and was reported in both organizations.

Chapter 6: Discussion of Results

This chapter situates the investigation results presented in Chapters 4 & 5, with previous research presented in Chapter 2, in the context of the research questions. One element that strengthens the findings of both the qualitative and quantitative investigations is that the results of each strongly reinforced each other; that is, the findings triangulated. Because of the strength of the triangulation, the basis of this chapter's discussion will be Table 18, which itemizes the triangulated findings. The triangulated findings correspond to those issues established as important during the qualitative analysis and those issues determined to be significant during the quantitative analysis.

Table 18 Triangulated Findings from the Qualitative and Quantitative Investigations

Qualitative Factors	Quantitative Factors
Information availability	Information from other disciplines
Relationship with supervisor	Frequency of contact with supervision
	Decision making authority
	Interactions between matriced managers
Understanding the big picture	Understanding other disciplines
Response to constraints	Time to perform work activities

Specifically, this chapter relates, compares, or extends the pertinent issues developed in the literature review (Chapter 2).

6.1 Introduction

As described in Chapter 3, the qualitative study identified the critical factors associated with individual's experience of the project. Four factors emerged (see Table 18) and pattern analysis showed strong links between them. The discussion that follows is based on the model presented in Figure 5.

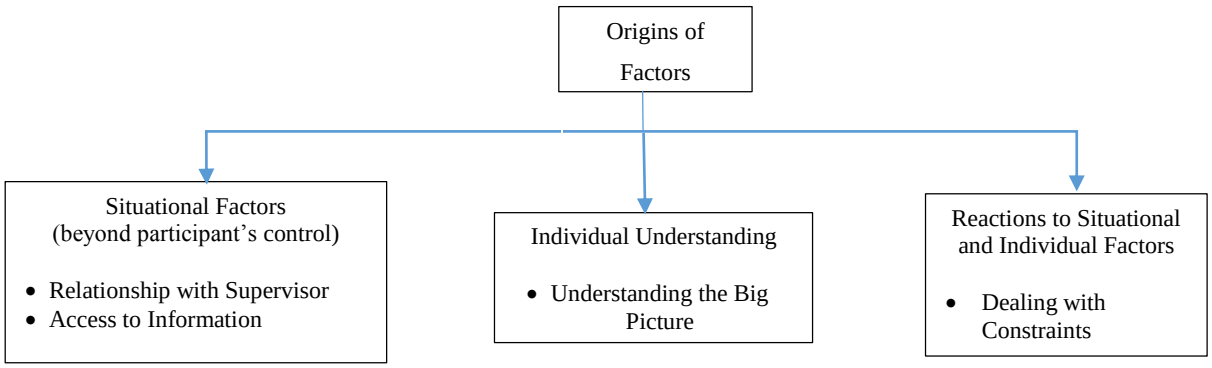

Figure 5 Factor Interaction Model

6.2 Relationship with Supervisor and Availability of Information

Two factors represented elements of the project environment that depended on the setting in which the individual found themselves. These were the Relationship with the Supervisor and Access to Information and represented situational conditions that the individual had little control over. In this sense, they were inputs from the project environment to the individual. The relationship with the supervisor, in particular, provoked very clear statements from the participants. In a positive sense, participants expressed the characteristics of the supervisor to be trusting, helpful, open minded, appreciative, a good listener, communicative, and being willing and able to sit down and discuss details of design issues. These traits were expressed unambiguously, and interactions with the leader were always pleasant. On the other hand, the interviewees also expressed negative reactions to some supervisors, describing them as micromanaging, distrusting, repeatedly checking and directing work details and progress, and harassing for immediate results.

The quantitative analysis also identified several issues associated with the supervisor as significant differentiators between the two groups of engineers. The frequency of contact with supervision was potentially the most critical. Group A experienced significantly more contact with their supervision than did Group B, which aligned with their differing performances. A second supervisor related issue is that initially, Group A reported more authority to make decisions about their work tasks than did Group B, possibly allowing them to become productive more quickly. Finally, as Group B slid increasingly behind schedule, they reported open disagreements between their project engineer and their discipline manager, presumably as the result of the progressive schedule slippage.

The positive characteristics of this supervisory element aligned well with the literature review provided in Chapter 2. The successful manager was described by Maihotra et al. (2001) as handling dissonance in a manner that maintains trust and respect for team members. Providing direction and a

forum conducive to collaboration was identified by Barczak et al. (2006) and Bakar et al. (2011). Further, Muller and Turner (2010) investigated issues at the intersection of emotional intelligence and intellectual competency and established that critical thinking (intellectual competency) and influence, motivation, and conscientiousness (emotional competencies) were present in successful managers. The characteristics identified in the interview statements dovetail with these previous findings: communicative, collaborative, and able to sit and discuss details with subordinates. In addition to aligning with previous research, however, this investigation extends previous investigations in that the connection between the availability of information and the relationship with the supervisor is established. First, individuals in search of information in this investigation turned to other individuals, rather than documents, written records, or other media to obtain needed information. Usually, the individual was the supervisor, provided the supervisor was amenable to discussion with the subordinate. The connection between a positive relationship with the supervisor and the availability of information, therefore, is logical but not well developed in the literature. This provides a potentially new element that describes the daily life of the project participant. Second, another element of this aspect of information availability and the relationship with the supervisor emerges from the quantitative analysis in which the frequency of contact with the supervisor was identified as a significant differentiator between the successful Group A and poorly performing Group B. This relationship between factors appears to be a new alignment, and may be associated with the differing performances of the engineering groups.

Further insight was gained about the availability of information from the interview data. Several of the literature review topics intersecting this factor were represented in statements by the participants. The statements made by the participants indicated that availability of information either was provided by a senior staff member or alternately, plagued the participant, in that they could not access information and decisions. The interesting note is information sources were typically other project individuals, not written, network, or internet documentation. This supports Stacey' (2009) suggestion that knowledge is not contained in the written and codified records of an organization; these are only tools that may facilitate person-interactions. Similarly, Senaratne and Sexton (2008) established that knowledge flows rely heavily on tacit knowledge and person-to-person contacts between project participants. In the study, individuals talked about the discussion with the project engineer, the discipline manager, or at times, individuals in other departments, to get their input. This reflects a broader issue associated with knowledge transfer. Usoro et al. (2007) described knowledge transfer as a process in which information is provided to a recipient, who then localizes, interprets, and adapts the knowledge in terms of their own experience.

This information availability issue also layers into the formation of networks within the project. In the words of Larsson (2007), knowing who to know and trust are essential elements of the project

dynamic. Chinowsky employed advanced network theory to understand interactions at play within networks. In the words of (Chinowsky et al., 2008), networks allow the individual to quickly mobilize and resolve unexpected problems, leading to improved collaboration. Successfully accessing information relied heavily on knowing who and the availability of people with whom to speak.

The negative reflection of this information availability issue was stated by individuals who could not get access to decisions to finalize planning or design elements. This reflects a process issue in the terms of the literature review, in which the flow of information was ineffective and became blocked by either the project processes or poor communication between individuals. Not being able to engage the broader network or having access to those who might resolve problems provided a source of frustration to individuals trying to resolve interdisciplinary problems.

The quantitative analysis indicated that one aspect of information availability differentiated the two groups. Group B reported that they received higher quality and more timely information from other disciplines. This is likely a timing issue. On a project such as this, Group A will tend to finish their design work first. When they need information from other disciplines, often the information needed is still being developed, so they must make assumptions that require back-checking later. For the Group B, much of the information that they incorporate into their designs would have been developed.

In summary, the relationship with the supervisor, as well as the access to needed information were important factors to the individuals on the project. Both represent influences from outside the sphere of influence that the individual could control. They therefore represent inputs from the organization to the environment of the individual participant.

6.3 Understanding the Project Context

Understanding the Project Context represents a characteristic that resides within the perspective of the individuals interviewed. Whether this understanding was the result of native intelligence, maturity, or experience, a number of individuals demonstrated a characteristic that enabled them to understand (or not) the broader project context. Stated generally, these individuals understood the world of the project and how it worked. Their statements corresponded to expressing how their work sequentially integrated technically with other disciplines, identifying how issues for which the individual was personally responsible were important to the project, or understanding how interpersonal issues would likely play out. However they were stated, the individual who understood the project context articulated a clear perception of project operations and the part that their participation played in those operations. These individuals could envision and anticipate outcomes and future developments. Conversely, several project participants made statements indicating that they did not understand the world beyond their immediate work activities. These individuals made statements indicating that they were less experienced and did not

understand the project processes. As a result, they could not anticipate likely outcomes of events and interactions. On several occasions, they stated that they understood little outside their immediate work group.

However, this characteristic of understanding the larger project context was not fixed. Both engineering groups reported significantly increasing their understanding of other disciplines over the eleven month course of the study. This indicates that this personal characteristic of understanding the larger project context was changeable; experience modified it. This increasing understanding is reasonable, since both groups had spent the previous eleven months working with other groups within the project.

Understanding the big picture, while not directly addressed in prior research, layers into several dimensions identified in the literature review. For example, communication and knowledge transfer represent elements that impact the understanding of the big picture. Javernick-Will and Scott (2010) linked the issues of knowledge sharing and interpersonal dynamics, and in so doing potentially identified two precursors of understanding the big picture. Success at both knowledge sharing and interpersonal dynamics could support a foundation for understanding the larger context. In another study, Chinowsky et al. (2008) considered shared values as essential to successful team performance. Understanding shared values and common project objectives intersects with improved perceptions of the big picture. Finally, work by Macht et al. (2013) correlated emotional intelligence and personality traits and identified the alignment of personality factors, such as extraversion to emotional intelligence scales in successful project managers. Emotional intelligence and extraversion are characteristics that could support an individual being able to perceive the big picture. Salas et al. (2008) discussed the need to building shared models of the team environment, task, and interactions to improve team performance. This shared model becomes the basis of each team member's perspective and provides context for understanding the big picture. Van den Bossche et al. (2006) argues that integrating both the cognitive and social factors was necessary to understand the development a common perspective.

Understanding the larger project context is a characteristic that can be modified over time, with experience, as demonstrated by both groups reporting improved understanding of other disciplines over time. The point here is that that understanding the project context can be modified and changed, potentially for the betterment of the project performance. Therefore, this study extends previous research and presents an opportunity for exploration and verification in further studies.

6.4 Dealing with Constraints

In the qualitative data analysis, the connection between understanding the big picture and dealing positively with constraints was clear and strong. Understanding the big picture enabled the participant to

deal with the many constraints permeating the complex project with a positive approach. Further, the model represented in Figure 5 suggests that the mode of dealing with constraints may be an outcome based on the situational conditions of the relationship with the supervisor and the access to needed information acting on the an individual's inherent personal characteristics. Individuals that dealt successfully with constraints could explain the constraint, why it was necessary, and/or how they managed and dealt with the constraint. Individuals that did not deal effectively with constraints complained repeatedly and provided no indication that they had an understanding of the constraint or a method of dealing with it.

The quantitative analysis identified one significant difference between the two groups of engineers associated with time constraints. Group A started the project reporting that they had significantly less time to produce their designs, than did Group B. The fact that the Discipline Manager of Group A started each week with task assignments for his staff, was established in the interview data. Even if a design submittal date was weeks away, this manager would issue interim objectives. This appears to have contributed to this group of engineers finishing on schedule, unlike their poorly performing counterparts in Group B.

As with the understanding the big picture, dealing with constraints is not directly referenced in the literature review. However, several issues that emerged in the literature review weave into the ability to deal with constraints. One, the formation of networks, may facilitate dealing with constraints in that they provide a mechanism to negotiate issues that may arise in the project. The activation of networks enables the project to address tasks quickly when unexpected problems arise (Chinowsky et al., 2008). Along similar lines of reasoning, Larsson's (2007) work identified the importance of knowing "who to know" as well as the importance of social networking in completing critical tasks. Networking, therefore, would provide an avenue to handle constraints and issues that confront individuals. Taking a somewhat different direction, several researchers addressed effective knowledge transfer, which may also facilitate dealing with constraints. Knowledge transfer is essential in developing and progressing the project and has been highlighted by Javernick-Will and Scott (2010), McNair et al. (2010), and Stacey (2009). Social interaction also ties to the investigation by Macht et al. (2013) of the intersection of emotional intelligence and personality traits. Macht et al. identified extraversion as a critical trait that aligns with emotional intelligence scales in successful managers.

This research directly connects the ability to deal with constraints with the understanding of the big picture. As described above, these issues are obliquely woven into issues surrounding dealing with constraints and the big picture, but not directly connected in the literature. This connection between dealing with constraints and understanding the big picture represents a potential opportunity to further investigate the between these two aspects of life on the project.

In summary then, sociability, networking, and effective knowledge all potentially contribute dealing positively with constraints. Previous research directions did not appear to directly relate to dealing with constraints, although some elements clearly impact handling restraints. Therefore, this study extends the work of previous investigators in new directions, in the identification and development of dealing with constraints as a factor that is important to individuals in the project setting. Further exploration in subsequent studies may confirm this finding and provide opportunity for continued research.

6.5 Summary

The four factors determined by this study to be important to project participants include two situational factors, including relationship with the supervisor and availability of information, one factor that represented a characteristic of the participant, understanding the big picture, and one factor that is a response, which was response to constraints. Each of the qualitative factors triangulated with at least one issue established during the quantitative analysis. The situational factors confirm elements found in the literature review and extend those elements by applying them to this design-build case study. The remaining two factors, understanding the big picture and response to constraints, were not well developed in the literature, but were obliquely supported by previous research. Understanding the big picture and response to constraints, therefore, extend previous research into new directions concerning participant interactions and the as-lived experiences of project life.

Chapter 7: Conclusions & Recommendations

7.1 Conclusions

The conclusions associated with this dissertation track directly with the four factors determined in the qualitative analysis to be important to project participants. The response to constraints was the most prolific issue to which the interviewees responded. This factor was determined to be important to the individual participants and interacted with all other factors developed in the analysis based on participant statements; access to information, relationship with the supervisor, and understanding the big picture. In addition, quantitative elements associated with these four factors were identified as significant, based on the survey responses.

First, the availability of information needed to perform work tasks was important to the project participants. The information sources cited were other people within the organization, sometimes, but not always, the supervisor. The availability of information aligned directly with two other factors, the relationship with the supervisor and the response to constraints. This relationship is reasonable and also emerged from the coded interview data. From the quantitative data, the timeliness and quality of the data from other groups emerged as a significant differentiator between the two groups of engineering groups. This appears to be a matter of timing. Group A, which finished their design early in the process, reported that information from other groups was relatively unavailable. Group B, completing their design later, would have benefited from the activities and design work from earlier groups that had completed their work.

The relationship with the supervisor was a second factor that emerged from the analysis of the interview data as important to the project participants. A positive relationship with the supervisor aligned with a positive response to constraints. Like the availability of information, the relationship with the supervisor represented a situational condition, in that it was out of the individual's control. The quantitative data indicated that both the frequency of contact with the supervisor and decision making authority were significant differentiators between the successful Group A and unsuccessful Group B. One other significant difference between the two engineering groups was the interactions between the matriced managers, with this interaction becoming increasingly negative for Group B. The matriced managers are complementary; when one of these managers underperforms, it places the other in an increasingly awkward position. The declining relationship between the two managers of Group B's was noticed and recorded.

A third factor determined to be important to the project participant was the understanding of the big picture. This characteristic allowed the individual to understand how the project elements interacted and how their individual efforts fit into the larger project context. This characteristic was inherent in the individual, whether it developed from maturity, emotional intelligence, or reflecting on experience. The quantitative analysis indicated that the understanding the needs, constraints, and responsibilities of other disciplines significantly increased in both engineering groups, over the course of the study.

Finally, the response to constraints was the final factor that emerged as important to the project participants. A positive response to constraints occurred when the individual understood or accepted the constraint, and made provisions for them in their work planning, creating a smoother interface between the individual and their working environment. An individual resisting constraints resulted in a refusal to accept or understand the constraint and a stated reluctance to accommodate the constraint. The response to constraints aligned positively with contextual understanding, the relationship with the supervisor, and the availability of information in the statements by the interviewees. The converse, a negative alignment between these factors was also present in the statements by the project participants. One constraint in particular, the time available to perform work tasks, emerged as a significant differentiator in the quantitative analysis.

These four factors, availability of information, the relationship with the supervisor, contextual understanding, and the response to constraints represent the four factors emerging from the qualitative analysis. Each triangulated with issues that emerged as significant differentiators between the successful and unsuccessful engineering groups in the quantitative findings.

7.2 Recommendations

This chapter provides recommends for development associated with future academic investigation as well as implementation suggestions for industry projects. Each is discussed in the sections that follow.

7.2.1 Academic Research Recommendations

Given that this investigation was exploratory in nature, the research questions, data, analysis, and results are intended to provide broad directional information that may potentially focus future investigations of teaming issues within the study of design and construction organizations. In addition, other types of projects, industries, or fields of interest may be subject to the similar teaming issues associated with interpersonal interactions. That is, there will be other settings for which the results are transferrable, such as within owner organizations, or owner-contractor relationships.

The study was a concurrent mixed methods investigation, consisting of qualitative and quantitative elements. Further refinement is possible in each type of method, and the potential future investigative directions are presented for consideration below.

Future Qualitative Investigative Directions

The qualitative investigation of this design-build infrastructure project consisted of three elements; identification of codes, determination of code interactions, and understanding of longitudinal changes evident in the study population. The codes identified in this case study included understanding the big picture, availability of information, dealing with constraints, and relationships with supervisors. There may be other codes worth considering, or possibly, the focus of each of these codes deserve to be sharpened. For example, dealing with constraints and challenges dominated the discussion in the statements made by the project participants. This code might be segmented, expanding into two or more codes, for example, internal and external challenges, or perhaps people driven and system driven constraints. In the same manner, the code associated with information availability might be expanded to examine sources within and outside the individual's department, or within and outside the project. Each of the codes established by this exploratory investigation may involve additional controversy or complications.

In addition to sharpening and focusing the codes associated with this research setting, the design-build infrastructure project, many other types of projects could be investigated for either transferability of the findings developed with this study or the development of additional codes that might apply to other research settings. The spectrum for additional types of projects is extremely broad, from other types of civil engineering projects, to projects associated with alternate engineering disciplines, to new product development endeavors, and to projects outside the engineering domain. The overarching research direction for each of these potential investigations would be to understand the personal interactions and reactions to the social dimensions affecting those projects. Finally, there may be a connection between long lasting and complex projects and applicability of social issues. This direction might provide information as to when social issues need particular attention.

Future Quantitative Investigative Directions

Quantitative investigations of each of the alternative research sites addressed in the preceding sections offer the potential to expand understanding of interpersonal interactions via the collection of survey data. A possible starting point for follow up investigations would be those areas for which the responses from this study population were determined to be significant. This would include further detail about the frequency and character of contact with the supervisor, the time available to perform work activities, decision making authority, understanding the big picture, and managerial relationships within

the organization. There may be other significant issues affecting the surveyed population, particularly on different research sites. Finally, as with the potential qualitative research investigations, there may be a time element or specific type of project associated with the social dimension for which social issues are particularly critical.

Future Opportunities

The information emerging from this study has the potential to be developed into a checklist or survey for use by project management on the indicators that could potentially impact the performance and perceptions of the project personnel. Relationships between supervisors and subordinates, as well as the frequency of that contact, the availability of information within the project structure, the understanding of the big picture, and response to and understanding of constraints are issues that, should the manager have insight into these issues, would provide those managers with an indication of the perceptions of project participants, and possibly anticipate the level of their performance. These surveys might be provided periodically over the course of the project. Even though individual participants might change over a long project duration, the information might prove useful to those who are managing at the time.

7.2.2 Industry Implementation Recommendations

Given that this case study was an exploratory investigation, the intent was to understand the broader brush of intrapersonal issues that impact the individual's lived experiences on large complex projects. In addition to this specific project type, the findings from this exploratory investigation might apply to many large complex organizations, given that people are the participants and their interactions are founded in human nature and their intent to understand their environment. Specifically, project managers can take a cue from the list of issues that have been established as important to the project participants. The top of the list, because it is at least partially controllable by the project manager is the understanding of the big picture. This study has demonstrated that improvements in this domain will broaden the project participants' acceptance of constraints. Project managers should ensure that all participants have an understanding of the big picture and how their work fits into this picture. Constraints and challenges on large complex project are ubiquitous and unavoidable on a large complex project. Accepting and understanding these constraints will improve the individuals' reaction and attitude in dealing with them. Conversely, not understanding the constraint can potentially create a negative reaction, with the individual constantly complaining and repeatedly mentioning the constraint. It is important that the project manager work with participants to understand and minimize the impact of project constraints and relay an understanding of the broader project. This can provide the project participant with a window to the big picture, and a broader understanding of the project workings. This knowledge was identified as important to multiple individuals on the project.

A second issue that the project manager may promote is that managers and supervisors increase the frequency of contact with their subordinates, improving both the familiarity between the individuals and managers involved, and potentially resulting in increased communication on such issues as delegation of authority, time to complete tasks , and perceptions of the pressures being experienced from other departments. The contact should address issues with which the individuals are grappling, and not be simply a status update and an opportunity to micromanage. Both the contact frequency and understanding of the big picture were identified as important to the participants during the interview series and can be addressed by a prospective project manager with minimal effort and maximal benefit.

In summary, based on this research, there are steps that project managers can take to improve the performance of the organization for which they are responsible. Improving the understanding of the big picture and increasing positive contact between subordinates and supervisors will provide initial steps in improving the performance of the engineering disciplines for which they are responsible.

7.3 Contribution of This Research

This research demonstrates several points that underlie the research questions. First, there are important issues that affect a predominance of individuals working on the project. This exploratory research has identified four codes that directly impact project participants, and include understanding the larger project picture, the availability of information, dealing with constraints, and the relationship with the supervisor. These codes interact and as a result, impact project performance. As the analysis of two groups' responses to the survey questions indicate, frequency of contact with the supervisor, time available to perform work activities, and decision making authority highlighted significant differences between the successful Group A and poorly performing Group B examined in this study. These issues were identified during an exploratory investigation within a complex design-build infrastructure project. Each element of the investigative direction might be refined and focused, but the existence of these factors that directly impact the execution of the work within the team clearly exist, and account for successful efforts. A future implication might be that managers opt for the use of a periodic survey, based on these study results that could provide insight into conditions and issues affecting the working level personnel, allowing the manager to take preemptive steps to improve performance.

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Appendix A – Interview Protocols

The attached interview protocols were used during the interviews with the project staff. Separate questions were prepared for the Engineering Manager, the Project Engineers, and the Engineering Group Supervisors (Discipline Managers) given their differing backgrounds, understanding, and perspectives.

Interview Questions
Engineering Manager

1. I'd like to talk about some of the personnel assignments. About a year + ago, the then Engineering Group Supervisor (EGS) and Utility Relocation Manager exchanged roles. Why? What events lead to your decision (personnel issues, some consensus)? Can you provide the background associated with that change; why was it performed, what were the intended effects, what were the actual effects?

2. How do you perceive the relative importance of the EGSs versus the Project Engineers (PEs)? Obviously both are important, but to whom do you count on for frequent communication or your go-to people?

3. I'd like to talk about the organizational structure. In the range of matriced organizations, how does this project fit (explain the functionally based matriced structure, balanced structure, and project based matrix structure)? Fit the current project onto the continuum. Is this arrangement what you would expect? How would modify it if you had it to do over?

4. Several people noticed that EGS no longer attend your weekly meeting—is this correct? What changed to lead you to decide this? Does this connote an adjustment in the relative status of the PEs/EGSs?

5. About a year and a half ago, a management change occurred involving the EGS and the Utility/Right of Way lead engineer. Can you provide the background associated with that change; why was it performed, what were the intended effects, what were the actual effects?
6. When did the transition from preliminary engineering to detailed design occur?

Interview Questions
Project Engineer (PE)

All of these questions are posed in the context of the previous 4-6 weeks (since we last talked). Please feel free to add comments or suggestions to make this interview more effective.

For PEs

1. Has the upcoming start of construction affected your work? How? Examples?
2. Have you noticed a shift in the dynamic between yourself and EGSs? Can you characterize it? I'd like now to talk about the matrix organization. Within any matrix, a balance of authority exists (explain project, balanced, and functional matrices). How would you characterize this project matrix? To whom do the EGSs report? To whom do the PEs report? Has there been any change? Is that reporting structure really the way it works? Can you describe the relationship with the EGSs?
3. Do you attend project-wide meetings? Are they worthwhile? Why?
4. How do you know what your next tasks will be? Where do you get an inkling? Meetings (with whom), documents, direction from other managers?
5. This document, (time-location chart) was provided as an example of a project map. Can you explain how it works? Where are your activities on this? Is this useful to you?
6. How have changes affected your work? What is driving the changes-construction or other design issues? How are they tracked and statused? Who approves them? (Rule vs actual)

7. During the period since we last talked, can you characterize the subject matter of the contact with the Engineering Manager (i.e. schedule, people, personnel issues, other)?
8. What is the frequency of the contact you have the Engineering Manager? Did you have any one-on-one meetings/interactions?

9. With whom did you address personnel or other sensitive issues or concerns (EGS/other PEs/ Engineering Manager)?
10. Since we last talked, what contacts (email, phone calls, or casual meeting) have you had with the EGSs? What was the frequency of the contact you have with the EGSs with whom you interface?
11. In the last 4 weeks, can you describe the topics of the interface (i.e. schedule, people, personnel issues, other)?
12. Since we last talked, what have you considered your major constraints?
13. How frequently did you address scheduling issues?
14. What has been your role in budgeting in the last 4 weeks? How frequently did you address budgeting issues?
15. Over the last several weeks, what meetings have you held (relative to your work area)?
16. In the last several weeks, what decisions did you make without, without checking with others? Under what circumstances did you make decisions without consulting others?
17. When you did check on a decision, did you check with the EGS?
18. When you did check a decision, did you check with the Engineering Manager?
19. Who determined what personnel were assigned to your tasks (you, EGSs, Engineering Manager)?

Interview Questions
Engineering Group Supervisors (Discipline Managers)

All of these questions are posed in the context of the previous 4-6 weeks (since we last talked). Please feel free to add comments or suggestions to make this interview more effective.

For EGSs

1. Has the upcoming start of construction affected your work? How? Examples?
2. Have you noticed a shift in the dynamic between yourself and the EGSs? Can you characterize it? I'd like to talk about the matrix organization. Within any matrix, a balance of authority exists (explain project, balanced, and functional matrices). How would you characterize this project matrix? To whom do the EGSs report? To whom do the PEs report? Has there been any change?
3. Do you attend project-wide meetings? Are they worthwhile? Why?
4. How do you know what your next tasks will be? Where do you get an inkling? Meetings (with whom), documents, direction from other managers?
5. This document, (time-location chart) was provided as an example of a project map. Can you explain how it works? Where are your activities on this? Do you find it useful?
6. How have changes affected your work? What is driving the changes-construction or other design issues? How are they tracked and statused? Who approves them?
7. What has been your role for this project in the last 4 weeks?
8. During the period since we last talked, can you characterize the subject matter of the contact with the Engineering Manager (i.e. schedule, people, personnel issues, other)?
9. What is the frequency of the contact you have the Engineering Manager? Did you have any one-on-one meetings/interactions?

10. With whom did you address personnel or other sensitive issues or concerns (EGS/other PEs/ Engineering Manager)?
11. Since we last talked, what contacts (email, phone calls, or casual, meeting) have you had with the PEs? What was the frequency of the contact you have with the PEs with whom you interface?
12. In the last 4 weeks, can you describe the topics of the interface (i.e. schedule, people, personnel issues, other)?
13. Since we last talked, what have you considered your major constraints?
14. How frequently did you address scheduling issues?
15. What has been your role in budgeting in the last 4 weeks? How frequently did you address budgeting issues?
16. Over the last several weeks, what meetings have you held (relative to your work area)?
17. In the last several weeks, what decisions did you make without, without checking with others? Under what circumstances did you make decisions without consulting others?
18. When you did check on a decision, did you check with the PE?
19. When you did check a decision, did you check with the Engineering Manager?
20. Who determined what personnel were assigned to your tasks (you, PEs, Engineering Manager)?

Interview Questions
Engineering Staff

For Engineering Staff

1. Has the upcoming start of construction affected your work? How? Examples?
2. Have you noticed a shift in the dynamic between your EGS and PE? Can you characterize it? Within any matrix, a balance of authority exists (explain project, balanced, and functional matrices). How would you characterize this project matrix? To whom do the EGSs report? To whom do the PEs report? Has there been any change?
3. Do you attend project-wide meetings? Are they worthwhile? Why?
4. How do you know what your next tasks will be? Where do you get an inkling? Meetings (with whom), documents, direction from other managers?
5. This document, (time-location chart) was provided as an example of a project map. Can you explain how it works? Where are your activities on this?
6. How have changes affected your work? What is driving the changes-construction or other design issues? What is your role in the changes? How are they tracked and statused? Who approves them?
7. Can you characterize the discussions between you and your EGS? Is it open, quick (just do this), or exploratory in nature. Do you develop your relationship or just "do this" and get back to work?
8. (For Civil Engineers only) About a year and a half ago, a management change occurred between the EGS and the Utility/ROW lead engineer. Can you describe working for the former EGS? Did the management switch change the way you interfaced with the organization?
9. Since the last time we talked, what contacts do you have with your EGS? How often? Can you characterize those contacts?

10. Since the last time we talked, what contacts do you have with your PE? How often? Can you characterize those contacts
11. Since we last talked, can you describe the nature of direction provided to you (i.e. clear and concise, moving target, generally clear, but sometimes needs clarification, etc.)?
12. In the last 8 weeks, what constraints have you faced as you performed your tasks (i.e. time, dual tasks, changing tasks)? Examples?
13. In the last 8 weeks, what decisions have you made on your own, without checking with others. What were the circumstances that permitted you to make a decision, without checking with others?
14. When you had to check a decision, did you check with your EGS?
15. When you had to check a decision, did you check with your PE?
16. In the last 8 weeks, what tasks were assigned to you? Who made those assignments?
17. Since we last talked, have you completed any tasks? Where did your product go (who used the information you generated)?

Appendix B – Survey Questions

The attached survey provides all the questions posed to the study population. It was downloaded from the Virginia Tech Survey Site.

Cross-functional Teams

This survey is a part of a broader study titled, "Preparing Engineering Students for the Challenges of Interdisciplinary Design Teams." Please read it, and if you want to participate in the study, complete the questions below.

Research Investigators

Drs. Lisa McNair, Marie C. Paretti, and Maura Borrego, Department of Engineering Education, Virginia Tech Mr. Robert Tucker, Department of Civil Engineering, Virginia Tech

Your Invitation to Participate

We are conducting a study that explores cross-functional teamwork in industry in order to improve undergraduate engineering education and improve team processes in organization such as yours. We are asking you, as a member of a cross-functional team, to complete the survey below about your experiences in this environment. We value your viewpoint and want the results of this study to reflect actual industry practices.

Participating will require only a small investment of your time: 10 minutes to complete the online survey.

• The risks associated with participating in this research are considered to be minimal.

• Survey responses are anonymous and your identity will not be tracked by the researchers or the survey software.

• In addition to helping improve undergraduate education, the study data will be used to develop one or more papers that will be submitted to academic journals and professional conferences.

• It is also possible that the Institutional Review Board (IRB) at Virginia Tech will view this study's collected data for auditing purposes. The IRB is responsible for overseeing the protection of human subjects who are involved in research.

• Your participation in this research is entirely voluntary. You are free to withdraw from this research at any time without penalty. You are also free to not answer any question, or to not complete any activity, and this decision will result in no penalty or loss of benefits to which you are otherwise entitled.

If you agree to participate in this study, please complete the questions below. Doing so will imply your consent to participate in this study.

1. Which organization do you support?

- Civil
- Tunnel and Aerial
- Systems
- Stations and Facilities
- Configuration Control

2. What is your primary role on the team?

- Structural
- Civil
- Electrical
- Mechanical
- Architectural
- Geotechnical

Team Functioning—within any design package, different disciplines need to work together. Based on your recent experience, select the most appropriate response to each of the following questions.

3. How well do you feel you understand the functions and responsibilities of the other disciplines?

- I understand everyone's function/responsibilities very well.
- I understand most of the other functions/responsibilities.
- I understand only the functions and responsibilities of only the few people I directly work with.
- I have only a very vague sense of other functions and responsibilities.
- I'm not at all familiar with the functions/responsibilities of other team members.

4. How well do you feel you understand the constraints, resource needs, and information needs of other disciplines?

- I understand the constraints and needs of all team members very well.

- I understand the constraints and needs of most other team members.
- I understand the constraints and needs of only the few people I directly work with.
- I have only a very vague sense of constraints and needs of other team members.
- I'm not at all familiar with the constraints and needs of other team members.

5. What information do you need from other disciplines during this phase of the project?

- Data/data results
- Draft plans/specifications
- Comments to "issued for review" documents
- Commitment dates
- Other:

6. How would you characterize the level of preparation for meetings?

- All team members are always well-prepared.
- Most team members are generally well-prepared.
- Team members have at least drafted major deliverables and circulated them prior to the meeting.
- Sometimes a number of team members are not prepared.
- Most team members are generally not well-prepared.

7. To what extent do other disciplines provide you with the information you need?

- Always
- Generally
- Generally, but I frequently request clarifications
- Sometimes
- Infrequently

8. How would you describe the quality of the information you receive from other disciplines?

Highly reliable; I can use it immediately and trust its accuracy.

Generally reliable, but I may check a few items first.

Generally reliable, but I frequently need to discuss the information in some detail with the provider or with others.

Frequently not reliable; I typically have to double-check or go elsewhere.

Generally unreliable; I do not use the information obtains from team members but instead seek it elsewhere or work without it.

9. How would you characterize the timeliness of the information you receive?

All relevant information is almost always provided in time for me to complete my tasks on time.

Key items are provided on time.

Some items are provided on time, but key items may frequently be late.

Information is often late.

Information is almost always late.

10. How would you characterize the time available for you to meet your own deliverables?

I always have plenty of time to complete my work.

I generally have enough time to complete my work.

I occasionally need an extension.

Time is often tight and I am working right to the wire to meet deliverable deadlines.

I rarely have enough time to meet the deadlines on my deliverables without extensive overtime.

11. How would you characterize the reliability and timelines of the work of others by department?

11a. Project Controls

Always reliable/on time Usually reliable/on time Sometimes reliable/on time Rarely reliable/on time Never reliable/on time Not Applicable

11b. Engineering--Structural

Always reliable/on time Usually reliable/on time Sometimes reliable/on time Rarely reliable/on time Never reliable/on time Not Applicable

11c. Engineering--Civil

Always reliable/on time Usually reliable/on time Sometimes reliable/on time Rarely reliable/on time Never reliable/on time Not Applicable

11d. Engineering--Electrical

Always reliable/on time Usually reliable/on time Sometimes reliable/on time Rarely reliable/on time Never reliable/on time Not Applicable

11e. Engineering--Mechanical

Always reliable/on time Usually reliable/on time Sometimes reliable/on time Rarely reliable/on time Never reliable/on time Not Applicable

11f. Engineering--Architectural

Always reliable/on time Usually reliable/on time Sometimes reliable/on time Rarely reliable/on time Never reliable/on time Not Applicable

11g. Engineering--Geotechnical

Always reliable/on time Usually reliable/on time Sometimes reliable/on time Rarely reliable/on time Never reliable/on time Not Applicable

11h. Construction

Always reliable/on time Usually reliable/on time Sometimes reliable/on time Rarely reliable/on time Never reliable/on time

11i. Procurement - Acquisition

Always reliable/on time Usually reliable/on time Sometimes reliable/on time Rarely

reliable/on time Never reliable/on time

11j. Document Control

Always reliable/on time Usually reliable/on time Sometimes reliable/on time Rarely reliable/on time Never reliable/on time

11k. Quality

Always reliable/on time Usually reliable/on time Sometimes reliable/on time Rarely reliable/on time Never reliable/on time

12. How would you characterize team members' attitudes?

Everyone has a strong positive attitude.

Most people have a positive attitude.

Generally a positive attitude exists, but there are rough spots.

Few people have a positive attitude.

No one has a positive attitude.

13. How well do the various dates in meeting minute commitments, action item lists, and the master schedule align?

Very well, most of the time

General alignment

Some alignment--changes occur frequently that are caught in the more recent action item lists and meeting commitments

There is minimal alignment between the various commitment dates

Minimal alignment between the various commitment dates

14. Of the various schedule commitment documents, which takes precedent?

Most recent action item list dates

Most recent meeting minute commitment dates

- Master schedule

The following questions address the interactions between the team and your functional unit.

15. How frequently do you interact with your EGS regarding the drawing package development (check all that applies)?

- Daily
- Weekly
- After each meeting team or functional meeting
- Prior to design reviews
- Occasionally or sporadically

16. How would you characterize your ability to make decisions or commitments in the drawing package development meetings without input from your EGS?

- I am free to make all decisions at the team level.
- I can make most decisions at the team level.
- I need to defer some major decisions/commitments to my functional manager first.
- I need to defer most decisions/commitments to my functional manager.

17. How would you describe the nature of the feedback do you get from your EGS?

- General interest
- Requests regular updates
- Concerned with overall direction of drawing package development
- Concerned with drawing package development occasionally
- Only confirms previous decisions

18. How would you characterize interactions between your Drawing Package Team Leader and your EGS?

- Smooth with no conflicts
- Generally smooth—conflicts resolved quickly

- Usually smooth, but conflicts result in tensions that require outside intervention
- Frequent conflict
- Rarely interact

19. If there are conflicts between the PE and EGS, what are they usually about?

- My time
- Project Scheduling
- Resources
- Technical issues related to the project
- "Turf"
- There are no conflicts

20. How is your performance appraisal performed?

- EGS only
- PE only
- EGS with written input from the PE
- PE with written input from the EGS
- Jointly

21. Can you characterize the feedback that you get on your performance?

- Frequent feedback: both positive and negative
- Occasional feedback; mostly positive
- Occasional feedback; mostly negative
- Minimal feedback

22. How challenging is your work on the project?

- Very challenging/difficult

Challenging, but workable

Generally easy, not particularly challenging

23. Please use the space below to provide any comments or additional information to help clarify your answers or provide details you think would benefit this research study.