A DESCRIPTIVE, CORRELATIONAL ANALYSIS BETWEEN SOCIAL CAPITAL AND PERFORMANCE OF SIX SIGMA PROFESSIONALS

by

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ABSTRACT

Social capital is a measure of the advantage created by a person's position within a network of relations. This descriptive, correlational research study examined the correlation between social capital of Six Sigma professionals and the organizational performance in a large electronics company with multiple sites throughout the United States. The literature review indicated constrained networks provide competitive advantage to Six Sigma professionals leading sustaining projects, and unconstrained networks provide competitive advantage to those leading entrepreneurial projects. Constraint is the summary measure of social capital used in this study. The investigation found no support indicating advantage to Six Sigma professionals leading sustaining projects from constrained networks and strong support indicating advantage for those leading entrepreneurial projects from unconstrained networks.

DEDICATION

I dedicate this research to the men and women who find little satisfaction in the status quo and choose to make a difference through systematic, logical, purposeful, meaningful, and perpetual improvements to their surroundings. Six Sigma professionals are unhesitatingly foremost among this esteemed cadre of change-agents.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1: INTRODUCTION

Six Sigma is a business strategy used to improve profitability, both on existing processes and in new development (Bañuelas & Antony, 2003; Harry & Schroeder, 2000). In 2001, the Industrial Research Institute's Process Effectiveness Network sponsored a panel discussion about shifting focus from improving existing processes aimed at cost reduction to the use of Six Sigma in the Research and Development (R&D) environment (Johnson, 2002). Since then, other companies with mature Six Sigma initiatives like DuPont, Dow, and 3M, also began to shift their focus to customer requirements and product development (Puaar, 2003).

As a business strategy, Six Sigma relies on social capital, a source of resources resulting from social structures or networks. Social networks that produce social capital are connections between people or between organizations that can be economically valuable. The two major types of social networks are known as *closure* and *brokerage*, and they operate differently. The researcher was interested in the unique combination of tasks that require both closure and brokerage types of social capital in the successful completion of projects and that provide a favorable setting for examining the relationship between social capital and performance. Return on Investment (ROI) provided a common measure for both types of projects (De Feo & Bar-El, 2002; Harry & Schroeder).

The study described in this dissertation examined the relationship between the social capital of Six Sigma professionals and the organizational performance of the Six Sigma teams they have led. Lin (2001b) suggested that social capital "should be defined as *resources embedded in a social structure which are accessed and/or mobilized in purposive actions*" (p. 29). In this context, networks provide different forms of social

capital depending on the types of established relationships between network members. Some network structures are conducive to mitigating risk and exploiting existing processes while others are well suited for exploring new product development (Burt, 2000).

This chapter provides an overview of the study. An explanation of the background of the problem, problem statement, purpose of the study, and its significance follows. A synopsis of the research design is presented along with the research questions and hypotheses. The chapter concludes with a definition of terms, assumptions, scope, and delimitations of the study. Chapter 2 presents an exploration of the literature related to the variables of the study. Chapter 3 delineates the detailed research plan, methodology, and design validity. Chapter 4 describes data collection and processing methods used in this study and the results of the analyses. Chapter 5 discusses conclusions inferred from reported data analyses and implications for leadership. The researcher concludes chapter 5 with recommendations for future studies.

Background of the Problem

Network theorists generally advocated one of two schools of thought with regard to the creation of social capital in either closed or brokerage type networks (Burt, 2000). Social network theorists refer to the focal actor as *ego* whereas the actors to whom ego is connected are referred to as *alters* (Burt, 1992). Closed networks demonstrate strong relationships between actors either by *cohesion* as in a dense network where everyone is connected to everyone else or *structural equivalence* in which mutual intermediaries connect ego to the same actors. Cohesion and structural equivalence are measures of *redundancy*. Burt (1992) explained that redundancy is present when multiple network

members are interconnected and provide the same network information and benefits as their counterparts. In closed networks, “competitive advantage comes from managing risk; closed networks enhance communication and facilitate enforcement of sanctions” (Burt, 2000, p. 347).

Brokerage networks are nonredundant in that they lack cohesion and structural equivalence. The redundant closed networks are separated by gaps that Burt (1992) referred to as structural holes. Structural holes provide opportunities to those who broker information to span the gap between nonredundant resources, particularly to entrepreneurs, by providing a means of rapidly acquiring new knowledge, exploration, and innovation (March, 1991; Ronchi, 2004). In brokerage networks, “competitive advantage comes from information access and control; networks that span structural holes provide broad and early access to, and entrepreneurial control over information” (Burt, 2000, p. 347).

In view of these considerations, one could expect gains in social capital, although in different forms, from both closure and brokerage. A compelling observation is that if one views social structure as a dynamic process, a cyclical interchange between closure and brokerage networks is conceivable. For instance, improving a process steeped in technology and operating in a closed, dense network bent on exploitation of the prevalent technology (March, 1991) can be extremely successful in the early stages of the improvement procedure. The rate of improvement decreases as improvement efforts yield less return for a fixed investment, similar to the learning curve phenomenon that implies, “as organizations produce more of a product, the unit cost of production typically decreases at a decreasing rate” (Argote, 1999, p. 1). When the point of diminishing

returns is evident, it becomes necessary to open the network by introducing brokers who are able to effectively explore the environment for new opportunities (March, 1991).

Nevertheless, "[t]here remains an important role for closure. It can be critical to realizing value buried in structural holes" (Burt, 2001b, p. 47), and in order to enjoy the benefits of recent exploration, new discoveries must be exploited, a process most effective in closed networks. Organizational leaders should resist the temptation to become satisfied with either exploration or exploitation of the technologies at their disposal because there should be continual movement between the two activities in order to maintain competitive advantage.

Since the introduction of Six Sigma in 1979, General Electric, Motorola, Honeywell, Samsung Electronics, Telefonica of Spain, Johnson and Johnson, DuPont, and other companies that have adopted Six Sigma report returns on investment (ROI) ranging from 10:1 to 100:1 for Six Sigma projects typically focused on existing product lines (De Feo & Bar-El, 2002). Return on investment is the ratio of net income to investment (Anthony & Reece, 1979). Each of these companies has expanded its Six Sigma initiatives to include Design for Six Sigma (DFSS) techniques as a means of addressing customer requirements and product design (De Feo & Bar-El).

Six Sigma professionals measure the health of a process by examining defects or variations present in the process under review. In a normally distributed process, a company operating at the two sigma level can expect 95.44% of their products to be error free, at three sigma level 99.73% are error free, and at the six sigma level 99.99% are error free. These figures equate to 45,600, 2,700 and 3.4 defects per million, respectively (Taghaboni-Dutta & Moreland, 2004). Harry and Schroeder (2000) reported that

companies operating at the three sigma level can expect a one sigma shift improvement the first year resulting in a 20% margin improvement, a 12 to 18% increase in capacity, a 12% reduction in the number of employees, and a 10 to 30% reduction in capital. Companies can expect a one sigma improvement shift each year until they reach the 4.7 sigma level when the cost savings become harder to acquire (Harry & Schroeder). After one has reached the 4.7 sigma level of doing business, the rate of improvement begins to flatten, and companies need to reassess the Six Sigma techniques they have relied upon previously. Techniques designed to improve existing processes and products need to give way to methodologies that focus on entrepreneurial schemes and other forms of exploration (McKenzie, 2004).

Design for Six Sigma (DFSS) is a technique that allows companies to use Six Sigma to enhance product development (Bañuelas & Antony, 2003; De Feo & Bar-El, 2002; Johnson, 2002; Puaar, 2003). In order to make the transition from process improvement to product development, Six Sigma teams must shift from the myopic approach to examining the existing processes in minute detail to a broader, more holistic view of the environment that influences their operation (Bañuelas & Antony; Edgeman & Bigio, 2004; Puaar, 2003). Consequently, the dense, highly cohesive social network that served the Six Sigma professional well when tasked to improve existing processes must open, allowing access to innovative solutions and product expansion (Kelly, 2001). Organizational leadership must look beyond the typical closed network in which Six Sigma professionals typically reside, ensure access to brokerage opportunities for innovative solutions (Burt, 1992, 2001b, 2004b; March, 1991), and engage those whose social capital provides competitive advantage in an entrepreneurial environment.

BR Company, the object of this doctoral dissertation study, introduced Six Sigma in 1999 and reported a cumulative gross benefit of $1.8 billion in the first four years of its Six Sigma initiatives (Sosbe, 2003). Not unlike other companies employing Six Sigma, BR Company is finding it advantageous to shift the Six Sigma focus from cost reduction efforts on existing processes to a focus on growth, identification of customer requirements, and new product development (Puaar, 2003).

Six Sigma cost reduction efforts on existing product lines typically meant emphasis on driving out variability, increasing manufacturing throughput, improving yield, and generating higher efficiencies within the well-defined confines of the process owner. Shifting emphasis to growth, identifying customer requirements, and focusing on new product development necessitate that Six Sigma professionals employ new techniques involving an expansive environment in order to capitalize on innovation and break free from existing paradigms (Bañuelas & Antony, 2003; Kuhn, 1996; March, 1991; Puaar, 2003).

The strategic challenge for BR Company and other companies undergoing the same emphasis shift in their Six Sigma initiatives could possibly be a better understanding of the type of social capital various Six Sigma professionals have when they are assigned to leading various teams. Six Sigma professionals do not use the same techniques for existing processes and for new product development, and the benefits associated with social capital emanating from different social network structures also change. Network theorists generally advocate one of two schools of thought with regard to the creation of social capital, closure and brokerage (Burt, 2000). Closed, highly cohesive, dense networks provide social capital conducive to managing risks, enhancing

communication, and enforcing sanctions whereas brokerage networks with their open structure and nonredundant ties to external sources provide social capital fitting for innovation and entrepreneurial initiatives (Burt, 2001b).

Statement of the Problem

Organizational leadership is expanding Six Sigma practices beyond improving existing processes (i.e., sustaining projects) into entrepreneurial projects related to growth and product development (Banuelas & Antony, 2003; De Feo & Bar-El, 2002; Johnson, 2002; Johnson & Swisher, 2003; Taghaboni-Dutta & Moreland, 2004). The social capital that provides competitive advantage to these two constructs emerges from two different social network structures, closed networks and open brokerage networks. Closed networks provide competitive advantage when seeking to improve existing processes (Coleman, 1988, 1990; Lin, 2001a), and brokerage networks provide competitive advantage to situations requiring new information as in the design of new products (Burt, 1992, 2001b, 2004b).

The problem confronting organizations like the BR Company is that failure to consider the type of social capital that Six Sigma professionals have before assigning them to a specific project could result in millions of dollars in lost revenue. BR Company reported gross savings from 14,000 Six Sigma projects of $1.8 billion (Sosbe, 2003). However, BR Company also reported 6000 additional Six Sigma projects that were started but never completed, bypassing a potential $715 million in savings (J. McKenzie, personal communication, July 2004). The results of this study contributed substantially to the body of knowledge on social capital, and leaders can more effectively match Six

Sigma professionals with project types and, as a result, experience a higher return on investment.

Literature addressing either closed or open networks in isolation is readily available (Burt, 1992, 2000; Coleman, 1988, 1990; Lin, Cook, & Burt, 2001). Coleman demonstrated the value of social capital emanating from closed networks in his germinal study examining high school completion rates. Burt (2000) argued the value of open networks with results obtained from several studies that examined the competitive advantage senior managers enjoyed in several settings. Burt (2004b) also reported a positive correlation between open networks (structural holes) and innovation.

In comparison, literature addressing both closed and open networks in the same study is limited to contrasting the two concepts (Burt, 2001b), documenting the competitive advantage of each drawn from conceptual constructs (Burt, 2000) or the impact of closed and open networks on organizational learning (March, 1991). None of these studies addressed the influence of open and closed network structures within a single organization. BR Company actively deploys Six Sigma professionals to improve both sustaining and entrepreneurial processes. This descriptive correlational study added to the body of knowledge regarding equilibrium between closed and open networks in a single organization and provided specific guidelines for the effective and efficient deployment of Six Sigma professionals based on their social capital.

Purpose of the Study

The purpose of this descriptive correlational study was to analyze the correlation between social capital and performance of Six Sigma professionals in a large electronics company with multiple sites throughout the United States. Social capital, the independent

variable, was derived from two network structures, closure and brokerage (structural holes). “The closure argument is that social capital is created by a network of strongly interconnected elements. The structural hole argument is that social capital is created by a network in which people can broker connections between otherwise disconnected segments” (Burt, 2001b, p. 7). In this study, the level of constraint concomitant with the Six Sigma professionals, as measured using network analysis techniques, was used to quantify social capital. Organizational performance, the dependent variable, was the financial benefit realized at the completion of the Six Sigma projects.

The primary measure of the independent variable, social capital, was network constraint, which is a measure of information redundancy within a social network. Closed networks exhibit high constraint and brokerage networks exhibit a low level of constraint (Burt, 2000). Data used to define the dyadic relationships within the social networks were collected by means of a name generator/name interpreter survey instrument. These data were used to calculate network constraint for each Six Sigma professional. The dependent variable for this study was the organizational performance of the Six Sigma professionals, and it was measured by financial benefit realized in the form of operating profit, cash flow, risks mitigated, and seized opportunities. The researcher collected these data from BR Company’s financial records.

Significance of the Study

Researchers have shown that networks rich in structural holes demonstrate the value of their social capital by obtaining early promotions, increased financial incentives, and better job assignments (Burt, 1997b) and by the correlation of social capital with improved performance of cross-functional teams (Rosenthal, 1996). Burt (2004 a, 2004b)

also examined evidence suggesting that social capital emanating from brokerage across structural holes correlates with innovation and successful ideas, and he argued the impact of trust and reputation on delivering strong performance on existing processes. This research study has provided empirical support to both theoretical considerations and practical applications of social network concepts regarding social capital.

First, the findings from this study augmented existing literature by empirically demonstrating the relationship between the social capital of Six Sigma professionals and organizational performance. Second, this study purposefully categorized the projects undertaken by the Six Sigma professionals as either sustaining or entrepreneurial in nature. Sustaining projects were projects seeking to exploit known processes and value streams (i.e., all activities that bring a concept or product to production and delivery) whereas entrepreneurial projects sought to explore new territory and develop new products or processes. Differentiating the Six Sigma projects by type in this manner provided a means of empirically demonstrating the correlation between the social capital of Six Sigma professionals and organizational performance based on the nature of the project undertaken. This study indicated statistically significant differences in the performance of Six Sigma professionals depending on the type of project undertaken.

Significance of the Study to Leadership

This research added to the body of leadership literature by empirically demonstrating a correlation between the social capital of Six Sigma professionals and organizational performance based on the nature of the project under their supervision. Results of this study indicated a statistically significant correlation between social capital and the performance of Six Sigma professionals leading entrepreneurial projects, while

the results were inconclusive for Six Sigma professionals leading sustaining projects. Leaders could use this added insight to their advantage when deploying Six Sigma professionals to lead a specific type of project. Six Sigma leadership should find it more productive to deploy Sigma professionals residing in open networks that are rich in structural holes to lead projects related to growth, understanding customer requirements, and new product development. In contrast, this research did not report conclusive findings regarding performance expectations of Six Sigma professionals deployed on projects intended to provide improvement to existing products or processes.

Nature of the Study

This descriptive correlational study investigated the relationship between the social capital of Six Sigma professionals and the performance outcomes of the Six Sigma projects under their supervision. The research population consisted of all the Six Sigma professionals at BR Company who completed Six Sigma projects between July 1, 2004 and June 30, 2005. The BR Company granted permission to use the company premises (see Appendix A). The social capital (independent variable) of the Six Sigma professionals was derived from data collected using an adaptation of the Social Capital Short-Form instrument (Burt, n.d.) (see Appendix B). Permission was granted from Burt to adapt and use the Social Capital Short-Form for this research study (see Appendix C). The instrument employs name generator techniques to obtain sociometric data. These data were used to construct sociograms that displayed patterns of correlation and derived quantitative measures regarding the social network of the Six Sigma professionals. The researcher conducted data analyses using the analysis tool UCINET (Borgatti, Everett, & Freeman, 2002). Social capital was quantified as network constraint where constraint is

the strength of ties between actors. The name generator is the more common method used to assess social capital (Lin, 2001b).

The financial benefit realized by Six Sigma professionals' completed projects was used as the measure of performance outcome and was the dependent variable in this research. Performance outcome data were extracted from the BR Company's database of Six Sigma projects. In addition to network constraint and performance outcomes, the sociometric survey provided information on variables relating to project type (sustaining or entrepreneurial), rank within the company, primary assignment, gender, and level of education. Sociometric surveys were distributed to the Six Sigma professionals through the BR Company electronic mail system.

Data representing the independent and dependent variables were then assembled into datasets ready for analysis. Since this was a descriptive correlational study aimed at examining possible correlations between social capital and performance, emphasis was placed on correlational and related descriptive analyses, and the resulting data were subjected to statistical testing.

A quantitative research method was applied, the preferred method when conducting ex post facto research (Leedy & Ormrod, 2001). A correlational methodology afforded the opportunity to examine the variables in their natural environments without manipulation. The researcher employed multivariate regression techniques to provide a more thorough explanation of the possible relationship between independent variables. Multivariate regression was not used to develop a predictive model.

A pilot study was conducted on 10 randomly selected Six Sigma professionals to verify the validity of the instrument. The researcher had anticipated the potential need for

a second pilot study, but the results of the pilot study did not indicate the need for substantial change to the survey instrument, so a follow-up was not necessary. The final instrument was sent via electronic mail to a sample of BR Company's Six Sigma professionals who successfully completed projects resulting in financial benefit between July 1, 2004 and June 30, 2005.

Research Questions

The general notion set forth by Lin (2001b) that the premise behind social capital is the "investment in social relations with expected returns in the marketplace" (p. 19) has found wide support (Burt, 1992; Coleman, 1990; Lin et al., 2001). Likewise, there is general agreement among network theorists about competitive advantage within closed networks with regard to preserving and maintaining resources (Burt, 2001b; Coleman, 1988, 1990; Lin) and competitive advantage within brokerage networks with regard to innovation and entrepreneurial activities (Burt, 1992, 2001b, 2004b; Granovetter, 1973; March, 1991). Growth and product development are measures of innovation and entrepreneurial activities within industrialized organizations. There appeared to be a lack of research examining the influence of social capital gained from differing social structures on performance within a single organization.

This study contributed to the body of knowledge by examining the performance outcomes of both closed and brokerage networks of Six Sigma professionals within BR Company. Six Sigma projects were classified as either sustaining (projects related to an existing product or process) or entrepreneurial (projects related to growth or product development), and the social capital of the Six Sigma professional leading a team was

correlated with the performance outcome for that team. Guiding this research were the questions:

R1: What is the degree to which the social capital (constraint) of the Six Sigma professional correlates to performance outcomes for sustaining projects?

R2: What is the degree to which the social capital (constraint) of the Six Sigma professional correlates to performance outcomes for entrepreneurial projects?

Hypotheses

Coleman (1988, 1990) emphasized the importance of network closure when addressing the construct of social capital. Other studies have demonstrated a positive relation between closed cohesive networks and group performance (Chang & Bordia, 2001), and more reliable communication channels and protection from people external to the group are exhibited in closed networks (Burt, 2000). Closed networks are likewise conducive to increased trust among mutual friends because of the fear of violations being disclosed to other group members (Granovetter, 1992), and closed networks augment the exploitation of existing resources (March, 1991). These authors had in common the premise that familiarity with the operating environment in which the social network resides exists in closed networks. Using network constraint as a measure of closure, this researcher posited a positive correlation between network constraint and performance when Six Sigma professionals lead projects in a known environment. Based on this prediction, the researcher formulated the following alternative hypothesis $H1_a$: There is a statistically significant positive correlation between constraint and performance outcomes for sustaining projects.

Conversely, there is empirical evidence suggesting that brokerage networks, identified as social networks that are rich in structural holes (gaps or disconnections between actors), exhibit low network constraint provide competitive advantage in certain instances. Previous studies suggested that network constraint is negatively correlated with new product innovation (Sethi, Smith, & Park, 2001) and the performance of cross-functional process improvement teams (Rosenthal, 1996). Weak ties between actors in a social network are a source of novel information (Granovetter, 1973; Hansen, 1999). A positive correlation exists between the social capital exhibited in brokerage networks and salary increases, early promotions, and innovation (Burt, 1992, 2001b).

Ancona and Caldwell (1992) reported clear support for their hypothesis that posited a positive relationship between ambassadorial activity and performance. March (1991) maintained that brokerage networks provide opportunity for exploration. The underlying premise of these studies is that competitive advantage is brought about by contacts outside the common environment in which the actor resides, a broker's network. Brokers perform better in open, less constrained networks (Burt, 1992), so one could expect increased performance for the Six Sigma professionals residing in open network structures when leading entrepreneurial projects. Based on this expectation, the researcher generated the following alternative hypothesis $H2_a$: There is a statistically significant negative correlation between constraint and performance outcomes for entrepreneurial projects.

Support for the alternative hypotheses is demonstrated by testing the associated null hypotheses for statistical significance. "A null hypothesis (often symbolized by the symbol H_0) postulates that any result observed is the result of chance alone" (Leedy &

Ormrod, 2001, p. 275). Rejection of the null hypothesis provides indirect support for the alternative hypothesis. The null hypotheses related to the aforementioned alternative hypotheses were:

$H1_0$: There is no statistically significant correlation between constraint and performance outcomes for projects related to a known value stream.

$H2_0$: There is no statistically significant correlation between constraint and performance outcomes for projects related to growth or product development.

Theoretical Framework

This descriptive correlational research study was intended to determine the degree to which the social capital attributed to the social network in which Six Sigma professionals resided affected the performance of their Six Sigma teams. Departing from the Weberian concept of addressing sociological problems by emphasizing the *actions* of the players within a group (Weber, 1920/1964), the researcher emphasized the *associations* between actors (Blau, 1964/1986) or group-affiliations (Simmel, 1923/1955) and the social capital concomitant with the structure of their correlations (Burt, 1992, 2000, 2001b). There was no intent to diminish the importance of social action and its contribution to the understanding of group dynamics, but rather the focus was on structural associations and concomitant social capital in order to give Six Sigma professionals an increased understanding of the relationship between social capital and the performance of Six Sigma teams. Understanding this relationship potentially added significant value to Six Sigma leadership at the team, middle, and upper management levels.

This study quantified team performance by using the financial benefit reported by the Six Sigma team as the measure of merit. Financial benefit included financial measures of operating profit, cash flow, risks mitigated, and opportunities captured. Harry and Schroeder (2000) indicated team success is measured in terms of margin improvement, increased capacity, reduction in the number of employees, and capital reduction. According to De Feo and Barnard (2004), performance results refer to shareholder value, profitability, sales, market share, costs, cycle time, rework reduction, environmental and community citizenship, and each can be measured in financial terms.

The International Society of Six Sigma Professionals (ISSSP) differentiates between hard benefits (e.g., cost reduction or revenue increase) and soft benefits (e. g., productivity and customer satisfaction) in their current benchmarking survey of Six Sigma activities (Benchmarking, 2005). The design of this study did not differentiate between the various types of financial benefit in order to focus on the overall worth of the project. Six Sigma professionals residing in closed social networks should provide more hard financial benefit, and Six Sigma professionals residing in broker networks should enjoy reporting more soft financial benefit. Using the nonspecific measure of gross financial benefit, the focus was on the social network's contribution to social capital, not the type of benefit realized.

Sociologists have described social capital in various ways. Coleman (1990) illustrated social capital by distinguishing it from the concept of human capital. He explained, "[H]uman capital is created by changing persons so as to give them skills and capabilities that make them able to act in new ways. Social capital, in turn, is created when the relations among persons change in ways that facilitate action" (p. 304). Lin

(2001b) suggested that social capital "should be defined as *resources embedded in a social structure which are accessed and/or mobilized in purposive actions"* (p. 29). Defining social capital in this manner emphasizes three distinct elements: (a) embedded resources, (b) accessibility, and (c) the use of these resources for purposive actions (Lin, 2001a). Burt (1992) stressed the value of position and argued, "that players with well-structured networks obtain higher rates of return" (p. 13). This study focused on network structure with particular attention given to social capital concomitant with open (brokerage) and closed networks.

Definition of Terms

Brokerage Network: Brokerage networks are rich in structural holes thereby providing social capital conducive to innovation, growth, and product development (Burt, 1992, 2000, 2001b; March, 1991).

Centrality: Centrality is the number of degrees associated with a point on the sociogram where a degree is the number of points that are directly connected to the point of interest or how well connected the point is to other points (Scott, 2000).

Constraint: Constraint is a measure of information redundancy within a person's network. "Constraint is high if contacts are directly connected to one another (dense network) or indirectly connected via a central contact (hierarchical network)" (Burt, 2000).

Network Closure: Network closure refers to dense networks in which everyone is connected. Individuals in these networks experience elevated levels of trust, improved transfer of complex knowledge, and increased social capital associated with sustaining projects (Burt, 1992, 2000; March, 1991).

Network Density: Network density is represented by the mean strength or a proportion of actual links to possible links (Marsden, 1990).

Network Size: Network size quantifies the number of direct ties that are attributed to individuals and is used to measure integration, popularity, or range (Marsden, 1990).

Six Sigma Professionals: Six Sigma Professionals in this study "possess the Six Sigma knowledge and skills necessary to implement, sustain, and lead a high focused Six Sigma initiative within a target business area our unit" (Harry & Schroeder, 2000, p. 201).

Social Capital: Social capital is "defined as *resources embedded in a social structure which are accessed and/or mobilized in purposive actions*" (Lin, 2001a, p. 12) and measured as a level of constraint.

Social Network: A social network is representative of a group of people interconnected through some means of communication that can be mapped in sociograms (Bass, 1990).

Sociograms: Sociograms represent a technique used in sociometry to map social networks in a series of nodes and interconnections (Bass).

Structural Holes: Structural holes span nonredundant sources of information and provide competitive advantage in the form of social capital for brokerage projects (Burt, 1992, 2001b).

Assumptions

The researcher assumed that the participants to the name generator questionnaire and the survey instrument would respond honestly and accurately. The questions put forth in the name generator and survey instrument were assumed to appropriately depict

and measure the social capital of the Six Sigma professionals at BR Company. The researcher further assumed that the BR Company Six Sigma database was accurate with regard to project definition, team demographics, and project outcomes. Additionally, the researcher assumed that the social network of the Six Sigma professionals has not significantly changed since project completion.

Limitations

Several aspects of this study were beyond the control of the researcher. First, the study was limited to voluntary participants and the accuracy of their responses. Second, the validity of algorithms employed by the UCINET (Borgatti et al., 2002) software to calculate network constraint limited the reliability of the findings. Third, the study was limited to the population of Six Sigma professionals documenting their 2004-2005 projects in the BR Company database.

Delimitations

The scope of this study was confined to the survey of the Six Sigma professionals who completed Six Sigma projects between July 1, 2004 and June 30, 2005 for the BR Company. This study focused on examining the correlation of the social capital of the Six Sigma professionals and their performance. Social capital was defined as a measure of network constraint (Burt, 1992), and financial benefit served as the measure of performance. Only Six Sigma professionals who have properly recorded projects in the company's Six Sigma database were included in the study. Restricting the population to the activities recorded in the company's Six Sigma database provided several favorable delimitations. First, access to the database is limited to company recognized Six Sigma professionals. Second, a financial analyst scrutinizes financial data before they are

accepted into the database. Finally, the Six Sigma database is the common repository for the entire company therefore Six Sigma professionals from all geographical locations and business units are represented.

Summary

This chapter has provided an overview of the research plan used to examine the correlation between the social capital concomitant with social network structure in which Six Sigma professionals reside and their teams' performance. The researcher explained the significance of the study with regard to advancing the understanding of the impact of social networks on performance and its contribution to leadership. Research questions and associated hypotheses used in this study were presented. The chapter concluded with a description of the underlying assumptions, scope, limitations, and delimitations of the study.

Chapter 2 offers a review of related literature that specifically addresses social capital concomitant with brokerage and closure networks along with the underlying sociological theories supporting these two constructs. In chapter 2, the researcher also reviews literature pertaining to Six Sigma and its impact contemporary organizations.

CHAPTER 2: LITERATURE REVIEW

Chapter 1 provided an overview of the background of the study and the problem facing organizational leaders as they deploy Six Sigma professionals to improve two fundamentally different tasks, improving existing processes or designing new error free processes. This descriptive correlational study analyzed the relationship between social capital and the performance of Six Sigma teams in a large electronics company with multiple sites throughout the United States. The literature review provides an overview of the scholarly contributions germane to this research.

Documentation

Literature for this review was obtained from multiple sources, including online services offered by the information and learning firms ProQuest Company, Thomson Gale™, Ebscohost, and Science Direct. Membership in professional organizations such as the American Sociological Association, American Society for Quality, and International Society of Six Sigma Professionals provided access to articles published in their journals and trade magazines. Access to the journal archive database, JSTOR provided access to additional scholarly journals for review. Books were the primary source for foundational information regarding this study while edited books offered a convenient source of topical literature. Sixty percent of the literature came from sources less than five years old. Excluding primarily germinal works addressing sociological and social network theory, 85% of the resource literature came from sources less than five years old in 2005.

Search results of major online databases, ProQuest, Ebscohost, and JSTOR for scholarly articles and dissertations are summarized in Table 1. While the results are not

exhaustive, they give a favorable indication that ample literature is available on the topic of this dissertation. More refined searches using nearly synonymous terms for brokerage (e.g., loose ties, weak ties, structural holes, open networks, and non-redundant) and closure (e.g., embeddedness, strong ties, nested networks, homophilic networks, dense, and redundant) added articles to the list at the expense of duplication. The searches contained in Table 1 are the most representative, comprehensive, and concise examples.

Table 1

Summary of Major Database Article Searches

Search String	Non-Peer Reviewed Articles	Peer-Reviewed Articles	Dissertations
"Social Capital" AND Performance	1225	1053	96
"Social Capital" AND Brokerage	44	42	
"Social Capital" AND Closure	180	196	16
Total	1449	1291	112

Literature Review

Social Capital

The social capital metaphor suggests an accumulation of wealth readily attributable to individual relationships. Field (2003) summarized the central thesis of the metaphor in two words: "relationships matter" (p. 1). The concept of relationship distinguishes social capital from financial capital and human capital in that the associated

value resides in the relationship, not the individuals. Human capital and financial capital are the sole property of individuals or the fictive person of a corporation (Burt, 1992). Financial capital enables the purchase of raw materials and facilities, and human capital provides the wherewithal to convert raw material into goods and services.

There exists growing consensus in extant literature to credit three germinal authors with introducing the concept of social capital, Pierre Bourdieu, James Coleman, and Robert Putnam (Field, 2003; Portes, 2000; Schuller, Baron, & Field, 2000; White, 2002). These authors represented two distinct views. Bourdieu (1997) was influenced by Marxist sociology. He posited, "Economic capital is at the root of all other types of capital" (p. 54). Bourdieu (1986) emphasized the connection between inequality and the production and reproduction of capital and the demarcation of classes. He wrote of "the share in profits which scarce cultural capital secures in class-divided societies" (Bourdieu, 1997, p. 49). Maintaining linkage between social and economic capital, Bourdieu defined social capital as

> [T]he aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance and recognition which provides each of its members with the backing of the collectivity—owned capital. (p. 51)

Coleman (1988) and Putnam (2004) advocated the concept of social capital from a functionalist perspective. Coleman posited,

> Social capital is defined by its function. It is not a single entity but a variety of different entities, with two elements in common: they all consist of some aspect of social structures, and they facilitate certain actions of actors—whether persons or

> corporate actors—within the structure. Like other forms of capital, social capital is productive, making possible the achievement of certain ends that in its absence would not be possible. (p. S98)

Similarly, Putnam (2004) provided a succinct definition of social capital to an interviewer inquiring into its meaning. Putnam stated, "Social capital refers to social networks and the associated norms of reciprocity" (p. 14). Coleman and Putnam both emphasized relations between individuals and the associated advantage.

In contrast, Bourdieu (1997) presented his concept of social capital by attempting to theorize the reproduction of social classes without fully developing his position (Schuller et al., 2000). Coleman (1988) understood social capital to exist only in relationships, but unlike Bourdieu he maintained that these relationships were functional and did not address the concept of difference as power. Coleman and Putnam (2004) have both been criticized for failing to consider the connection between social capital and power. Bourdieu has received criticism for failing to recognize the value of social capital to underprivileged groups (Field, 2003).

The influence of social structure on social capital is a common concept in the writings by Bourdieu, Coleman, and Putnam. All three agree "on a social-capital metaphor in which social structure is a kind of capital that can create for certain individuals or groups a competitive advantage in pursuing their ends" (Burt, 1992, p. 32). Social network theory provides a means of understanding social structure.

Social Network Theory

Leadership theorists have long recognized the importance of understanding interaction between leaders and followers. "Leadership depends on interaction" (Bass,

1990, p. 658). Bass documented the effects of physical and psychosocial space on this interaction, and he recognized the importance of sociometry when researching the effects of interaction. Sociometry, as developed by Jacob Moreno, provided a graphical representation of networks using sociograms, "to investigate how psychological well-being is related to the structural features of what he termed 'social configuration' " (Scott, 2000, p. 9). Sociograms, a series of lines representing interactions between actors and points or nodes representing the actors themselves, provided a schematic view of the social group under investigation. Sociograms also provided a means of representing relationships between individuals' social network and the larger society. This aggregate view of the social structure is noticeably absent from studies cited by Bass, and it does not gain prominence until researchers begin to develop the concept of social capital.

Lewin, a gestalt psychologist contemporary of Moreno, also contributed to the early development of network analysis. While Moreno was pursuing his interest in sociometry, Lewin formalized the field theory that emphasized the importance of conflicting social forces. Lewin (1951) suggested that "*Field theory is probably best characterized as a method*: namely, a method *of analyzing causal relations and of building scientific constructs*" (p. 45). Both Moreno and Lewin expressed more interest in the social relations between actors than in the personal attributes of the principal actors in the network.

Sociologists during the early 20th century expressed differing views on whether emphasis should be on the action of the actor or the association between actors. Weber (1920/1964) defined sociology as "a science which attempts the interpretive understanding of social *action* [italics added] in order thereby to arrive at a causal

explanation of its course and effects" (p. 88). Scholars who focused on social action concerned themselves with underlying values and norms that either limited or reinforced interactions between societal members. "A concern with social action, broadly conceived as any conduct that derives its impetus and meaning from social values, has characterized contemporary theory in sociology for some years" (Blau, 1964/1986, p. 13). There is agreement among sociologists that social values greatly influence social relations, but the line of reason tends to divert attention from the structure of association between actors (Blau).

Conversely, Georg Simmel (1923/1955) advocated a sociology that emphasized the associations between actors. As cited in Spykman, 1925/1965, Simmel stated,

> Sociology, then, will have to investigate the whole range of socializations from the most simple to the most complex, from the most fleeting to the most permanent. It will have to deal with all the relationships and interactions which constitute human *association* [italics added]: with imitation, representation, the creation of parties, the formation of classes and secondary subdivisions, and the incorporation of social reciprocities in special structures. (p. 43)

Simmel suggested that what represented these human associations was the "co-efficiency of several cohesive forces which restrict and modify one another" (p. 21). Conflict, not unlike Lewin's (1951) concept of social forces, is the dynamic force that draws some people into group affiliations while repelling others (Simmel).

The motivations and purposes that attract members into specific groups can be either hostile or benevolent. In economic terms, there is the benevolent relationship between buyer and seller where the common goal is the exchange of merchandise.

Hostile relationships exist between two buyers vying for the same goods or two sellers in competition for the same buyer. Opportunity for a third person to broker the relationship between groups is present in both cases. Simmel (1923/1950) referred to the person who brokers the relationship as the *tertius gaudens* or "the third who enjoys" (p. 154). Blau (1964/1986) developed the social exchange theory suggesting that "the objective of this theory is to explain patterns (or structures) of social relations, not individual behavior, in structural terms, not in cultural or psychological ones" (p. xi). Social exchange theory provided a link between microsociological and macrosociological analysis and advanced systematic theory (Blau).

Sociological theory failed to address adequately the relations of micro level interactions to macro level patterns until Granovetter (1973) advanced the weak tie theory that draws attention to the importance of distant and irregular relationships. His study of the highly cliquish community of Boston's West End demonstrated the ineffectiveness of closed social networks (cliques) to block impending urban renewal initiatives that were threatening their community. Lack of ties to the outside thwarted innovation and their ability to marshal an effective defense against the initiatives. Charleston, a neighboring city rich in weak ties effectively blocked urbanization in its community. Weak ties provided a bridge between two otherwise isolated social networks. "Weak ties, often denounced as generative of alienation are here seen as indispensable to individuals' opportunities and to their integration into communities; strong ties, breeding local cohesion, lead to overall fragmentation" (Granovetter, p. 1378). Persons with few weak ties find themselves deprived of information rich communication (Granovetter, 1983).

White (2002) defined a social network "as a web of social relations or resources that surround individuals, groups or organizations and the characteristics of their ties" (p. 261). When conducting a sociocentric study, network analysts map the complete network of relational ties of all members of a bounded community obtained from relevant data for each member of the network. Egocentric networks focus on a single member (ego) and the ego's relationship with others (alters) (Webster & Morrison, 2004) and alter-alter relationships (Everett & Borgatti, 2005; Marsden, 2005). Even though sociocentric and egocentric network designs differ, there is a relationship between them (Marsden). For each object in a sociocentric design, there is an egocentric design (Marsden, 2002), and sociocentric networks emerge from densely sampled egocentric networks (Kirke, 1996). Other names for egocentric networks include neighborhood networks or first order networks (Everett & Borgatti).

Growing interest in the relational aspects of group dynamics necessitated social science researchers to modify their method of analysis. The typical emphasis on attribute data and the accompanying variable analysis proved insufficient when studying the influence of relations between actors. Researchers (Blau, 1964/1986; Simmel, 1923/1950, 1923/1955) found that they could not adequately define these relationships in terms of actor attributes when trying to capture the value of the social capital inherent to a group or organization. Relations are jointly owned between actor pairs and the actor pairs' relationship with the entire system. Sociograms, graph theory, dyads, and block models provided utility in network analysis since the 1930s. Wasserman, Scott, and Carrington (2005) reported that the sophisticated new models augmenting the tools available to network analysts have been remarkably successful in recent years. The availability of

these new analytical tools and powerful desktop computer application software designed to execute these models greatly enhances the researcher's ability to analyze social capital concomitant with the structure of social networks. The social capital concept provides a useful metaphor that has attracted the attention of policy makers, anthropologists, economists, and especially sociologists (Lin et al., 2001).

Interest in social capital has given rise to unprecedented interest in social network analysts. Putnam (2004) reported that a new research article on social capital used to appear once every three years compared to the 300 research articles published in 2003. Network theorists adopted positions either advocating that competitive advantage emanated from networks rich in structural holes, or that strongly interconnected actors provided the source of competitive advantage. Some scholars suggested competitive advantage emanated from brokerage networks because networks rich in structural holes provided opportunity to bridge disconnected groups (Burt, 1992; Granovetter, 1973). In comparison, the advantage of strong ties between actors in closed networks has been well documented (Coleman, 1988, 1990; McGrath & Krackhardt, 2003). Burt (2000) demonstrated the ability to integrate these two seemingly diverse concepts by concluding, "Brokerage across structural holes seems to be the source of added value, [and] closure can be critical to realizing the value buried in the structural hole" (p. 398).

Closure

Closed networks demonstrate strong relationships between actors either by cohesion, as in a dense network where everyone is connected to everyone else, or structural equivalence, where mutual intermediaries connect ego to the same actors (Burt, 1992). Cohesion and structural equivalence are measures of redundancy. In closed

networks, “competitive advantage comes from managing risk; closed networks enhance communication and facilitate enforcement of sanctions” (Burt, 2000, p. 347).

Coleman’s (1988, 1990) germinal work on network closure as social capital has markedly influenced the study of social capital in the English-speaking world (Schuller et al., 2000). Strongly interconnected actors residing in a dense closed network enjoy enhanced access to information and the benefit of network sanctions making it less risky for members to trust one another (Burt, 2001b). Coleman (1990) wrote, “An important form of social capital is the potential for information that inheres in social relations” (p. 310). For example, a “social scientist who is interested in being up-to-date on research in related fields can make use of everyday interactions with colleagues to do so, but only in a university in which most colleagues keep up-to-date” (Coleman, 1988, p. S104).

Strong ties represented by substantial investment in time, emotional intensity, intimacy, and reciprocal services augment closure (Granovetter, 1973). New York’s wholesale diamond market illustrates the interaction of trust and obligation. Prior to closing a sale, the seller freely hands over a bag of stones to the potential buyer who in turn privately examines the stones at leisure. There is complete trust without formal assurance between the seller and buyer that no tampering occurs. This open exchange of trust and obligation demonstrates the inherent social capital residing in this closed community of Jewish merchants. Without these ties, elaborate and expensive bonding and insurance instruments would reduce efficiencies (Coleman, 1988).

Cohesive networks offer advantages when addressing issues that arise within a known discipline (Burt, 2000). Closed networks offer an advantage in the exploitation of organizational knowledge (March, 1991). The classic learning curve is an example of the

value associated with closed networks. For example, the number of hours required to produce a Liberty Ship during World War II deceased by 45% in the first year of production. Conversely, the cost of producing Lockheed's L1011 actually increased to the point that Lockheed was forced to cancel the program. A dramatic increase in personnel, from 14,000 to 25,000 employees over a two-year period, polluted the pool of experience workers with *green* workers, resulting in negative influence on the learning curve (Argote, 1999).

Cohesive groups are vulnerable to the negative influence of groupthink and its three antecedents. First, the cohesive groups are insulated from the judgments of qualified outsiders. Second, group leaders are not constrained by outside forces to avoid pushing their own agenda. Third, the rigor of bureaucratic control, such as filling out balance sheets of pros and cons for available options, is missing (Janis, 1982).

Brokerage

Brokerage networks are nonredundant in that they lack cohesion and structural equivalence. Burt (1992) referred to the gaps that form between closed networks as structural holes. Structural holes provide opportunity to those who broker or span the gap between nonredundant resources particularly to entrepreneurs by providing a means of rapidly acquiring new knowledge, exploration, and innovation (March, 1991; Ronchi, 2004). In brokerage networks, "competitive advantage comes from information access and control; networks that span structural holes provide broad and early access to, and entrepreneurial control over information" (Burt, 2000, p. 347).

Burt (1992) expanded the theory of weak ties with the introduction of structural holes. He explained, "A Structural Hole is a gap or disconnection between contacts in a

personal network" (as cited in Rosenthal, 1996, p. xi). Structural holes provide entrepreneurial opportunities for the *tertius gaudens* (Burt, 1992). The *tertius gaudens* is "the third who enjoys" (Simmel, 1923/1950, 154). The *tertius gaudens* is in a position to negotiate or broker between two otherwise disassociated actors. Burt (2000) suggested that leaders operating in environments rich in structural holes enjoy quicker promotions, increased salaries, marginally higher raises, and more favorable project assignments than their counterparts in highly constrained social networks. Frequent interactions represented by strong ties among actors tend to increase project effectiveness while weak ties provide a more efficient transfer of knowledge (Hansen, 1999). The integration of closure (strong ties) and brokerage (weak ties) has been addressed in several studies (Burt; Nicolaou & Birley, 2003; Podolny & Baron, 1997).

Closure and Brokerage Integration

Podolny and Baron (1997) studied the effects of network contents on salaried personnel in high-technology engineering and manufacturing company with approximately 25,000 employees. They used the same informal ties Burt (1992) used in his development of the structural hole hypothesis (i. e., task advice, strategic information, social support, and mentorship) and essentially the same name generator to collect network data. Podolny and Baron found support for Burt's conclusion that brokering across structural holes positively influenced mobility (promotion). However, Podolny and Baron also documented "empirically that the network structure most conducive to organizational advancement depends significantly on the content of the social tie involved" (p. 674). Structural holes provided a positive effect on promotion when

transmitting resources and information, and they negatively influenced promotion when there was a need to transmit identity and consistent role expectations.

> Perhaps it can be said that all structural holes are not of the same color; some are 'white holes,' propelling the individual upward through the organization and providing socioemotional benefits, while others are clearly 'black holes,' holding individuals at a particular rank in the organization and causing negative psychological consequences. (Podolny & Baron, p. 689)

Networks that display high closure and cohesiveness provide advantage in settings requiring transmit of identity and role expectations.

Burt (2000) reviewed the argument and evidence on the connection between social networks and social capital, focusing on senior managers and organizations. His goal was to ascertain network structures that constitute social capital. Three network structures emerging from the review were clique networks, entrepreneurial (broker) networks, and hierarchical networks. Clique networks, characterized as small, dense, and non-hierarchical, exhibited substandard performance. Entrepreneurial networks that are large, sparse, non-hierarchical, and rich in opportunities to broker across structural holes provided increased creativity, innovation, better job evaluations, and subsequently early promotions and better wages. Hierarchical networks that are large and sparse with a single, prominent contact provided opportunity to borrow social capital. Social capital is borrowed through a strong tie from managers residing in their own entrepreneurial network. This construct provides an appealing alternative for managers who are not considered legitimate by other members of the organization such as "women in many

populations of senior managers, men who are too young to be taken seriously as members of the population, or men in an organization that is primarily women" (Burt, p. 408).

Burt (2000) concluded it would be better for researchers to focus on network mechanisms giving rise to the effects social capital than attempting to integrate social capital metaphors. Empirical evidence clearly supported the concept that social capital is more a function of brokerage across structural holes than closure within networks. These two network mechanisms, brokerage and closure, can be included in a general model of social capital. "Structural holes are the source of value added, but network closure can be essential to realizing the value buried in the holes" (Burt, p. 345). Contingency factors identified by Burt that affect the strength of the correlation between social capital and performance are (a) personality and culture, (b) network content, (c) number of peers and task uncertainty, (d) network structure within and beyond groups, and (e) borrowed social capital.

In a study aimed at understanding the influence of social networks on the direct commercialization of intellectual property belonging to universities known as the spinout phenomenon, Nicolaou and Birley (2003) advocated the contingency approach to social capital. The contingency approach blends the two distinct theoretical propositions defining the source of social capital, brokerage (Burt, 1992) and closure (Coleman, 1988, 1990). Nicolaou's and Birley's study of the spinout phenomenon within the United Kingdom, Imperial College, particularly focused on the effects of redundancy in the strength of ties associated with 45 spinouts and 111 inventors. The dependent variable was the decision of academic inventors to remain or leave the institution. Nicolaou and Birley suggested widening the results of their study beyond academics and apply spinouts

to other entrepreneurial activity, concluding. They recommended, “We believe that strong nonredundant ties in instrumental networks and strong supportive ties in expressive relationships are important antecedents of entrepreneurial behavior” (Nicolaou & Birley, p. 1719). Pragmatically, Nicolaou and Birley illustrated network structure can positively predispose academics to become more involved in technology transfer, the importance of organizing networking events, and the value in the establishment of technology transfer offices to serve in brokering roles.

Six Sigma

Six Sigma is a business strategy used to improve profitability (Bañuelas & Antony, 2003; Harry & Schroeder, 2000). Six Sigma differs from historical quality improvement initiatives in that its focus is limited to improving the quality of existing processes and products without purposeful linkage to profitability. While Six Sigma includes elements that target quality improvement, financial measures typically define the improvement outcomes. Six Sigma professionals employ a variety of techniques to eliminate variability in business processes throughout the life cycle of the product from product conception, design, development, production, and delivery, to after-delivery support profitability (De Feo & Barnard, 2004; Fleming, Coffman, & Harter, 2005; Harry & Schroeder, 2000).

Six Sigma began in 1979 as an initiative to improve quality and reduce the costs associated with poor quality at Motorola (Harry & Schroeder, 2000). While the focus of existing quality improvement strategies focused on improving individual operations, Six Sigma took a holistic approach and sought to improve all operations within a process. The metric that identified success was 3.4 defects per million opportunities in a given

process, which is the technical representation of six sigma (Bañuelas & Antony, 2003). The lower case Greek letter sigma symbolizes standard deviation: a statistic representing the average deviation from the mean in a given distribution (Vogt, 1999). Harry and Schroeder (2000) illustrate the significance of this six sigma figure with a carpet cleaning experience. If one were to hire their wall-to-wall carpet cleaned in a 1,500 square foot house from an agency operating at the three sigma level, four square feet of carpet would remained soiled. Cleaning the carpet to the six sigma level would result in a soiled area less that the size of a pinhead.

Six Sigma professionals have traditionally concentrated on projects that would mitigate risk on existing processes (Harry & Schroeder, 2000). Recent trends indicate Six Sigma professionals are also taking on projects that enhance the company's ability to develop new products (Johnson, 2002) and employee and customer engagement (Fleming et al., 2005). The unique combination of tasks that require both types of social capital provides a favorable setting for examining the relationship between social capital and performance. The acceptable performance measure for these project categories is return on investment (ROI) (DeFeo & Bar-El, 2002).

Since the introduction of Six Sigma in 1979, General Electric, Motorola, Honeywell, Samsung Electronics, Telefonica of Spain, Johnson and Johnson, DuPont, and other organizations that have adopted Six Sigma reported ROI ranging from 10:1 to 100:1 for Six Sigma projects typically focused on existing product lines. Each of these companies has expanded its Six Sigma initiatives to include Design for Six Sigma (DFSS) techniques as a means of addressing customer requirements and product design (DeFeo & Bar-El, 2002). Harry and Schroeder (2000) reported that companies operating

at the 3-sigma level can expect a 1-sigma shift improvement the first year, resulting in a 20% margin improvement, a 12 to 18% increase in capacity, a 12% reduction in the number of employees, and a 10 to 30% reduction in capital. Companies can expect a 1-sigma improvement shift each year until they reach the 4.7-sigma level; then, the cost savings become harder to acquire (Harry & Schroeder). After one reaches the 4.7-sigma level of doing business, the rate of improvement begins to flatten, and companies need to reassess their Six Sigma technique. Techniques designed to improve existing processes and products need to give way to methodologies that focus on entrepreneurial schemes and other forms of exploration (McKenzie, 2004).

Major corporations, including General Electric, Allied Signal, Raytheon, Polaroid, and Asea Brown Boveri have also deployed Six Sigma initiatives to improve their processes, and they have successfully recovered significant portions of losses attributed to the cost of poor quality (Harry & Schroeder, 2000). The cost of poor quality in most companies reportedly accounts for about 25% of annual sales (DeFeo & Bar-El, 2002). Companies deploying Six Sigma principles aimed at improving existing processes or products can expect 1-sigma improvement per year until reaching the 5-sigma level when the rate of improvement continually decreases (Harry & Schroeder).

A company whose processes are operating at the 3-sigma level can expect 66,807 defects per million opportunities (DPMO). A 1-sigma improvement decreases the expected DPMO to 6,210, the next round of improvements brings the defect level down to 233 per million opportunities, and finally processes operating at the 6-sigma level can expect only 3.4 DPMO (DeFeo & Bar-El, 2002). Incrementally, that represents reductions in DPMO of 60,597, 5,977, and 230 as the processes achieve 4-, 5-, and 6-

sigma status respectively. This apparent diminishing return provides strong impetus for Six Sigma professionals to shift their emphasis to other aspects of the operation and deploy different techniques.

Companies that invoked Six Sigma practices to either fix or improve the existing value stream of existing products or processes used the *define, measure, analyze, improve and control* (DMAIC) methodology (Banuelas & Antony, 2003; Taghaboni-Dutta & Moreland, 2004). There is increasing evidence that companies are taking a proactive approach by focusing their Six Sigma efforts on product development by using the design for Six Sigma (DFSS) approach (Banuelas & Antony; DeFeo & Bar-El, 2002; Johnson, 2002; Johnson & Swisher, 2003). This research concentrated on the BR Company that has successfully deployed Six Sigma principles to either fix or improve existing products and processes (hereafter referred to as sustaining projects) generating a gross benefit of $1.8 billion in the first four years of Six Sigma implementation (Sosbe, 2003). The BR Company is now deploying Six Sigma professionals to address entrepreneurial projects that are projects related to growth, identifying customer requirements, and new product development (McKenzie, 2004).

Design for Six Sigma (DFSS) is a technique that allows companies to address entrepreneurial opportunities and use Six Sigma to enhance product development (Bañuelas & Antony, 2003; DeFeo & Bar-El, 2002; Johnson, 2002; Puaar, 2003). In order to manage the transition from process improvement to product development, the Six Sigma team must shift from the myopic approach to examining the existing processes in minute detail to a broader, more holistic view of the environment that influences their operation. Consequently, the dense, highly cohesive social network that served the Six

Sigma professional well when tasked to improve existing processes must open, allowing access to innovative solutions and product expansion (Kelly, 2001). Organizational leadership must look beyond the typical closed network in which Six Sigma professionals typically reside and ensure access to brokerage opportunities for innovative solutions (Burt, 1992, 2001b, 2004b; March, 1991). Competitive advantage belongs to those whose social capital is suited for the impending task.

The company that is the object of this doctoral dissertation study, the BR Company, introduced Six Sigma in 1999 and reported a cumulative gross benefit of $1.8 billion in the first four years of their Six Sigma initiative (Sosbe, 2003). Not unlike other companies employing Six Sigma, BR Company is finding it advantageous to shift the Six Sigma focus from cost reduction efforts on existing processes to a focus on growth, the identification of customer requirements, and new product development (Puaar, 2003). Six Sigma cost reduction efforts on existing product lines typically meant emphasis on driving out variability, increasing throughput, improving yield, and higher efficiencies within the well-defined confines of the process owner. Shifting emphasis to growth, the identification of customer requirements, and new product development calls for Six Sigma professionals to employ new techniques involving a more expansive environment in order to capitalize on innovation, new ideas, and break free from existing paradigms (Bañuelas & Antony, 2003; Kuhn, 1996; March, 1991; Puaar, 2003).

Summary

The review of literature revealed a substantial amount of research addressing the closure and brokerage constructs of social capital individually. Conversely, there were few empirical studies addressing the influence of closure and brokerage social capital

constructs simultaneously in a single setting. In this study, the researcher sought to answer questions regarding the correlation between social capital and performance across a single enterprise where Six Sigma professionals with different types of social capital (closure and brokerage) are deployed to lead either sustaining or entrepreneurial projects.

Conclusion

This chapter provided a review of the literature pertaining to social capital, social network theory, Six Sigma, and the empirical measures used in social network analysis. The germinal works of Pierre Bourdieu, James Coleman, and Robert Putnam provided the basis for reviewing the concept of social capital. The evolution of Jacob Moreno's sociogram and the ensuing discipline of sociometry introduced the pertinent notion of closure and brokerage in network theory. Finally, the chapter concludes with a review of Six Sigma principles found in extant scholarly publications and BR Company archives.

CHAPTER 3: METHODOLOGY

The previous chapters provided general background information regarding the nature of the study, its significance to academia and leadership, and a review of related literature. This chapter further delineates the proposed methodology employed to conduct this research. The intent of this descriptive correlational research study was to add to the body of knowledge by further defining the correlation between social capital and performance of Six Sigma teams in a large, multi-site, electronics company within the United States.

Research Design

Figure 1 provides a graphic representation of the research design. This descriptive correlational study began with a problem definition and a suggested area of exploration that could possibly add to the body of knowledge surrounding the issue. A comprehensive literature review and the development of an appropriate research design followed in sequence. A pilot study was conducted before beginning the formal study. After the data were collected and analyzed, detailed findings were reported in chapter 4. Finally, chapter 5 provides a research summary and recommendations for further study.

The researcher used the random selection procedure to draw samples from the sampling frame. Construction of these subsets of the sampling frame was accomplished by first listing alphabetically all Six Sigma projects in the sampling frame and assigning each project a unique number, beginning with number one and continuing sequentially until every project had a number assigned. Second, a random number table was generated using the Microsoft Excel *randbetween* function, drawing from all the inclusive numbers from 1 to 210 (where 210 represents the size of the sampling frame).

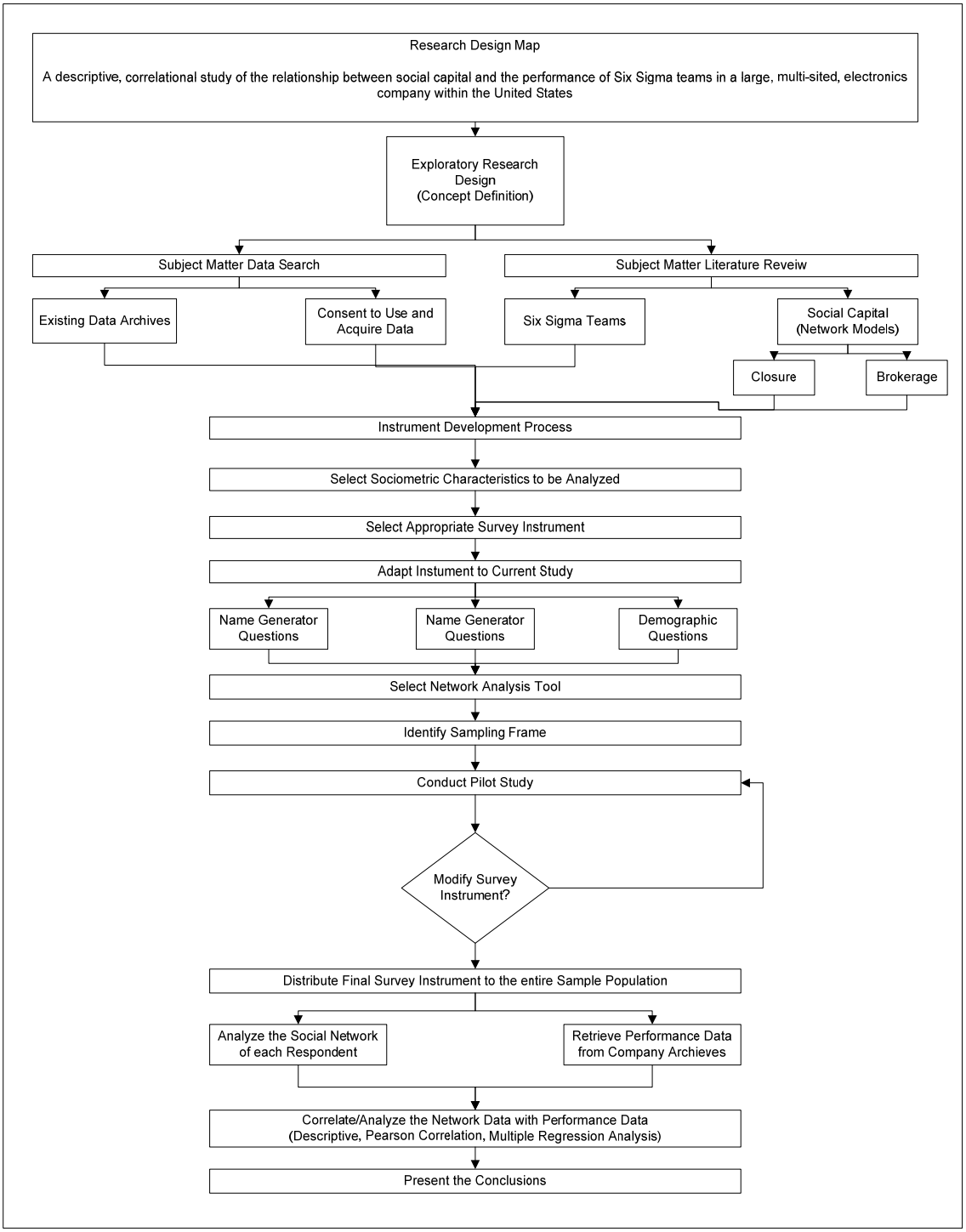

Figure 1. Research design map.

Third, a contiguous block of cells equal to the size of the desired sample was selected from the random number table. Duplicate numbers were discarded, and the next cell was

included in the set, repeating this step until the subset of random numbers equaled the desired sample size.

Finally, the numbers in the subset of the random number table were associated to the unique number assigned to the Six Sigma project. The projects identified by this procedure constituted the sample. This entire procedure was repeated for each instance requiring a sample. A pilot study was conducted before the main study by distributing the sociometric and demographic surveys to a randomly selected sample of 10 Six Sigma professionals. The responses from the pilot study were used to construct sociograms of the network in which the Six Sigma professionals reside, and constraint scores were calculated.

After the data were analyzed, a qualitative interview was conducted with each of the responding Six Sigma professionals in the pilot study. These interviews were conducted within one week after the initial data analysis, either in a face-to-face setting or over the telephone. Results from the interviews were used to make adjustments to the survey instruments. Since the changes to the survey instrument were minor, it was not necessary to conduct a second pilot survey with a sample of five additional Six Sigma professionals as the researcher had planned before beginning to collect data for the main study. Leedy and Ormrod (2001) suggested the use of pilot studies to "try out particular procedures, measurement instruments, or methods of analysis" (p. 116).

This study was a non-experimental quantitative correlational examination of a possible correlation between the social capital of Six Sigma professionals and their reported performance outcomes. Social capital concomitant with the various social network structures in which the Six Sigma professionals resided were quantified as a

level of constraint. Constraint is the strength of the relationship between the Six Sigma professionals and the other members of the social network measured by the proportion of time and energy expended to maintain the relationship (Burt, 1992). Social network theorists suggested that different types and levels of social capital emanate from various types of social network structures (Lin et al., 2001). The measure for performance outcomes was the reported financial benefit recorded in BR Company archives at the conclusion of the Six Sigma project.

Financial benefit includes measures of operating profit, cash flow, mitigated risks, and opportunities captured. Documenting the financial benefit at the conclusion of Six Sigma projects is regulated by BR Company policy (J. McKenzie, personal communication, March 2005). Operating profit refers to the resulting increases in profit or reduction in the Estimated Cost at Completion that is directly attributed to Six Sigma. Examples of operating profit include additional award fees, increased profit resulting from increased sales, or the elimination of unallowable charges. Cash flow is the improvement in cash flow before and after the Six Sigma project. Accelerated cash receipts and working capital improvements are examples of cash flow improvements. Any risk with a probability of occurrence greater than 50% is reported at the full potential value, and Six Sigma efforts that contribute to the elimination of those risks are booked at the full value. Opportunities captured because of Six Sigma initiatives are booked at their full monetary value.

Appropriateness of Design

The purpose of correlational research methods is to investigate relationships between two or more variables (Leedy & Ormrod, 2001). Researchers are cautioned that

correlations are easily misinterpreted as being synonymous with causation (Miller & Salkind, 2002), and Leedy and Ormrod explicitly stated, “Correlation does not, in and of itself, indicate causation” (p. 193). Correlation provides the researcher with enough supporting evidence to declare whether a relationship exists, and it provides information regarding the strength of the relationship (Leedy & Ormrod). The purpose of this study was to examine the correlation between the social capital of the Six Sigma professionals and their team’s performance.

Measuring the variables of this study along a natural continuum instead of creating groups and treating each category as discrete units provided increased statistical power when analyzing the data (Cone & Foster, 1993). Cone and Foster likewise suggested “that correlational designs are often most appropriate when you conceptualize your independent variables as natural continua” (p. 177), and correlational designs are appropriate if the researcher does not manipulate the independent variable. The intent of this study was to examine ex post facto data that reflected the influence of past correlation. There was no intent to manipulate the independent variable.

Research Questions

The general notion put forth by Lin (2001b) that the premise behind social capital is the “investment in social relations with expected returns in the marketplace” (p. 19) found wide support (Burt, 1992; Coleman, 1990; Lin et al., 2001). Likewise, there was general agreement among network theorists suggesting competitive advantage with closed networks with regard to preserving and maintaining resources (Burt, 2001b; Coleman, 1990; Lin 2001), and competitive advantage with brokerage networks with regard to innovation and entrepreneurial activities (Burt, 1992, 2001b, 2004b;

Granovetter, 1973; March, 1991). Growth and product development are ready measures of innovation and entrepreneurial activities within industrialized organizations. There appears to be a lack of research that examines the influence of social capital on performance gained from differing social structures within a single organization.

This study contributed to the body of knowledge by examining performance outcomes of both closed and brokerage networks of Six Sigma professionals within the BR Company. Six Sigma projects were classified as either sustaining (i.e., projects related to an existing product or process) or entrepreneurial (i.e., projects related to growth or product development), and the social capital of the Six Sigma professionals leading the team was correlated with the performance outcome. Guiding this research were the questions:

R1: What is the degree to which the social capital (constraint) of the Six Sigma professional correlates to performance outcomes for sustaining projects?

R2: What is the degree to which the social capital (constraint) of the Six Sigma professional correlates to performance outcomes for entrepreneurial projects?

Hypotheses

Coleman (1988, 1990) emphasized the importance of network closure when addressing the construct of social capital. Other studies have demonstrated a positive relation between a closed, cohesive network and group performance (Chang & Bordia, 2001), and more reliable communication channels and protection from people external to the group are exhibited in closed networks (Burt, 2000). Closed networks are likewise conducive to increased trust among mutual friends because of the fear of violations being

disclosed to other group members (Granovetter, 1992), and closed networks augment the exploitation of existing resources (March, 1991).

These authors had in common the underlying premise that familiarity with the operating environment in which the social network resides exists in closed networks. Using network constraint as a measure of closure, this researcher posited a positive correlation between network constraint and performance when Six Sigma professionals lead projects in a known environment or value stream. Hence, the researcher formulated the following alternative hypothesis $H1_a$: There is a statistically significant positive correlation between constraint and performance outcomes for sustaining projects.

There is empirical evidence suggesting that brokerage networks, identified as social networks that are rich in structural holes (gaps or disconnections between actors) and exhibit low network constraint, provide competitive advantage in certain instances. Previous studies suggested that network constraint is negatively correlated with new product innovation (Sethi et al., 2001) and the performance of cross-functional process improvement teams (Rosenthal, 1996). Weak ties between actors in a social network are a source of novel information (Granovetter, 1973; Hansen, 1999). A positive correlation exists between the social capital exhibited in brokerage networks and salary increases, early promotions, and innovation (Burt, 1992, 2001b).

Ancona and Caldwell (1992) reported clear support for their hypothesis that posited a positive relationship between ambassadorial activity and performance. March (1991) maintained that brokerage networks provide opportunity for exploration. The underlying premise of these studies is that competitive advantage is brought about by contacts outside the common environment in which the actor resides, a broker's network.

Brokers perform better in open, less constrained networks (Burt, 1992), so one could expect increased performance for the Six Sigma professional residing in open network structures when leading entrepreneurial projects. Based on this expectation, the researcher generated the following the alternative hypothesis $H2_a$: There is a statistically significant negative correlation between constraint and performance outcomes for entrepreneurial projects.

Support for alternative hypotheses are demonstrated by testing the associated null hypotheses for statistical significance. "A null hypothesis (often symbolized by the symbol H_0) postulates that any result observed is the result of chance alone" (Leedy & Ormrod, 2001). Rejection of the null hypothesis provides indirect support of the alternative hypothesis. The null hypotheses associated with the alternative hypotheses in this study were:

$H1_0$: There is no statistically significant correlation between constraint and performance outcomes for projects related to a known value stream.

$H2_0$: There is no statistically significant correlation between constraint and performance outcomes for projects related to growth or product development.

Population

The general population involved in this study included all the full time Six Sigma professionals of the BR Company. Six Sigma professionals represent approximately 1% of the company's 80,000 employees. These 640 Six Sigma professionals were active in all the business units across the company with major concentrations in Arizona, California, Texas, and New England. The population was limited to those Six Sigma professionals who completed projects between July1, 2004 and June 30, 2005 with

documented financial benefit. Financial benefit was limited to operating profit, cash flow, risks mitigated, and opportunities captured. These four financial metrics were used because they are the financial metrics that are reported to BR Company leadership, and they are used to measure the success of the Six Sigma initiatives throughout the company.

A pilot study was conducted during October and November 2005. Leedy and Ormrod (2001) suggested the use of pilot studies to "try out particular procedures, measurement instruments, or methods of analysis" (p. 116). The Adapted Social Capital Short Form questionnaire (see Appendix B) was sent by electronic mail to 20 randomly selected Six Sigma professionals throughout the BR Company before commencing the main study. The first 10 completed surveys constituted the sample for the pilot study. Data obtained from the pilot study were used to construct sociograms of the network in which the Six Sigma professionals resided and to calculate pertinent network statistics, including dyadic constraint, dyadic redundancy, effective size, efficiency, and hierarchy. It was not necessary to conduct a second pilot study since the results of the first pilot study did not call for significant changes to the survey instrument. Figure 2 depicts the population selection process, including the pilot studies.

Informed Consent

Participants in this study were informed that their participation was voluntary before they were asked to complete any survey instrument. Participants were required to acknowledge consent by electronically signing the Informed Consent Form (see Appendix D) before completing either the sociometric or the demographic survey. It was

made expressly clear to potential participants that they were under no obligation to participate, and those electing not to participate simply did not complete the surveys.

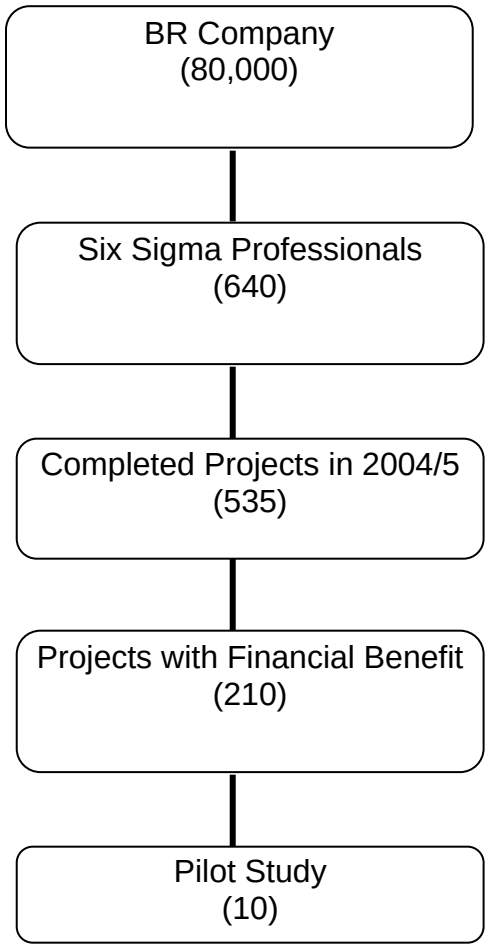

Figure 2. Population selection process.

Sampling Frame

The BR Company employs 80,000 people of which 640 work full-time as Six Sigma professionals. BR Company attempts to maintain approximately 1% of its population working as full-time Six Sigma professionals for a two to three year period before they are reassigned to other positions within the company. Continually developing Six Sigma professionals from the entire workforce enhances the probability of maintaining a diverse mix of professional skills.

The approximate 640 Six Sigma professionals completed 535 Six Sigma projects between July 1, 2004 and June 30, 2005. Limiting the search to include only projects with financial benefit in the form of operating profit, cash flow, risk mitigated, and opportunities captured (the measure of performance used in this study), reduced the total count to 210 projects. A significant number of Six Sigma professionals completed multiple projects within the sample timeframe, but their names were only included once in the sampling frame. There were 126 different Six Sigma professionals responsible for completing 210 projects and booking $764,105,960 in financial benefit between July 1, 2004 and June 30, 2005. Other pertinent data obtained from the BR Company database included the name and electronic mail address of the Six Sigma professional executing the project, the business unit that hosted the project, project details, and the financial benefit associated with the project.

A sample size of 30 projects predictably represents the sampling frame with a 95% level of confidence, assuming a standard deviation of 12 and a margin of error of four. The equation (Triola, 2001, p. 329) depicted in Figure 3 was used to calculate the sample size.

$$n = \frac{N\sigma^2(z_{\alpha/2})^2}{(N-1)E^2 + \sigma^2(z_{\alpha/2})^2}$$

Figure 3. Sample size estimation of mean with finite population correction factor.

The standard deviation was estimated by using the results of a previous study (Triola, 2001). Rosenthal (1996) conducted a study involving Process Improvement Teams, and she reported an overall *SD* = 6 for the network constraint exhibited by all the team members in her study (p. 111). Rosenthal measured constraint on a scale ranging from zero to one whereas in this study the researcher is proposing the use of a scale

ranging from 1 to 100. Therefore, Rosenthal adjusted her results by a factor of 100. Rosenthal reported a *SD* = 3 associated with the standard deviation surrounding the individual team members. As a conservative measure, two standard deviations (2x3) were added to the base standard deviation (6) to derive the estimated *SD* = 12 that was used to calculate the sample size for this study.

Confidentiality

This study ensured confidentiality by means of a mutual written agreement between the researcher and each of the participants. The Informed Consent Form (see Appendix D) was presented to the potential participants before any interview or survey was administered, and they were clearly informed that their participation was voluntary. Participants were able to withdraw from the study at any time without consequence, their personal anonymity was guaranteed, and they were assured that all records and the list of participants would be confidential. All research records and datasets, electronic and paper, were stored in a private, secure storage area, to which only the researcher has access. A coding scheme was employed to identify participants.

Geographic Location

This dissertation had no specific geographical limitations. The selection of participants was only limited by the confines of the sampling frame previously described. Participants were employed at multiple BR Company sites, including major locations in Arizona, California, Texas, and New England.

Instrumentation

The instrument for this study is an adaptation the Social Capital Short-Form (see Appendix B) that was developed at the University of Chicago Graduate School of

Business specifically to measure social capital of professionals (Burt, n.d.). Permission from Burt was granted to the researcher to use the Social Capital Short-Form (see Appendix C) in this research study. Burt (1992, 1997b, 2000, 2001b, 2004b) argued extensively that social capital is a function of the structure of one's social network. This questionnaire was purposefully designed to gather data for a computer network analysis of an individual's social capital (Burt, n.d.).

The Social Capital Short-Form questionnaire poses name generator questions (e.g., Who would be identified as essential sources for a person assuming your position?, With whom have important matters been discussed?, and Who is your immediate supervisor?). Then, the names are arranged into a convenient list and name interpreter questions are used to identify the strength and frequency of contacts within the egocentric network. The name generator method of accessing social capital is "the more common method and has been used extensively in the network literature" (Lin, 2001b, p. 87).

Name generators such as the Social Capital Short-Form emphasize relationships and correlations between actors in the social setting rather than the actor's personal attributes. Moreover, name generators are well suited for collecting data about egocentric networks (Marsden, 2005), and this study focused on the egocentric network of individual Six Sigma professionals.

Data Collection

Survey and questionnaires are used extensively in the study of social networks for both whole networks and egocentric networks (Marsden, 2005). Researchers studying whole networks usually send questionnaires to the entire predetermined population, and respondents are asked to either rank or rate relations with the other actors in the network.

Egocentric network studies are not artificially bounded. Questionnaires that include name generators are sent to a large open population, allowing the respondents to identify actors residing in their social networks. Both techniques rely heavily on self-reported data. In this study, the researcher sought to assess the correlation between individual Six Sigma professionals and the performance of their team and used surveys designed to define egocentric networks.

Surveys that include name generator questions provide the more common method of obtaining data to assess social capital in egocentric networks (Lin, 2001b). Name generators have been used to conduct network analysis on a variety of disciplines to include managerial performance (Rodan & Galunic, 2004), conversation (Bearman & Parigi, 2004), social policy (White, 2002), marketing (Webster & Morrison, 2004), and innovation (Burt, 2004b).

Data for this research study were collected from the participants by two distinct methods. The Social Capital Short-Form adaptation (see Appendix B) was used to collect name generator and name interpreter data for both the pilot study and the main study. A follow-up to the pilot study was conducted either face-to-face or over the telephone. Other data pertaining to the performance outcome came directly from the BR Company database of Six Sigma projects.

The adapted Social Capital Short-Form was introduced with an electronic copy of the Informed Consent Form (see Appendix D) that was completed before the participant could proceed with answering the questionnaire. The participants' responses were translated into an Excel spreadsheet that was parsed and imported into UCINET (Borgatti et al., 2002) for network analysis. The data files were also formatted and merged with

data from the BR Company Six Sigma database and subsequently imported into SPSS for correlational, regression, and descriptive analyses.

Data collected during interviews regarding quality and clarity of questions were tabulated in order to capture the responses and detect trends from all the pilot study participants. Name generator and name interpreter responses were codified and manually entered in the UCINET (Borgatti et al., 2002), and the network analysis was repeated and the data preserved for comparative analysis with the results of the questionnaire generated network analysis.

Data Analysis

Variables

Independent Variable. The independent variable in this study was the social capital of Six Sigma professionals. Social capital can be measured in many ways (Burt, 2000). Measures of network size, density, and hierarchy describe social capital to some extent. "Network constraint measures the extent to which a network is directly or indirectly concentrated in a single contact" (Lin et al., 2001, p. 39). Constraint varies with the three dimensions of size, density, and hierarchy, providing a more inclusive indication of social capital in a single measure (Burt). Network constraint is the measure of social capital in this study.

Constraint. Constraint is a summary measure of the extent to which a network is concentrated to a single contact (Lin et al., 2001). The measure will be used to determine the extent to which the Six Sigma professional *i*'s network is connected, directly or indirectly, with contact *j*: $c_{ij} = (p_{ij} + \Sigma_q p_{iq} p_{qj})^2$, for $q \neq i, j$, where p_{ij} is the proportional strength of the invested relation with contact *j*. More, p_{iq} defines the proportional strength

of the invested relation with contact *q* in the same network, and p_{qj} accounts for redundancy within the network. Summing the product of $p_{iq}p_{qj}$ across all contacts q and adding *i*'s direct contact with *j* defines the time and energy expended by *i* to maintain the network (Burt, 1992; Lin et al., 2001). Squaring the expression provides an index that varies from 0 to 1, and it is dependent upon the proportional relationships between actors. In this study, the index figure is increased by a factor of 100 in order to eliminate decimal representations.

Network Size. Network size is the number of contacts in a network. As network size increases, constraint decreases because the ego is required to allocate less time and energy with alters in the network. Burt (2000) examined five study populations and reported a negative (-0.66) correlation between network constraint and size. Effective size is "the number of alters minus the average degree of alters within the ego network, not counting ties to ego" (Borgatti et al., 2002) in which degree is determined by the number of vertices adjacent to a particular vertex in symmetric graphs.

Network Density. Network density represents the average strength of the tie between contacts and is a form of network closure (Burt, 2000). Density is measured by dividing the number of ties in the Six Sigma professional's network (not counting ties involving the Six Sigma professional) by the total number of potential ties within the network and multiplying the quotient by 100 (Borgatti et al., 2002). Network density provides the most common singular measure of network cohesion (Webster & Morrison, 2004).

Hierarchy. Hierarchy (H), like density, is a form of closure, but contacts are not equally connected. Hierarchy is also similar to the measure of constraint in that both

measure redundancy, but hierarchy measures the extent to which the redundancy is attributable to a single contact (Burt, 2000). The mathematical basis for hierarchy rests in the ratio contact specific constraint to the mean level of constraint across the network $H = c_{ij}/(C/N)$, where c_{ij} is the constraint imposed on the Six Sigma professional *i* by *j*, and (C/N) represents the mean level of constraint for the entire network (Burt, 1992). Burt suggested applying the Coleman-Theil disorder index (Coleman, 1964) to quantify the distribution of choices available to individuals in the network, resulting in the equation in Figure 4.

$$\frac{\sum_j \left(\frac{c_{ij}}{C/N}\right) \ln\left(\frac{c_{ij}}{C/N}\right)}{N \ln(N)}$$

Figure 4. Hierarchy: Ego's constraint to a single alter.

In this equation, the sum of the hierarchy ratio is multiplied by its natural logarithm and divided by the maximum sum possible (Burt).

Dependent Variable. Performance of the teams led by Six Sigma professionals was the dependent variable for this study. Measures of performance include productivity (Rothman, Kirk, & Knapp, 2003), leader rating (van Der Vegt & Janssen, 2001), and outcome-based, behavior-based, or competency-based measures (Scott & Einstein, 2001). Checkland (1999) suggested that performance measures take into account efficacy (i.e., output actually produced), efficiency (i.e., the use of minimal resources), and effectiveness (i.e., whether the project was worth doing) when evaluating system level performance.

The measure of performance for this study was the financial benefit realized because of the Six Sigma professional's project. Financial benefit is a commonly

collected metric influenced by other performance measures of behavior, efficacy, efficiency, and effectiveness (De Feo & Barnard, 2004). Guidance provided by the BR Company suggested Six Sigma professionals include operating profit, cash flow, risks mitigated, and opportunities captured when documenting the financial benefit of their projects (J. McKenzie, personal communication, June 9, 2004). Operating profit results from a reduction in estimate of total costs to fulfill contractual requirements at the end of the task from either previous estimates or contract requirements. The increases in operating profit must have direct linkage to financial books of record and do not include any forecasted future benefit in order to be attributed to a Six Sigma effort.

Cash flow improvements directly attributable to Six Sigma are represented by the difference between before and after cash flows within the same year. Accelerated cash receipts and reduced costs without impact to cash receipts are examples of cash flow improvements. Risk mitigation refers to the elimination of risks identified from Risk and Opportunity Reports or risks identified during estimates to complete reviews. Risk mitigation is reported at the factor valued of the risk based on probability of occurrence. Opportunities captured include Six Sigma activities that result in additional business to the company. Opportunities captured are reported at their full potential value.

Other financial measures considered as indicators of performance included budget reduction, customer benefits, and cost avoidance. Budget reductions and customer reduction measures were eliminated from consideration in this study because they are not universally reported across the BR Company. Select business units have chosen to add these measures because of local interest in the measure. Cost avoidance measures, while a universal measure across the BR Company, were excluded from the performance

measure because cost avoidance measures are not well defined and do not require rigorous financial review. Operating profit, cash flow, risks mitigated, and opportunities captured are well-defined universal measures that are regularly reported to the BR Company leadership, which adds credence to the measure.

Analyses

This study examined the correlation between the social capital of Six Sigma professionals and performance outcomes. Moreover, as indicated in the hypotheses, it was predicted that the type of project (sustaining or entrepreneurial) affects the polarity of correlation measure between constraint and performance. Both the independent variable (constraint) and the dependent variable (performance outcome) are continuous. Assuming that the sample is normally distributed and independent, and knowing that both the independent and dependent variable follow a natural continuum, parametric statistics provided a suitable means of treatment (Cone & Foster, 1993).

Before conducting any statistical analysis, the researcher performed quantification of the social capital of each participating Six Sigma professional by analyzing the social network in which they resided. Constraint is the quantifiable measure of social capital (Burt, 1992, 2000, 2004b) and the primary measure of social capital used in this study. Constraint, and the associated measures density, effective size, efficiency, hierarchy, network size, and nonredundant contacts were determined from the data collected from the name generator and processed by the network analysis tool UCINET (Borgatti et al., 2002). Table 2 further describes each measure and shows the underlying equation and germane citations.

Constraint, the associated variables derived from the network analysis, and the control variables collected from the questionnaire underwent descriptive, correlational, and multiple regression analyses. The independent variables in this study included age, network size, effective size, efficiency, constraint, hierarchy, redundancy, education, density, and rank, and gender. Descriptive statistics for each variable included measures of the mean, standard deviation, minimum value, and maximum value. These data were used to summarize the collected data (Triola, 2001) and provided an opportunity for an overall understanding of the sample data.

The Pearson correlation coefficient was calculated for each independent/dependent variable pair using Excel and was presented in a correlation matrix. The critical value was 0.361 for an $n = 30$, and $\alpha = 0.05$ (Triola, 2001, Table A-6). Resultant correlation coefficients indicated the degree to which the variables were related. Absolute values exceeding the critical value indicate the presence of a linear

Table 2

Descriptive Metrics for Network Analysis

Name	Description	Equation	Citation
Constraint	A measure of the extent to which an ego's relationship leads directly or indirectly to an alter.	$\left(p_{ij} + \sum_q p_{iq} p_{qj}\right)^2, q \neq i, j$	(Borgatti, et al., 2002; Burt, 1992, p. 55)
Density	A measure of network completeness that evaluates the extent to which all possible relations are connected.	$\left(\frac{ties}{pairs}\right) x100$	(Borgatti, et al., 2002; Scott, 2000)
Effective size	"The number of alters minus the average degree		(Borgatti, et al., 2002, program

	of alters within the ego's network, not counting ties to the ego."		help index)
Efficiency		Effective size / number of alters	(Borgatti, et al., 2002)
Hierarchy	Ego's constraint to a single alter.	$\frac{\sum_j \left(\frac{c_{ij}}{C/N}\right) \ln\left(\frac{c_{ij}}{C/N}\right)}{N \ln(N)}$	(Borgatti, et al., 2002; Burt, 1992, p. 71)
Network size	Network size is the number of actors to which ego is directly connected.		(Borgatti, et al., 2002, program help index)
Nonredundant contacts	Nonredundant contacts are disconnected in the sense that they have no connection to one another.	An actor-by-actor matrix indicates the extent that ego is connected to each other actor in the network.	(Borgatti, et al., 2002; Burt, 1992)

correlation and, if the slope polarity is as predicted, there will be justification to reject the null hypotheses.

Constraint and other continuous control variables collected from the questionnaire and the network analysis were processed using a stepwise regression technique in order to provide a more robust measure of the interaction between the continuous variables in this study. Other continuous variables include age, network size, effective size, efficiency, constraint, hierarchy, redundancy, education, density, and rank. Resultant coefficients were compared to the critical value and the predicted slope polarity of the hypotheses as the basis of either accepting or rejecting the null hypotheses. Typing the Six Sigma project as either entrepreneurial or sustaining was obtained from self-reported data on the questionnaire. The researcher examined two categorical variables for possible

influence on performance. They were identification of the Strategic Business Unit within the BR Company that hosted the project and self-report responses about whether the project was classified as sustaining or entrepreneurial in nature.

Multivariate regression techniques were employed to provide a more thorough explanation of the possible interaction between independent variables. Multivariate regression was not used to develop a predictive model. Stepwise regression was used to mitigate the effects of too many insignificant variables on the adjusted coefficient of multiple determination, R^2 (Triola, 2001). Preventive measures mitigated the influence of the five troublesome conditions reported by Cone and Foster (1993): multicollinearity, singularity, nonlinear relationships, non-normal distributions, and homoscedasticity.

Validity and Reliability

The validity and reliability of a measurement instrument generally attest to the ability of the instrument to measure the intended characteristics and yield consistent, repeatable measurements of a stable characteristic, respectively (Leedy & Ormrod, 2001). Valid and reliable measurements influence the worth of the measurement results and whether meaningful and useful conclusions can be drawn from the participant's responses (Creswell, 2003).

Design Validity

Miller and Salkind (2002) suggested, "perhaps the most important publication in the past 50 years relative to understanding research design and planning experiments is that of Donald T. Campbell and Julian C. Stanley" (p. 50). Of particular interest to internal validity are the eight classes of extraneous variables that could influence the research outcome. Extraneous variables include history, maturation, testing,

instrumentation, statistical regression, bias selection of comparison groups, experimental mortality, and selection-maturation interaction (Campbell & Stanley, 1963). Each of these extraneous variables will be consider in turn. The extraneous effects of history did not pose any difficulty to this ex post facto study. Performance outcome (dependent variable) was a matter of BR Company record, and data describing the independent variables were collected on a single questionnaire adapted from the Social Capital Short-Form (see Appendix B), so it is unlikely that any event occurring during this short time span would affect the survey results.

Maturation, the response impact as a function of time, was not considered a factor in this study due to the short duration of time necessary to complete the questionnaire. The effects of testing the actual process of completing the questionnaire was a cause for concern. The BR Company has launched into a new phase of Six Sigma implementation that calls for emphasis on entrepreneurial efforts aimed at growth and new product development (McKenzie, 2004). Respondents to the questionnaire might have been inclined to present themselves as residing in networks more in line with company expectations than was actually the case. Respondents to network analysis questionnaires tend to overstate their value (Molina, 2001). This was one of the areas addressed during the interview portion of the pilot study, and no bias on the part of the participants was detected. There was no need to restate any of the questions.

Instrumentation was the same for each participant in the study. Small changes were made to the survey instrument because of the recommendations from the members of the pilot study. All participants ultimately were asked to complete the same survey instrument. The same algorithms were used in the treatment of each participant's data.

The same instrument was used to collect data, and using the same algorithms to treat the collected data alleviated concerns that administration of the instrumentation introduced error. Statistical regression, which refers to the selection of groups based on their extreme scores, was not a problem with this study.

Bias in the selection of comparison groups was not a factor in this study since there was no control group. The effect of experimental mortality was self-correcting in the design of the sampling frame. Randomly selected projects led by Six Sigma professionals who had terminated employment with the BR Company employment were discarded from the study. Finally, selection-maturation interaction between the extraneous variables and the experimental variables of the designed study was not a factor because a control group was not used in this study.

Factors with the potential to jeopardize the external validity of the design were considered in the design and conduct of the study. Campbell and Stanley (1963) identified the following three experimental factors: (a) the reactive or interactive effect of pretesting, (b) the interaction effects of selection biases and the experimental variables, and (c) the reactive effects of the experimental setting. None of these factors posed significant problems in this study. The effects of pretesting were minimal because the sample size of the pilot study was relatively small, and the likelihood of its members being randomly chosen for the primary study was insignificant. Interaction effects of selection bias was not a factor because this study was limited to the Six Sigma professionals employed by the BR Company and was not generalizable to other settings. Finally, the reactive effects of the experimental setting were not a factor in this ex post facto study because there was no experimental setting in the classic sense. While general

concerns of the validity of the design have been addressed, there remains the necessity of addressing the validity of the instrument used to collect the data for this study, which is primarily the name generator.

Name Generator and Name Interpreter Validity and Reliability

The basis of the questionnaire used in this study was the name generator and name interpreter; therefore, a good understanding of the validity and reliability of this type instrument is germane to this discussion. While Marsden (2005) reported, "methodological research on name generator instruments rarely addresses questions of validity because criterion data from other sources are unavailable" (p. 12), there is substantial research examining the in-practice performance of name generator instruments. Researchers examined the differences between various name generators, the manner in which respondents react to difficulties they sometimes encountered with the instruments, how terms in the instrument were understood, and how the cognitive and communicative processes implicated in answering the survey questions were understood (Marsden, 2005; Sudman, Bradburn, & Schwarz, 1996). Name generators use different criteria in the selection of alters such as specific social exchanges, affective criteria, particular role relations, or time constraints (Marsden).

Burt (1997a) demonstrated the construct validity of a multiple name generator questionnaire by examining the correlation between constraint (a measure of structural holes) and achievement (early promotion), using data obtained by Burt in 1992. Burt (1997a) drew five conclusions:

1. Use multiple name generators.
2. Measure the strength of relations in terms of intimacy and activity.

3. Understand that personal discussion generators are a minimum module sufficient to reveal social capital effects.
4. Know that corporate authority relations are an unproductive alternative.
5. Be aware that the best research strategy is to elicit both kinds or multiple personal discussion generators and multiple corporate authority generators (pp. 370-371).

Each of these conclusions was incorporated in the Social Capital Short-Form adapted for this study (see Appendix B).

Name interpreters provide data about the alters identified by the name generator by either self-reports or proxy reports. Influencing factors affecting the quality of self-reports and proxy reports include the idea that memories about others are not as elaborate as memories about self, proxy respondents tend to base their responses on their own behavior as opposed to memories, and the quality of proxy response rises with respondent-alter interaction (Marsden, 2005). Interviews with cited alters or comparisons of responses to observations or a known standard are methods of determining accuracy or reliability of self-report data (Marsden, 1990). One of the methods of the pilot study was an interview designed to ascertain the accuracy and reliability of self-report data.

This study was about the description of social ties between actors as opposed to indicators that differentiate between individual units. Marsden (1990), writing about relationships in social networks, suggested that researchers seeking to obtain information about descriptions of the social ties within the network should be concerned about accuracy. Therefore, emphasis was on informant accuracy even though Marsden cited reliability to be high (0.8) when examining the correlation between responses and observations.

Summary

Chapter 1 provided an overview of the research plan to examine the correlation between the social capital concomitant with the social network structure in which the Six Sigma professional resides and group performance. Chapter 2 provided a review of the literature pertaining to social capital, social network theory, and Six Sigma.

This chapter detailed the methodology the researcher used in this descriptive correlational research design to study the correlation between social capital and the performance of Six Sigma teams in a large, multi-site, electronics company within the United States. This chapter also detailed the research design, research questions and hypotheses, the study population, data collection and analysis methods, and it established the validity and reliability of the design and instruments.

The data obtained from this study augmented theoretical considerations regarding social capital and Six Sigma professionals and provided support to the development of leadership theory regarding the deployment of Six Sigma professionals based on whether the project is entrepreneurial or sustaining in nature. Generalizing the results of this study to other companies cannot be assumed without careful consideration of organizational and cultural differences between them and the BR Company. Replication of this study in other large organizations with embedded Six Sigma professionals leading both sustaining and entrepreneurial projects should not pose any difficulty for future researchers.

CHAPTER 4: PRESENTATION AND ANALYSIS OF DATA

The general notion set forth by Lin (2001b) that the premise behind social capital is the "investment in social relations with expected returns in the marketplace" (p. 19) found wide support (Burt, 1992; Coleman, 1990; Lin et al., 2001). Likewise, there is general agreement among network theorists suggesting competitive advantage with closed networks with regard to preserving and maintaining resources (Burt, 2001b; Coleman, 1988, 1990; Lin 2001b) and competitive advantage with brokerage networks with regard to innovation and entrepreneurial activities (Burt, 1992, 2001b, 2004b; Granovetter, 1973; March, 1991). Growth and product development are ready measures of innovation and entrepreneurial activities within industrialized organizations.

This descriptive correlational study contributed to the body of knowledge by examining performance outcomes of both closed and brokerage networks of Six Sigma professionals within the BR Company. Six Sigma projects were classified as either sustaining (i.e., projects related to an existing product or process), or entrepreneurial (i.e., projects related to growth or product development), and the social capital of the Six Sigma professional leading the team was correlated with the performance outcome. Guiding this research were the following questions:

R1: What is the degree to which the social capital (constraint) of the Six Sigma professional correlates to performance outcomes for sustaining projects?

R2: What is the degree to which the social capital (constraint) of the Six Sigma professional correlates to performance outcomes for entrepreneurial projects?

Chapter 4 describes in detail the data collection and data processing methods used in this study and the results of the analyses. Results are reported in three categories: (a)

attribute data, (b) relational data, and (c) correlational data. Attribute data refer to qualities and characteristics of the participant. Relational data refer to the contacts, ties, and connections of the social network in which the participant resides. Correlational data provide a means of examining the following hypotheses:

$H1_0$: There is no statistically significant correlation between constraint and performance outcomes for sustaining projects.

$H1_a$: There is a statistically significant positive correlation between constraint and performance outcomes for sustaining projects.

$H2_0$: There is no statistically significant correlation between constraint and performance outcomes for entrepreneurial projects.

$H2_a$: There is a statistically significant negative correlation between constraint and performance outcomes for entrepreneurial projects.

Interpretation of these data is presented in chapter 5.

Data Collection Process

Data collection for this descriptive correlational research study began by obtaining permission to access the BR Company data relating to completed Six Sigma projects. These data are stored in a dedicated electronic database used solely by Six Sigma professionals to record the results of their Six Sigma projects. BR Company granted the researcher administrative privileges to access the entire database. An ad hoc report feature of the database facilitated the generation of a special report that extracted pertinent data for this research study.

The resulting report indicated that the approximate 640 Six Sigma professionals completed 535 Six Sigma projects from July 1, 2004 to June 30, 2005. Limiting the

search to include only projects with financial benefit (negative figures represent financial losses for the project) in the form of operating profit, cash flow, risk mitigated, and opportunities captured, the measure of performance used in this study, reduced the total count to 210 projects. A substantial number of Six Sigma professionals completed multiple projects within the sample timeframe; their names were only included once in the sampling frame. There were 126 different Six Sigma professionals responsible for completing 210 projects and booking $764,105,960 in financial benefit from July 1, 2004 to June 30, 2005. Other pertinent data obtained from the BR Company database included the name and electronic mail address of the Six Sigma professionals executing the project, the business unit that hosted the project, project details, and the financial benefit associated with the project.

Random sample sets used throughout this study were drawn from the sampling frame. The construction of these subsets of the sampling frame was accomplished by first listing alphabetically all Six Sigma professionals in the sampling frame and assigning each professional a unique number, beginning with number one and continuing sequentially until every professional had a number assigned. Second, a random number table was generated using the Microsoft Excel *randbetween* function, drawing from all the inclusive numbers from 1 to 126. Third, a contiguous block of cells from the random number table equal to twice the size of the desired sample was selected. Duplicate numbers were discarded and the next consecutive cell was included in the set. Leedy and Ormrod (2001) suggested return rate for questionnaires is often 50% or less therefore this step was repeated until the subset of random numbers equaled 200% of the desired sample size. Finally, the numbers in the subset of the random number table were

associated to the unique number assigned to the Six Sigma professional. Questionnaires were sent to these Six Sigma professionals. This same procedure was used for both the pilot study and the main research study.

Pilot Study

A pilot study was conducted during October and November 2005. Leedy and Ormrod (2001) suggested the use of pilot studies to "try out particular procedures, measurement instruments, or methods of analysis" (p. 116). The Adapted Social Capital Short Form questionnaire (see Appendix B) was sent via electronic mail to 20 randomly selected Six Sigma professionals throughout the BR Company before the main study. Data obtained from the pilot study were used to construct sociograms of the network in which the Six Sigma professionals reside and calculate pertinent network statistics, including dyadic constraint, dyadic redundancy, effective size, efficiency, and hierarchy.

Pilot surveys were reviewed for apparent inconsistencies in the demographic data, social network analyses were executed, and follow-up qualitative interviews were conducted within four days of receiving the surveys. Completion of the network analyses provided opportunity to acquire proficiency in using the UCINET (Borgatti et al., 2002) analysis tool, and ensured participants correctly responded to instructions (Cone & Foster, 1993). Inputs from participants in the pilot study resulted in three modifications to the survey. First, the survey was protected as a *form* in order to make data input easier for participants. Second, additional clarification provided necessary detail to assist participants in completing the name generator. Lastly, but, perhaps most significantly, a typographical error in the question requesting the participant's gender that asked the participant to either check a box marked with a capital M for male and a lower case f for

female was corrected by annotating the selection box for both genders with a capital letter. Since the improvements to the questionnaire were self-evident, it was not necessary to conduct a second pilot study.

The initial proposal to translate the Adapted Social Capital Short Form questionnaire (see Appendix B) after incorporating recommended improvements suggested by pilot study participants into a web-based survey was abandoned because a lack of resources. BR Company agreed to provide a webmaster to accomplish the translation and establish a web interface, but schedule availability became an issue of concern. Waiting for an available webmaster would necessitate a four to six month delay in data collection. Given the success of the pilot study using questionnaires sent via electronic mail as attachments to potential participants, electronic mail was used to distribute the Adapted Social Capital Short Form questionnaire (see Appendix B) to the sample group.

Finalize Survey

Expecting a 50% response rate, questionnaires were sent via electronic mail to 63 randomly selected Six Sigma professionals in the sampling frame. After 30 days, 18 completed surveys were received for a 29% response rate. A follow-up transmittal, netted three additional responses indicating a 33% response rate. An additional 25 questionnaires were sent two weeks after the last response to randomly selected Six Sigma professionals to ensure a statistically significant sample size was obtained from the study population. Eleven questionnaires were completed and returned, a 44% response rate. Two potential participants declined in writing, and one participant failed to complete the name interpreter matrix, making it impossible to calculate network constraint. These

three responses were discounted and numbered among the non-responses. Overall, 32 of 88 questionnaires were completed and returned for a response rate of 36%.

Data Processing

Methodical processing of each questionnaire immediately upon receipt mitigated potential inconsistencies and unintentional biases in the results. Adapted Social Capital Short Form questionnaire (see Appendix B) and Informed Consent Form (see Appendix D) were received as electronic mail attachments. Participants included their name on the questionnaire in order for this researcher to extract financial benefit information from the BR Company database. Financial benefit is the measure of performance for this study. A spreadsheet was constructed to record directly reported demographic data and social network data, except the participants' name (see Appendix E).

Special precautions were taken to ensure anonymity since the participants' name appeared on the returned questionnaires. The participants' name was replaced with a four digit random number that served as personal identification throughout the remainder of the study. A copy of each questionnaire was printed with the four-digit code entered as the participant's name as an added measure to mitigate potential bias. The paper copy served as data source for subsequent network analyses. All electronic communications with attachments were archived on a dedicated removable storage device (thumb drive).

The final survey question asked the participant to assemble the names from the name generator questions into a single name interpreter matrix and identify the relationship between each person (referred to as the participant's *alters* throughout this study) on the matrix as either *Especially Close*, *Distant*, or *Neither Especially Close or Distant.* The participant's identification number (referred to as the *ego*) was added to the

matrix along with the indicated strength of relationship with alters based on answers to previous questions. Based on correspondence with a network analyst and assistant to Professor Burt, an entry was rated *Especially Close* if the ego indicated intimacy with an alter as either *Especially Close* or *Close*, or if the participant reported daily, weekly, or monthly communication with the alter. All other conditions resulted in the relationship as being *Distant* (T. Cox, personal communication, December 1, 2005). This completed the name interpreter matrix.

The name interpreter matrix was translated into a symmetrical dataset used to quantify the participant's social network. Quantified network measures included dyadic constraint, dyadic redundancy, effective network size, network efficiency, and hierarchy. Qualitative terms in the matrix *Especially Close*, blank entry (indicating neither distant nor especially close), and *Distant* were quantitatively scored 1.0, 0.4, and 0, respectively. This scoring technique corresponds with Burt's suggestion that relations between contacts scored 1.0, 0.4, and 0, for contacts classified as often, some, and rare, respectively (Burt, 2004a). A dataset representing each participant was created in order to facilitate subsequent network analyses. See Appendix F for a representative dataset.

Results

The criteria used to calculate the required sample size of 30 in chapter 3 proved conservative. A 95% level of confidence was projected from a population of 200, SD = 12, and margin of error of four using the equation depicted in Figure 3. Actual data collected from the BR Company database and returned surveys revealed the population was N = 126, SD = 3.2 for the dyadic constraint (independent variable), and there were 32 respondents to the questionnaire. Transposing the same equation to solve for margin of

error, and substituting actual population, sample size, and SD data, the margin of error for dyadic constraint was reduced from the projected level of 4 to 0.96 for this study.

Results are reported in the three categories of attribute data, relational data, and correlational data. Attribute data are regarded as qualities and characteristics belonging to the participant (Scott, 2000). These data were obtained directly from the survey and the BR Company database. Relational data refers to the contacts, ties, and connections of the social network in which the participant resides (Scott). These data were derived by processing name generator and name interpreter data with the aid of UCINET software (Borgatti et al., 2002). Correlational data were derived using Excel and SPSS version 14.0.

Attribute Data

The ages of all participants in the study ranged from 27 to 60 years old (M = 46.4, SD = 7.36). Age of participants who identified the Six Sigma projects they led as entrepreneurial ranged from 27 to 53 years old (M = 45.6, SD = 7.55). One participant from the entrepreneurial population elected not to provide age data. The age of participants who identified the Six Sigma projects they led as sustaining ranged from 32 to 60 years old (M = 47.0, SD = 7.37).

Financial benefit realized from all Six Sigma projects led by the participants in this study ranged from $33,000 to $7,100,000 ($M$ = $2,095,300, SD = $1,916,600). Financial benefit realized from entrepreneurial Six Sigma projects led by the participants in this study ranged from $507,000 to $7,100,000 ($M$ = $3,147,300, SD = $2,214,500). Financial benefit realized from sustaining Six Sigma projects led by the participants in this study ranged from $33,000 to $2,300,000 ($M$ = $1,167,100, SD = $690,700).

The highest education levels of the participants in the study included one participant with some college education, nine with Bachelor's degrees, 19 with Master's degrees, and three with doctorates. The highest education levels held by participants in the study who conducted entrepreneurial Six Sigma projects were seven participants with Bachelor's degrees, seven with Master's degrees, and one with a doctorate. Highest education levels held by participants in the study who conducted sustaining Six Sigma projects were one participant with some college, two with Bachelor's degrees, 12 with Master's degrees, and two with doctorates. Table 3 tabulates these data with percentages for the separate populations in parentheses.

Table 3

Highest Level of Education Completed (Percentage of Population in Parentheses)

Population	Some College	Bachelor's	Master's	Doctorate
Entire Sample	1 (3%)	9 (28%)	19 (59%)	3 (9%)
Entrepreneurial		7 (47%)	7 (47%)	1 (7%)
Sustaining	1 (6%)	2 (12%)	12 (71%)	2 (12%)

Prior to the pilot study, dialogue with the Six Sigma community suggested questions regarding tenure with BR Company and tenure as a Six Sigma professional problematic. Recent mergers and acquisitions would confound responses. Questions addressing the participants' rank within the company and their primary assignment served to define professional Six Sigma experience.

Participants in this study included a total of 21 individual contributors, six managers, four middle managers, and one senior manager. Participants who identified the Six Sigma project they led as entrepreneurial included six individual contributors, five

managers, and four middle managers. Participants who identified the Six Sigma project they led as sustaining included 15 individual contributors, one manager, and one senior manager.

While all the participants in this study were Six Sigma professionals, some were assigned primary functions within the BR Company other than working as full-time Six Sigma professionals. Six Sigma was an ancillary assignment for these professionals. Assignments for all participants in this study were 19 Six Sigma, six engineering, two program management, one finance, one manufacturing, one general management, and two classified themselves as other. Assignments for participants in this study who classified their Six Sigma project as entrepreneurial were seven Six Sigma, four engineering, one program management, one finance, and two classified themselves as other. Assignments for participants in this study who classified their Six Sigma project as sustaining were 12 Six Sigma, two engineering, one program management, one general management, and one manufacturing.

Relational Data

Relational data refer to the contacts, ties, and connections of the social network in which the participant resides (Scott, 2000). These data were derived by processing name generator and name interpreter data provided by the participant with the aid of UCINET software (Borgatti et al., 2002). Relational data includes network size, effective network size, network density, network efficiency, network hierarchy, dyadic redundancy, and dyadic constraint.

Network size of all social networks ascribed to participants in the study ranged from 14 to 21 (M = 18.2, SD = 2.43). Network size of participants who identified their

Six Sigma projects as entrepreneurial ranged from 15 to 21 (*M* = 19.5, *SD* = 1.96). Network size of participants who identified their Six Sigma projects as sustaining ranged from 14 to 21 (*M* = 17.1, *SD* = 2.28).

Effective network size of all social networks ascribed to participants in the study ranged from 6.2 to 15.5 (*M* = 10.8, *SD* = 2.84). Effective network size of participants who identified their Six Sigma projects as entrepreneurial ranged from 7.3 to 15.4 (*M* = 11.6, *SD* = 2.73). Effective network size of participants who identified their Six Sigma projects as sustaining ranged from 6.2 to 15.5 (*M* = 10.0, *SD* = 2.80).

Network density of all social networks ascribed to participants in the study ranged from 11.11 to 100 (*M* = 54.59, *SD* = 25.11). Network density of participants who identified their Six Sigma projects as entrepreneurial ranged from 11.11 to 100 (*M* = 52.16, *SD* =27.05). Network density of participants who identified their Six Sigma projects as sustaining ranged from 27.45 to 100 (*M* = 56.73, *SD* = 23.86).

Network efficiency of all social networks ascribed to participants in the study ranged from 0.44 to 0.86 (*M* = 0.70, *SD* = 0.12). Network efficiency of participants who identified their Six Sigma projects as entrepreneurial ranged from 0.45 to 0.86 (*M* = 0.69, *SD* = 0.13). Network efficiency of participants who identified their Six Sigma projects as sustaining ranged from 0.44 to 0.86 (*M* = 0.70, *SD* = 0.12).

Network hierarchy of all social networks ascribed to participants in the study ranged from 0.002 to 0.092 (*M* = 0.024, *SD* = 0.21). Network hierarchy of participants who identified their Six Sigma projects as entrepreneurial ranged from 0.002 to 0.088 (*M* = *0*.023, *SD* = 0.023). Network hierarchy of participants who identified their Six Sigma projects as sustaining ranged from 0.003 to 0.092 (*M* = 0.024, *SD* = 0.021).

Dyadic redundancy of all social networks ascribed to participants in the study ranged from 2.00 to 10.48 (*M* = 4.69, *SD* = 2.11). Dyadic redundancy of participants who identified their Six Sigma projects as entrepreneurial ranged from 2.00 to 10.48 (*M* = 5.16, *SD* = 2.47). Dyadic redundancy of participants who identified their Six Sigma projects as sustaining ranged from 2.11 to 7.80 (*M* = 4.28, *SD* = 1.71).

Dyadic constraint of all social networks ascribed to participants in the study ranged from 14.6 to 28.7 (*M* = 20.3, *SD* = 3.26). Dyadic constraint of participants who identified their Six Sigma projects as entrepreneurial ranged from 16.2 to 24.7 (*M* = 18.6, *SD* = 2.25). Dyadic constraint of participants who identified their Six Sigma projects as sustaining ranged from 14.6 to 28.7 (*M* = 21.8, *SD* = 3.35).

Sociograms were constructed depicting the social network of each participant as a means of providing visual reassurance of the numerical calculations. The most constrained social network was reported by participant Ego-3222, and the least constrained social network was reported by participant Ego-8287. Figures 5 and 6 provide graphical depictions of their respective social networks. In both cases, the graphical portrayal is limited to only those relations with alters classified as *Especially Close* in order to remove clutter from the diagram. All relations were considered when calculating network scores used in the analyses associated with this study.

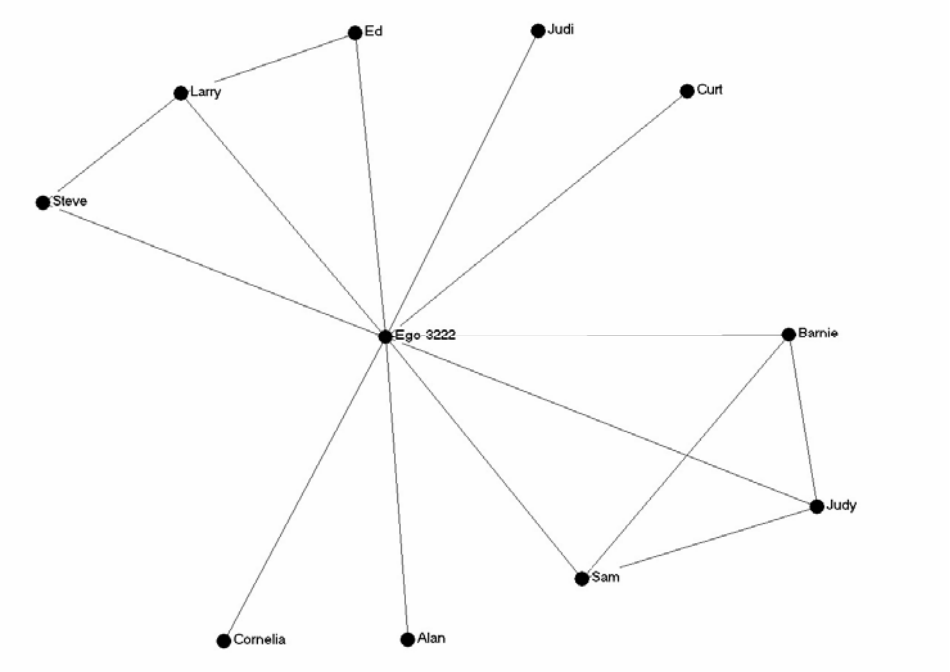

Figure 5. Sociogram of Most Constrained Network (Constraint=28.69).

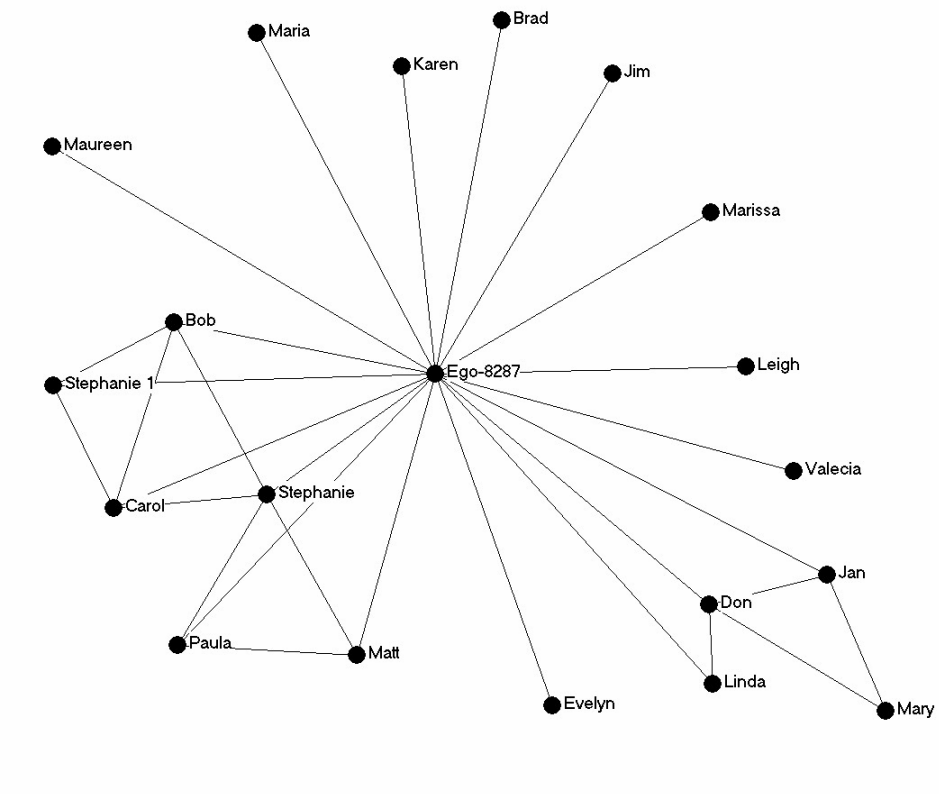

Figure 6. Sociogram of Least Constrained Network (Constraint=14.63).

Correlational Data

Correlational data were analyzed to address the research questions posed in this study. The two research questions were taken in turn and examined using the appropriate attribute and relational data previously reported in this chapter. Stepwise regression performed on each correlation matrix indicated network size as the most influential independent variable and dyadic constraint as the second most influential independent variable. This result is not unexpected since size is one of the three terms combined to produce the constraint measure (Burt, 2004a). This research was descriptive in nature and did not employ strict hypothesis testing as expected when testing hypotheses evolving from scientific theory. Statistical tests were conventionally reported, but the study emphasized descriptive data analysis.

With the first question, the researcher sought to understand the degree to which the social capital (constraint) of the Six Sigma professional correlated to performance outcomes for sustaining projects. Hypotheses addressing this question were structured using constraint as the independent variable and performance as the dependent variable. Dyadic constraint measured social capital, and financial benefit served as the measure of performance. Formally stated, the hypotheses addressing this question read:

$H1_0$: There is no statistically significant correlation between constraint and performance outcomes for sustaining.

$H1_a$: There is a statistically significant positive correlation between constraint and performance outcomes for sustaining projects.

Pearson Product-Moment correlational data derived from continuous variables associated with Six Sigma professionals reporting sustaining projects are portrayed in Table 4.

The researcher found no significant relationship when examining the relationship between dyadic constraint and performance (financial benefit) for sustaining projects. There was no support for rejecting the null hypotheses with a correlation coefficient r = .471 and a critical value equal to .482 at α =.05. Figure 7 depicts a scatter plot of the correlation between constraint and financial benefit for sustaining projects. Figure 7 includes an R-squared trend line derived from these two variables.

Multivariate regression techniques explained possible interaction between the independent variables in this study. Regressing the entire suite of continuous independent variables for sustaining projects resulted in an R^2 = .576 and adjusted R^2 = -.130. However, these scores were overly inflated because of issues with singularity and multicollinearity. Singularity resulted from including network measures of size, density, and hierarchy, since dyadic constraint is a summary measure of these three parameters. Variance Inflation Factors (VIF) calculations resulted in scores that ranged from 1.252 to 166.793. Myers (1986) indicated VIF scores greater than 10 suggest harmful multicollinearity is present. Removing the variables contributing to singularity and those variables with the highest VIF scores resulted in a more meaningful model. Regressing financial benefits against dyadic redundancy, education, dyadic constraint, age, and rank resulted in an R^2 = .381 and an adjusted R^2 = .099. VIF scores ranged from 1.086 to 1.355.

Table 4

Sustaining Correlation Table (N=17)

	1	2	3	4	5	6	7	8	9	10
1. Performance	—									
2. Age	.049	—								
3. Network Size	-.163	.257	—							
4. Effective Size	-.441	-.055	.588*	—						
5. Network Efficiency	-.344	-.243	.195	737**	—					
6. Dyadic Constraint	.471	-.052	-.779**	-.892**	-.532*	—				
7. Network Hierarchy	-.308	-.182	-.124	.507*	.501*	-.279	—			
8. Dyadic Redundancy	.236	.318	.060	-.435	-.921**	.211	-.372	—		
9. Education	-.218	-.170	.083	-.139	-.146	.014	-.149	.102	—	
10. Network Density	.400	.164	-.225	-.715**	-.896**	.593*	-.567*	.758**	.092	—
11. Rank	.239	.293	.247	-.123	-.289	-.065	-.024	.388	.175	-.032

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

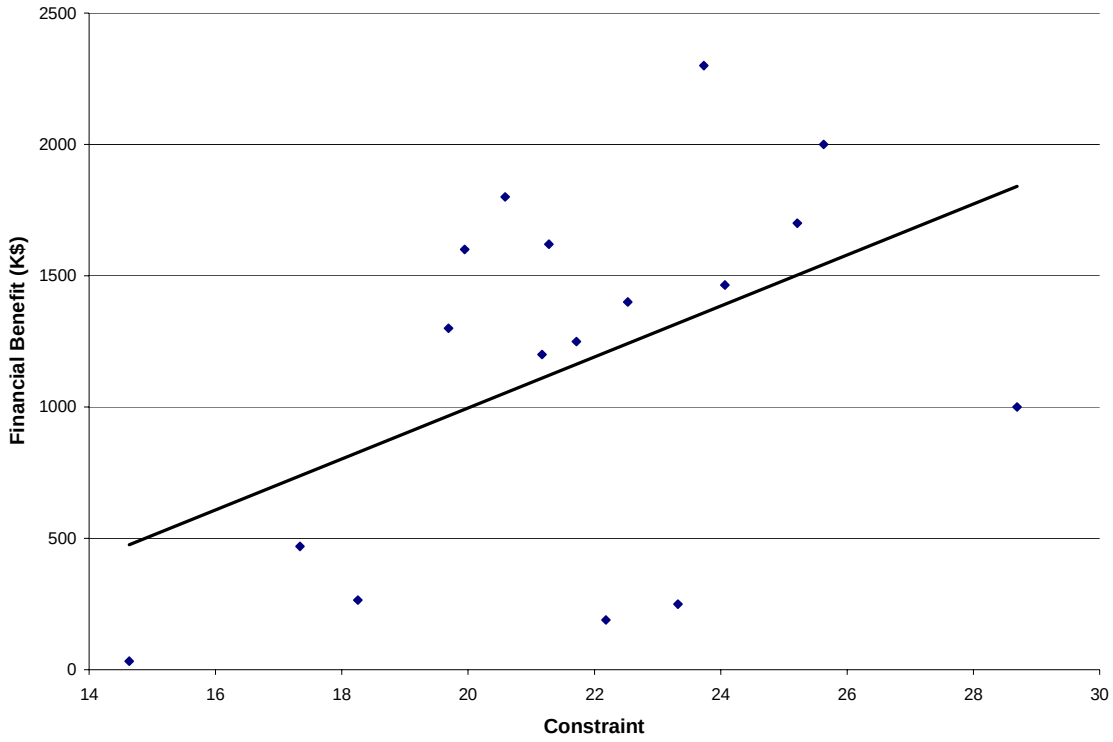

Figure 7. Sustaining projects: the correlation between constraint and financial benefit.

With the second question, the researcher sought to understand the degree to which the social capital (constraint) of the Six Sigma professional correlates to performance outcomes for entrepreneurial projects. Hypotheses addressing this question were structured using constraint as independent variable and performance as the dependent variable. Dyadic constraint measured social capital, and financial benefit served as the measure of performance. Formally stated, the hypotheses addressing this question read:

$H2_0$: There is no statistically significant correlation between constraint and performance outcomes for entrepreneurial projects.

$H2_a$: There is a statistically significant negative correlation between constraint and performance outcomes for entrepreneurial projects.

Pearson Product-Moment correlational data derived from continuous variables associated with Six Sigma professionals reporting entrepreneurial projects are depicted in Table 5. The researcher found a statistically significant relationship when examining the relationship between dyadic constraint and performance (financial benefit). There is support for rejecting the null hypotheses with a correlation coefficient r = -.737 and a critical value equal to .514 at α = .05. Figure 8 depicts a scatter plot of the correlation between constraint and financial benefit for entrepreneurial projects.

Figure 8 includes an R-squared trend line derived from these two variables. R-squared represents the coefficient of multiple determination, ranging from zero to one. Due to the effect of squaring the terms, the coefficient is always positive regardless of the slope of the trend line. Regressing the entire suite of independent variables for entrepreneurial projects resulted in an R^2 = .889 and adjusted R^2 = .518. However, these scores were overly inflated because of issues with singularity and multicollinearity. Singularity resulted from including network measures of size, density, and hierarchy, since dyadic constraint is a summary measure of these three parameters. Multicollinearity was detected when examining the Variance Inflation Factors (VIF) scores that ranged from 1.219 to 705.571. Removing the variables contributing to singularity and those variables with the highest VIF scores resulted in a more meaningful model. Regressing financial benefits against dyadic redundancy, education, dyadic constraint, age, and rank resulted in an R^2 = .696 and an adjusted R^2 = .505. VIF scores ranged from 1.024 to 1.823.

Table 5

Entrepreneurial Correlation Table (N=15)

	1	2	3	4	5	6	7	8	9	10
1. Performance	—									
2. Age	-.110	—								
3. Network Size	.553*	.093	—							
4. Effective Size	.794**	-.008	.356	—						
5. Network Efficiency	.600*	-.052	-.065	.794**	—					
6. Dyadic Constraint	-.737**	-.037	-.824**	-.676**	-.437	—				
7. Network Hierarchy	.118	-.109	-.214	.422	.675**	-.111	—			
8. Dyadic Redundancy	-.461	.020	.253	-.579*	-.942**	.234	-.622*	—		
9. Education	-.103	-.099	-.069	-.078	.006	.053	.285	-.065	—	
10. Network Density	-.363	.112	.038	-.656**	-.754**	.401	-.494	.635*	-.078	—
11. Rank	-.285	-.045	.259	-.085	-.454	-.083	-.258	.608*	-.108	.027

Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

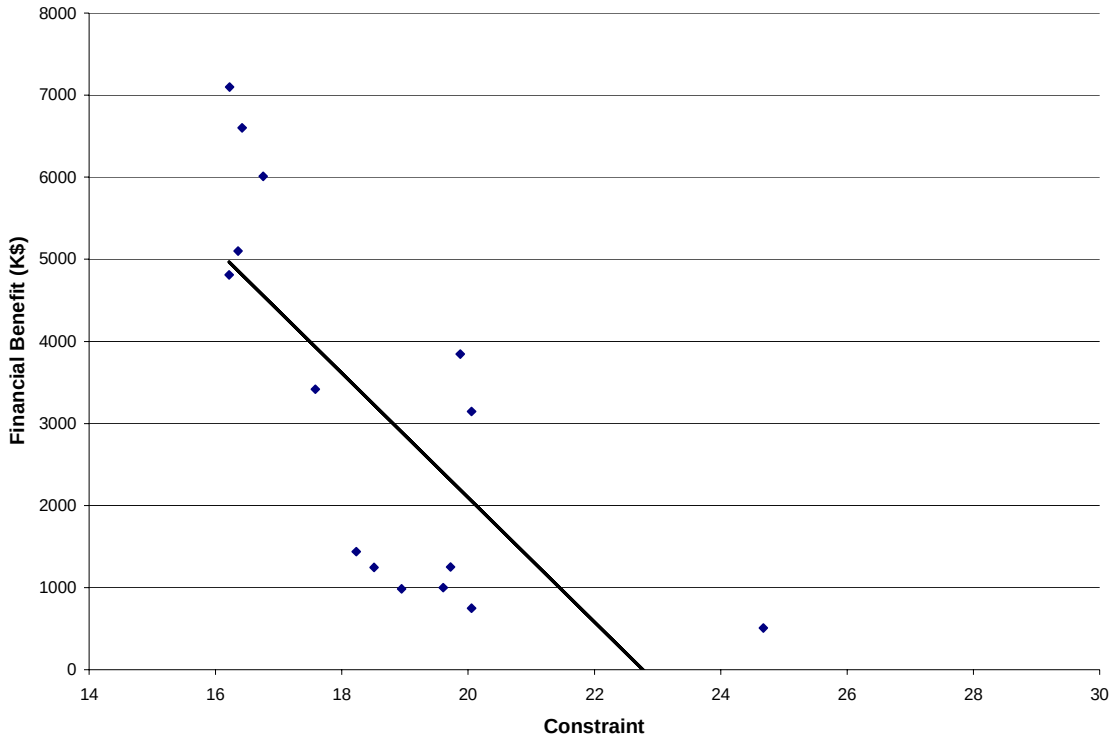

Figure 8. Entrepreneurial projects: the correlation between constraint and financial benefit.

Table 6 summarizes correlations relating to both hypotheses. Slopes in each case were in the predicted direction, however the strength of correlation associated with the sustaining projects was insufficient to reject the null hypothesis

Table 6

Correlation between constraint and performance outcomes (financial benefit)

Hypotheses	*r* =	Predicted Slope
H1: Sustaining projects.	.471	Positive
H2: Entrepreneurial projects.	-.737	Negative

Summary

The data associated with this descriptive correlational study were analyzed to determine the relationship between social capital and the performance of Six Sigma teams within the BR Company. Chapter 4 provided detailed descriptions of data collection and analysis methods. Data results are reported in the three categories of (a) attribute data, (b) relational data, and (c) correlational data. Attribute data are regarded as qualities and characteristics belonging to the participant (Scott, 2000). These data were obtained directly from the survey and the BR Company database. Relational data refer to the contacts, ties, and connections of the social network in which the participant resides (Scott, 2000). These data were derived by processing name generator and name interpreter data with the aid of UCINET software (Borgatti et al., 2002). Correlational data were derived using Excel and SPSS version 14.0.

Data analyses failed to reject the null hypothesis suggesting a positive relationship between dyadic constraint and performance in sustaining projects. Data analyses showed strong support for rejecting the null hypothesis suggesting a negative relationship between dyadic constraint and performance in entrepreneurial projects. Results are summarized and recommendations for future research are provided in chapter 5.

CHAPTER 5: SUMMARY AND RECOMMENDATIONS

Six Sigma is a business strategy used to improve profitability, both on sustaining existing processes and entrepreneurial development (Bañuelas & Antony, 2003; Harry & Schroeder, 2000). Leaders face considerable challenges when deploying Six Sigma professionals into these two differing environments. The environment concomitant with the need to exploit sustaining processes and that of exploring entrepreneurial development are considerably different. This study examined the influence of the Six Sigma professional's social capital from both environments on the performance of the teams under their charge.

The literature review suggested competitive advantage from these two constructs emerges from two different social network structures: closed networks and open networks. Lin (2001b) suggested that social capital "should be defined as *resources embedded in a social structure which are accessed and/or mobilized in purposive actions*" (p. 29). In this context, networks provide different forms of social capital depending on established relationships between network members. Some network structures are more conducive to mitigating risk and exploiting existing processes while others are better suited for exploring new product development (Burt, 2000).

This descriptive correlational study analyzed the correlation between social capital and performance of Six Sigma professionals in the BR Company, a large electronics company with multiple sites throughout the United States. Network analysis techniques were used to quantify dyadic constraint, the primary independent variable. Financial benefit (dependent variable) was the measure of organizational performance.

Guiding this research were inquiries as to the degree to which the social capital (constraint) of the Six Sigma professional correlated with the performance outcomes of sustaining and entrepreneurial projects. A positive relationship between constraint and performance outcome was hypothesized for sustaining projects, and a negative correlation between constraint and performance outcomes was hypothesized for entrepreneurial projects.

Chapter 1 provided general background information regarding the statement of the problem, nature of the study, and its significance to academia and leadership. Chapter 2 provided a review of extant and foundational literature pertaining to social capital and Six Sigma. Chapter 3 presented the study's methodology and research design. Chapter 4 presented data and associated analyses resulting from the execution of the research design. Conclusions inferred from reported data analyses, implications for leadership, and recommendations for future studies follow.

Conclusion

The purpose of this study was to examine the degree to which the social capital (constraint) of the Six Sigma professional correlates to organizational performance outcomes for both sustaining and entrepreneurial projects. Hypotheses were structured using social capital as independent variable and performance as the dependent variable. Dyadic constraint was employed as the measure of social capital and financial benefit served as the performance measure.

Social Capital and Performance in Sustaining Projects

Examining the correlation between dyadic constraint (social capital) and performance (financial benefit) for sustaining projects indicated no statistically

significant correlation. Even though the slope of the R^2 trend line was in the predicted direction, there was no support for rejecting the null hypotheses with a correlation coefficient r = .471 and a critical value equal to .482 at α =.05. The results of the study did not warrant rejecting the null hypothesis, or accepting the alternative hypothesis, that read:

$H1_0$: There is no statistically significant correlation between constraint and performance outcomes for sustaining.

$H1_a$: There is a statistically significant positive correlation between constraint and performance outcomes for sustaining projects.

While the data do not support the hypothesis suggesting a positive correlation between constraint and performance for sustaining projects, outright rejection of theories suggesting competitive advantage exists for persons residing in closed networks when exploiting established processes and technologies is premature. Mitigating correlates might have unduly influenced the results of this study. For instance, Six Sigma professionals are viewed as change agents throughout the BR Company (McKenzie, 2004), suggesting that Six Sigma professionals are expected to bring innovation to projects they lead. Perhaps a larger sample size may have obtained significant effect. Future studies that examine the correlation between social capital and performance of the embedded leadership of existing processes and product lines may also generate different results.

Dyadic constraint measures a range on a continuum from 0 to 100 with a score of 100 representing a completely closed network. Burt (2005) summarized constraint scores from eight different study populations, and the resultant summary filled the entire

spectrum with relative uniformity. Dyadic constraint scores in this study for Six Sigma professionals describing their projects as sustaining were in the lower quartile of the continuum ranging from 14.6 to 28.7 (M = 21.8). Dyadic constraint scores on the lower end of the spectrum indicate an open social network, a structure more conducive to entrepreneurial endeavors (Bur).

Social Capital and Performance in Entrepreneurial Projects

Examining the correlation between dyadic constraint (social capital) and performance (financial benefit) for entrepreneurial projects indicated a statistically significant correlation. There was support for rejecting the null hypotheses with a correlation coefficient r = -.737 and a critical value equal to .514 at α=.05. The results of the study warranted rejecting the null hypothesis and accepting the alternative hypothesis that read:

$H2_0$: There is no statistically significant correlation between constraint and performance outcomes for entrepreneurial projects.

$H2_a$: There is a statistically significant negative correlation between constraint and performance outcomes for entrepreneurial projects.

Results are consistent with previous research that concluded a negative correlation between network constraint and increased salary, outstanding performance evaluations, early promotions, large bonuses, French salary, Asia-Pacific salary, and recognition of TQM team achievements (Burt, 2005). The consistency with Rosenthal (1996) in her study of social networks and team performance is strikingly similar in that she reported a -.79 correlation between constraint and team performance compared to the correlation of -.74 in this study. Examination of the correlation between constraint and performance of

the Six Sigma professionals within the BR Company reinforced prior research that suggested a negative correlation between network constraint and performance (Burt, 1992, 2000, 2005; Hansen, 1999; March, 1991; Ronchi, 2004).

General Conclusion

This study indicated significant differences in the performance of Six Sigma professionals depending on the type of project undertaken. The alternative hypothesis predicting a positive correlation between constraint and performance for sustaining projects was rejected. There was insufficient evidence to conclude there is a positive correlation between constraint and performance for sustaining projects.

The second alternative hypothesis that suggested a negative correlation between constraint and performance for entrepreneurial projects was accepted as statistically significant ($p = 0.01$). There is a demonstrable increase in the organizational performance outcomes of Six Sigma professionals leading entrepreneurial projects with less dyadic constraint in their social network. Important findings in this study for those in leadership roles that involve Six Sigma professionals suggest the influence of the social capital concomitant with the Six Sigma professional is different for sustaining projects and entrepreneurial projects.

Implications

BR Company, like others that have entrenched Six Sigma principles into their culture as a strategy to improve profitability (Bañuelas & Antony, 2003; Harry & Schroeder, 2000), launched initiatives to extend Six Sigma beyond the scope of improving sustaining operations to include entrepreneurial activities (Johnson, 2002; McKenzie, 2004). The first implication of this study is that the initiatives to expand Six

Sigma into entrepreneurial activities within the BR Company have been effective. A random sample from the 126 Six Sigma professionals completing projects between July 1, 2004 and June 30, 2005 indicated that 47% of those projects were entrepreneurial projects as opposed to sustaining projects. More importantly to the BR Company stakeholders, the entrepreneurial projects accounted for 70% of the financial benefit realized from all the Six Sigma projects in this study, $47,210K of $67,051K reported by the sample.

A second implication from this study is that Six Sigma professionals within the BR Company typically reside in open social networks. Dyadic constraint scores ranged from 14.6 to 28.7 for those Six Sigma professionals reporting sustaining projects, and 16.2 to 24.7 for entrepreneurial projects, with a mean of 20.3 for all projects. Dyadic constraint is measured on a continuum between 0 and 100, indicating the Six Sigma professionals at BR Company are categorized within the lower quartile of the continuum. Perhaps this provides insight to understanding the reduced performance of those Six Sigma professionals reporting sustaining projects.

A third implication is that the social capital concomitant with Six Sigma professionals within the BR Company is not conducive for the conduct of sustaining projects in that there is no significant correlation between their social capital and performance. Correlational data between dyadic constraint and performance was inconclusive with an $r = .471$. The trend was in the predicted direction perhaps suggesting BR Company leadership may want to look to their embedded professionals, those with extensive tacit product and process knowledge, to effect improvements on existing technologies.

A fourth implication is that Six Sigma professionals residing in open social networks clearly provide increased financial benefit by working entrepreneurial projects. When examining dyadic constraint against performance, this study demonstrates the competitive advantage of an open social network with a strong correlation of -.737 (p = 0.01). This strong negative correlation indicates Six Sigma professionals leading entrepreneurial projects demonstrate increasingly higher performance the more open and less constrained the social network in which they reside. Six Sigma professionals residing in open networks and leading entrepreneurial projects accounted for 70% of the financial benefit reported by the entire sample in this study.

The central problem this research study addressed was that the failure to consider the type of social capital concomitant with the Six Sigma professional before assigning them to a specific project could result in millions of dollars in lost revenue for organizations like the BR Company. Implications derived from this study should encourage the leadership at BR Company to continue their initiative to shift Six Sigma emphasis from sustaining projects that focus on existing processes and products to entrepreneurial projects that focus on growth and new product development. Dyadic constraint scores of the BR Company Six Sigma professionals indicate they reside in open networks, and this study reports a strong correlation between constraint scores and increased performance when leading entrepreneurial projects. BR Company leadership should reconsider the deployment of Six Sigma professionals to lead sustaining projects due to the reduced financial benefit realized by those projects (53% of the Six Sigma professionals sampled only accounted for 30% of the financial benefit in this study).

Recommendations

The results of this study do not support the hypothesis that there is a positive correlation between the social capital of Six Sigma professionals leading sustaining projects and performance. Future research might include additional criteria in the determination of what projects are categorized as sustaining or entrepreneurial projects, eliminating bias associated with the direct report technique used in this study to determine the project type. A stratified sampling scheme only including Six Sigma professionals who have led sustaining projects to examine the correlation between social capital and performance within that stratified population might also be considered. This technique would ensure a more stringent representativeness to the sample in the study (Cone & Foster, 1993).

Another implication of this study regarding sustaining projects is that perhaps deploying Six Sigma professionals to improve existing processes and products might not be the most effective use of Six Sigma professionals. The BR Company might attain higher return on investment by providing tailored training in the principles of Six Sigma to the managers and supervisors with extensive explicit and tacit knowledge of existing processes and products requiring improvement. A separate study comparing the performance of Six Sigma professionals deployed to an existing improvement site to the performance of current managers and supervisors executing Six Sigma principles on the possesses and products under their charge could provide greater insight to BR Company leadership. Maintaining an active staff of 800 Six Sigma professionals is an expensive overhead for the BR Company. If a study indicated more efficiency exists with the technique of using the current managers to execute Six Sigma principles on sustaining

projects, the BR Company could reduce the size of its full-time Six Sigma staff, which should translate into measurable cost savings for the company.

A longitudinal study that examines the robustness and permanency of the social network concomitant with the Six Sigma professional could provide BR Company leadership additional insight into the performance of their Six Sigma professionals. Such a study could address potential correlates that could affect social capital over time. Consideration could be given to personality, product type, operating environment, and leadership style.

Replicating this study in other companies that employ Six Sigma principles on both sustaining and entrepreneurial projects could potentially pose little difficulty to future researchers. General Electric, Motorola, Honeywell, Samsung Electronics, Telefonica of Spain, Johnson and Johnson, and DuPont are among the companies that use financial benefit as a measure of performance. Each of these companies have also expanded their Six Sigma initiative to include Design for Six Sigma (DFSS) techniques as a means of addressing customer requirements and product design (De Feo & Bar-El, 2002), indicating the existence of both sustaining and entrepreneurial projects.

Summary

This descriptive correlational study analyzed the correlation between social capital and the performance of Six Sigma professionals in the BR Company, a large electronics company with multiple sites throughout the United States. Network analysis techniques were used to quantify dyadic constraint, the primary independent variable. Financial benefit (dependent variable) was the measure of organizational performance.

Guiding this research were inquiries as to the degree to which the social capital (constraint) of the Six Sigma professional correlated with the performance outcomes of sustaining and entrepreneurial projects. A positive correlation between constraint and performance outcome was hypothesized for sustaining projects, and negative correlation between constraint and performance outcomes was hypothesized for entrepreneurial projects. The results of the study fail to support the hypothesis suggesting a positive correlation between constraint and performance for sustaining projects. There is statistically significant support for the hypothesis suggesting a negative correlation between constraint and performance for entrepreneurial projects.

The findings from this study are important for those in BR Company leadership roles that involve Six Sigma professionals and suggest the influence of the social capital concomitant with the Six Sigma professional is different for sustaining projects and entrepreneurial projects. It is recommended that BR Company leaders reconsider their approach to deploying Six Sigma professionals to work sustaining projects. It is further recommended that they continue or increase the use of Six Sigma professionals to lead entrepreneurial projects.

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APPENDIX A: PERMISSION TO USE PREMISES

CONFIDENTIAL

DOCUMENT ON FILE

APPENDIX B: ADAPTED SOCIAL CAPITAL SHORT-FORM

CONSENT TO ACT AS A RESEARCH PARTICIPANT

Introduction

Gerald Heidt, a Doctoral Candidate at the University of Phoenix and an independent researcher, has been given permission by the Vice President of BR Company Six Sigma, Supply Chain, and Chief Learning Officer and the Director of BR Company Six Sigma Institute to conduct a research study on the influence of Social Capital on Six Sigma professionals at the BR Company.

Interviewee:

I, [enter your name], have volunteered to participate in this research study. My participation in the study is entirely voluntary and my participation or non-participation will not be reported to the supervisory staff. I understand that

1. I may refuse to participate and/or withdraw at any time without consequences to my employment.

2. Research records and list of interviewees will be confidential.

3. Personal anonymity will be guaranteed.

4. Results of research data will be used for presentation and publications.

5. As the data is presented, I can choose to be identified as the source of that information for group discussion purposes.

6. Gerald Heidt (researcher) can be reached through electronic mail at gheidt47@email.uophx.edu, should you have any questions, or research related issues that are not explained to your satisfaction in the following sociometric questionnaire.

There are no other agreements, written or verbal, related to this study beyond that expressed in this consent and confidentiality from. I, the undersigned, understand the above explanation, and I give consent to my voluntary participation in this research.

I [enter your name] understand that by completing and submitting the following sociometric questionnaire constitutes my consent to the above conditions.

The following survey is an adaptation of the Social Capital Short-Form, [1] which is the short-form of the sociometric questionnaires developed at the University of Chicago's Graduate School of Business to measure the social capital of managers and other professionals. It also includes questions designed to identify core relations relevant to your work as a Six Sigma professional. Social capital is a function of the contact network around a manager, and the purpose of this questionnaire is to assemble data for a complete network analysis of your social capital.

The questions ask about the people with whom you work and relax—friends, family, colleagues, and other contacts relevant to your professional activities.

Everything you enter here is confidential. No one but the researcher, Gerald Heidt, will see your responses. He will take responses from the website, aggregate the data into a network model, and summarize the results. Only the summarized results will be published.

Given the potential complexity of network analysis, it is critical that your answers be as accurate and complete as possible.

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[1] Burt, R.S. (n.d.). Social Capital Short-Form. Retrieved April 7, 2005, from http://gsbwww.uchicago.edu/fac/ronald.burt/research/QUEST.pdf. Copyright 1998 by Ronald S. Burt. Adapted with permission.

General Background

1. **Your name:** _____

2. **Your birthday:** (Month / Year): _____ / _____

3. **Gender:** ☐ Male ☐ Female

4 **What is the highest level of education you have completed?**

☐ High school or equivalent

☐ Some college

☐ Bachelor's degree or equivalent

☐ Master's degree or equivalent

☐ Doctorate or equivalent

Personal Work Style

5. The following items describe how an individual works, their personal work style**. For each of the ten items below, circle A or B to select the phrase that better describes you personally.**

   It is important to select phrases that describe how you actually operate, rather than how you feel you should or would like to operate. There are no right or wrong answers. Select only one phrase per item. If you disagree with both phrases, select the one with which you disagree less.

A.	**When evaluating opportunities, I am likely to look …**	A. for a chance to be in a position of authority B. for the long-run implications
B.	**My strength lies in the fact that I have a knack for …**	A. being easygoing B. getting a point across clearly
C.	**In discussions among peers, I am probably seen as …**	A. an outspoken advocate B. motivating people to my views
D.	**I believe that people get into more trouble by …**	A. unwilling to compromise B. not letting other know what they really think
E.	**In a leadership role, I think mystrength lies in the fact that I …**	A. won people over to my views B. kept everyone informed
F.	**In evaluating my aims in my career, I probably put more**	A. my ability to create an aura of excitement B. being in control of my own destiny

	emphasis on …	
G.	**As a member of a project team, I …**	A. seek the advice of colleagues B. closely follow the original mandate of the group
H.	**Others are likely to notice that I …**	A. let well enough alone B. let people know what I think of them
I.	**In an emergency, I …**	A. take the safe approach B. am quite willing to help
J.	**I look to the future with …**	A. unshakable resolve B. a willingness to let others give me a hand

Current and Most Recent Job

Please answer the questions on this and the next page with respect to your current, or most recent, full time job.

6. **Your primary business unit?** Check the most applicable box.

☐ JDS	☐ SMS
☐ JIS	☐ STSC
☐ OCS	☐ TAS
☐ SAC	☐ Corporate

7. **Your primary functional area in the company?** Check the most applicable box.

☐ Sales (customer origination)	☐ Engineering/research	☐ Human resources
☐ Service (customer support)	☐ Marketing/distribution	☐ Pgm. management
☐ Manufacturing/productions	☐ Finance	☐ Supply Chain
☐ Six Sigma Professional (full time)	☐ General management	☐ Other

8. **Your general rank in the organization?** Check the most applicable box.

☐ Individual Contributor – you don't supervise anyone else's work.

☐ Manager – you supervise one or more individual contributors

☐ Middle Manager – you supervise one or more managers

☐ Senior Manager – you supervise or more middle managers

☐ CEO – you are the most senior executive in firm (could be President or other title)

9. **Your satisfaction in your job?** Check the most applicable box.

☐ **Completely Dissatisfied** ☐ **Neither Satisfied nor Dissatisfied** ☐ **Completely Satisfied**

10. **Your immediate supervisor? Please write his or her first name and last name in the box.**

FIRST NAME and LAST NAME

11. **How did you come to the job?** Check the most applicable box.

☐ Hired from outside the company

☐ Transferred from another division or plant within the company

☐ Promoted up from another position in the same division or plant

12. **How did you learn about the job?** Please check as many as apply.

☐ I saw an ad in a newspaper (or magazine, or trade or technical journal, etc.)

☐ I found out through an employment agency (or personnel consultants, "head-hunters," etc.)

☐ I submitted an application before anyone told me about the job

☐ Someone I didn't know contacted me and said that I had been recommended.

☐ I asked a friend, who told me about the job.

☐ A friend who knew I was looking for something new contacted me.

☐ A friend who didn't know I was looking for something new contacted me.

☐ Other (please specify): _____

B. **If a friend was involved, please write the friend's first name and last name in the box to the right.**

13. **Did you have an ally in the company whose support helped you get the job?**

No or don't know (if no or don't know, skip to top of next page)

Yes, Who? Please write the person's first name and last name in the box to the right.

FIRST NAME and LAST NAME

B. **Why do you think this person supported you for the job?**

_____

Rounding Out Your Contact Network

The next questions ask for the names of people with whom you have specific kinds of relations. People with whom you have more than one kind of relation can be listed more than once. Remember, your responses will remain confidential.

	FIRST NAME and LAST NAME
14. Think of your current or most recent job in more general terms. Getting things done usually requires the support of colleagues and contacts. Suppose you were moving to a new job and wanted to leave behind the best network advice you could for someone moving into your old job. Who are the **three or four people you would name to your replacement as essential sources of support for success in your job?** These could be people in the firm, or contacts in other firms.	

	FIRST NAME and LAST NAME
15. Of your colleagues, **who has been the most difficult?** (Remember, your responses are confidential.)	

B. Why was it so difficult to work with this person? _____

	FIRST NAME and LAST NAME
16. **If you decided to find a new job, in another firm, who are the two or three people with whom you would most likely discuss and evaluate your job options?** These could be family, friends, people where you work, or contacts in other firms.	

The following three (3) questions are designed to identify core relations relevant to your work as a Six Sigma Professional.

16a. Who are the four or five people in the COMPANY'S Six Sigma Professional community to whom you have turned or would turn when faced with a challenging Six Sigma problem or opportunity? Please enter the first and last names, then the approximate time for which you have known each person. You can include previously named people.	First and Last Name Years Known
16b. Looking beyond the COMPANY'S Six Sigma Professional community, who are the four or five people to whom you have turned or would turn when faced with a challenging Six Sigma problem or opportunity? Please enter the first and last names, then the approximate time you have known each person. You can include previously named people.	First and Last Name Years Known
16c. If one classifies *sustaining* projects as projects aimed at improving product or processes within an existing value stream and *entrepreneurial* projects as projects aimed at product development, growth, or identifying customer requirements. How would you best describe your PROJECT: sustaining or entrepreneurial? (PROJECT specifically refers to the Six Sigma project that you led and booked complete in the Six Sigma database, Power Steering, during calendar years 2004/5. If you completed and booked more than one project during 2004/5, the PROJECT of interest is identified in the correspondence requesting your participation in	Sustaining: ___ Entrepreneurial: ___

this study.)	

17. Considering all of the professional contacts you have made in your career so far, **who have been your most valued contacts in the sense that they were the most important to your achievements?**	FIRST NAME and LAST NAME
18. Shifting to a broader view of your network, consider the people with whom you like to spend your free time. Over the last six months, **who are the two or three people you have been with most often for informal social activities such as going to lunch, dinner, drinks, films, visiting one another's homes and so on?**	FIRST NAME and LAST NAME
19. From time to time, most people discuss important matters with other people, people they trust. The range of important matters varies from person to person across work, leisure, family, politics, whatever. The range of relations varies across work, family, friends, and advisors. If you look back over the last six months, **who are the three or four people with whom you discussed matters important to you.**	FIRST NAME and LAST NAME
20. In conclusion, **please write in the box the first Name and last initial of your spouse or the Person with whom you are living as if married.** (If there is no such person, just leave this box blank.)	FIRST NAME and Last Initial

Assembling the Contacts

The remaining few questions are about the people you just named. You will need a nonredundant list of the people for reference. The list you construct in the spaces to the right will be visible for each subsequent question.

You could have named as many as 23 different people on the preceding pages. Most people have multiple kinds of relations to key contacts, however, so they name some people more than once. The number of different people named is usually less than the maximum possible.

In the spaces to the right, list – up to a maximum of 20 names – each person written on the preceding three pages.

List people in the order that they were first mentions; first the name on page 5, then the names on page 6, then the names on page 7.

Please make sure that no one is listed more than once in the list, and no lines are skipped between names.

	PEOPLE NAMED	
Write the name of the first person you named –	1.	
Second person you named --	2.	
Third person you named --	3.	
	4.	
Fifth person you named --	5.	
	6.	
	7.	
Eighth person you named --	8.	
	9.	
and so on, making sure that no one is listed twice,	10.	
and there are no blank lines between names	11.	
	12.	
	13.	
	14.	
	15.	
	16.	
	17.	
	18.	
	19.	
	20.	

Final Name Generator!

21. Now that you have a list of contacts, please give it a quick scan. **Is anyone significant missing? Is there someone without whom your career would be much more difficult, or someone without whom you would have been much more effective?** If yes, write the first name and the last name of the most significant missing person in the next empty space in the list. (If there are no empty spaces remaining, please leave the list as it is.)

Now about the strength of your relationship with each person …

Circle the option that best describes your relationship with each person.

Are you **especially close** in the same sense that this is one of closest personal contacts?

Or are you merely **close** in the sense that you enjoy the person, but don't count him or her among you closest personal contacts?

Or are you **less than close** in the sense that you don't mind working with the person, but you have no desire to develop a friendship?

Or are you **distant** in the sense that you really don't enjoy spending time with the person unless it is necessary?

22. How close are you with each person?

(Circle best approximation)

						PEOPLE NAMED
1.	Especially close	Close	Less than close	Distant	1.	
2.	Especially close	Close	Less than close	Distant	2.	
3.	Especially close	Close	Less than close	Distant	3.	
4.	Especially close	Close	Less than close	Distant	4.	
5.	Especially close	Close	Less than close	Distant	5.	
6.	Especially close	Close	Less than close	Distant	6.	
7.	Especially close	Close	Less than close	Distant	7.	
8.	Especially close	Close	Less than close	Distant	8.	
9.	Especially close	Close	Less than close	Distant	9.	
10.	Especially close	Close	Less than close	Distant	10.	
11.	Especially close	Close	Less than close	Distant	11.	
12.	Especially close	Close	Less than close	Distant	12.	
13.	Especially close	Close	Less than close	Distant	13.	
14.	Especially close	Close	Less than close	Distant	14.	
15.	Especially close	Close	Less than close	Distant	15.	
16.	Especially close	Close	Less than close	Distant	16.	
17.	Especially close	Close	Less than close	Distant	17.	
18.	Especially close	Close	Less than close	Distant	18.	
19.	Especially close	Close	Less than close	Distant	19.	
20.	Especially close	Close	Less than close	Distant	20.	

Beyond emotional closeness there is **duration** and **frequency**

23. How long have you known each person? (Best guess)

1.	Approximately	_____	Years
2.	Approximately	_____	Years
3.	Approximately	_____	Years
4.	Approximately	_____	Years
5.	Approximately	_____	Years
6.	Approximately	_____	Years
7.	Approximately	_____	Years
8.	Approximately	_____	Years
9.	Approximately	_____	Years
10.	Approximately	_____	Years
11.	Approximately	_____	Years
12.	Approximately	_____	Years
13.	Approximately	_____	Years
14.	Approximately	_____	Years
15.	Approximately	_____	Years
16.	Approximately	_____	Years
17.	Approximately	_____	Years
18.	Approximately	_____	Years
19.	Approximately	_____	Years
20.	Approximately	_____	Years

24. On Average, How Often Do You Talk to Each Person?

(Circle best approximation;
any social or business discussion)

						PEOPLE NAMED
1.	Daily	Weekly	Monthly	Less Often	1.	
2.	Daily	Weekly	Monthly	Less Often	2.	
3.	Daily	Weekly	Monthly	Less Often	3.	
4.	Daily	Weekly	Monthly	Less Often	4.	
5.	Daily	Weekly	Monthly	Less Often	5.	
6.	Daily	Weekly	Monthly	Less Often	6.	
7.	Daily	Weekly	Monthly	Less Often	7.	
8.	Daily	Weekly	Monthly	Less Often	8.	
9.	Daily	Weekly	Monthly	Less Often	9.	
10.	Daily	Weekly	Monthly	Less Often	10.	
11.	Daily	Weekly	Monthly	Less Often	11.	
12.	Daily	Weekly	Monthly	Less Often	12.	
13.	Daily	Weekly	Monthly	Less Often	13.	
14.	Daily	Weekly	Monthly	Less Often	14.	
15.	Daily	Weekly	Monthly	Less Often	15.	
16.	Daily	Weekly	Monthly	Less Often	16.	
17.	Daily	Weekly	Monthly	Less Often	17.	
18.	Daily	Weekly	Monthly	Less Often	18.	
19.	Daily	Weekly	Monthly	Less Often	19.	
20.	Daily	Weekly	Monthly	Less Often	20.	

25. **The next task is to describe the strength of relations between the listed people.** You do this by circling codes in the matrix below. This is a complex question, but it is essential to measuring social capital – and answering the question is a simple task when taken one column at a time.

Begin with the first person listed. Relations with the first person are listed in the first column. Indicate his or her relationship with the person in each row in or of three ways.

Circle EC if there is an ESPECIALLY CLOSE relation between the row person and the first person

Circle D if the row person and first person are DISTANT in the sense that they rarely work together, are total strangers as far as you know, or do not enjoy one another's company, or

Leave D.EC blank to indicate that the two people are neither distant nor especially close.

If there is an especially close relationship between the first and fourth person, for example, you would circle EC in the fourth row of the first column (dotted box). If the first and tenth persons do not enjoy one another's company, you would circle D in the tenth row of the first column.

Do not feel obliged to circle a D or EC for every relation. A relation for which neither is circled is a relation somewhere between especially close and distant. The task here is merely to identify the extremes of distant versus especially close relations.

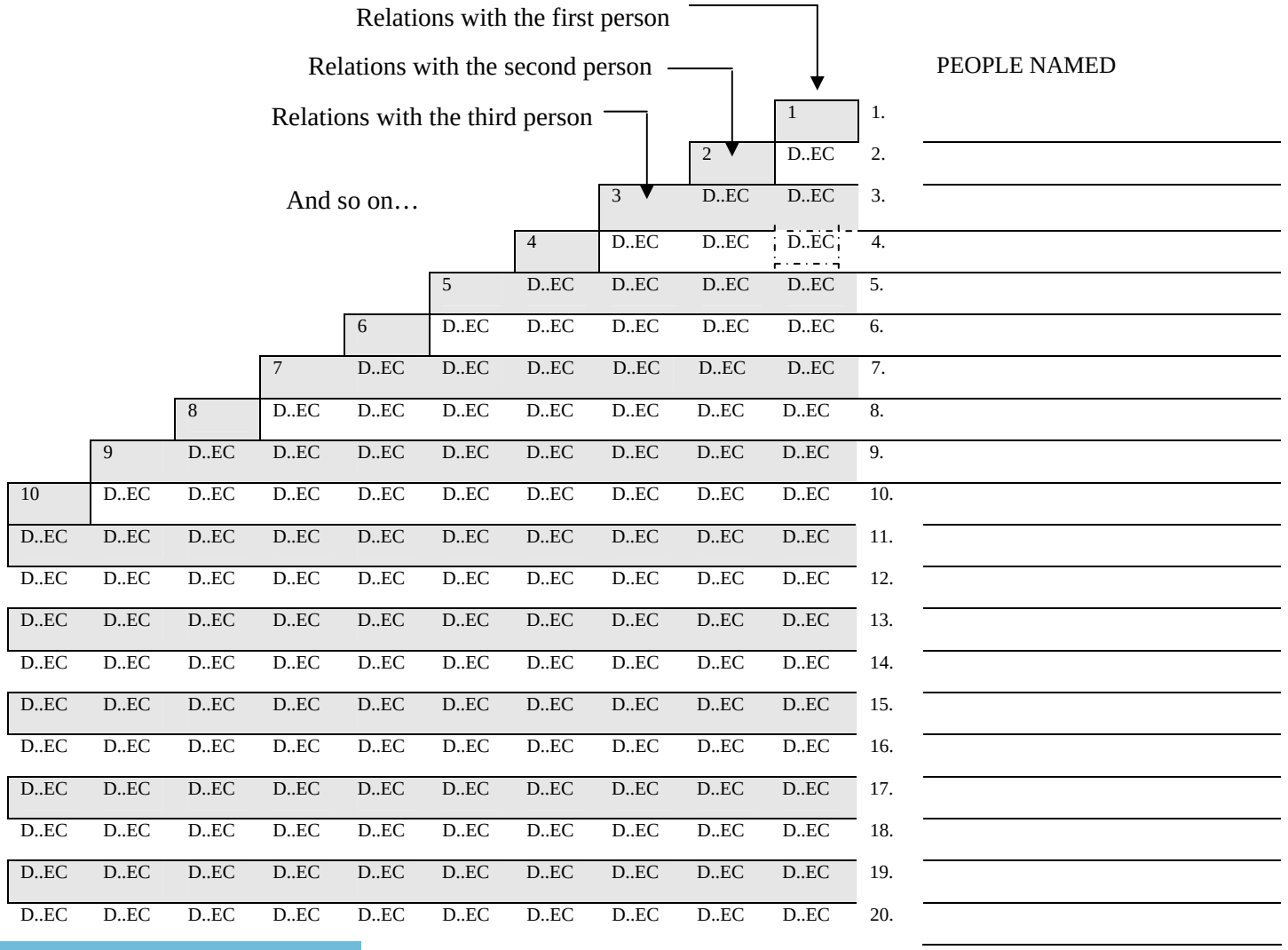
Now move to the second person on the list. Relations with the second person are listed in the second column from the right. Note that the columns get shorter as you proceed.

Again, circle each EC in the second column indicate especially close relations or D to identify distant relations.

Continue to the third person (third column), and so on, until you reach the end of the list.

								11
							12	D..EC
						13	D..EC	D..EC
					14	D..EC	D..EC	D..EC
				15	D..EC	D..EC	D..EC	D..EC
			16	D..EC	D..EC	D..EC	D..EC	D..EC
		17	D..EC	D..EC	D..EC	D..EC	D..EC	D..EC
	18	D..EC	D..EC	D..EC	D..EC	D..EC	D..EC	D..EC
19	D..EC	D..EC	D..EC	D..EC	D..EC	D..EC	D..EC	D..EC
20	D..EC	D..EC	D..EC	D..EC	D..EC	D..EC	D..EC	D..EC

Hang On…this is an essential question, AND the last question.



Thank you for your time and patience.

Prepared for the Chicago Management Council
1998

APPENDIX C: PERMISSION TO USE SOCIAL CAPITAL SHORT-FORM

Ron Burt
<ron.burt@gsb.uchicago.edu>
04/07/2005 10:28 AM

To: Gerald E Heidt
cc:
Subject: Re: Request permission to use Short Form Sociometric Questionnaire

You are welcome to them, Jerry. Marsden has a good review chapter on network data in a 2005 book from Cambridge U press edited by peter carrington et al. Do look at the content results in the Brokerage and Closure book that Tracy distributes in Raytheon's SLP (Figure 1.7). / Ron

Professor Burt:

I request your permission to use/adapt questions from your *Short Form Sociometric Questionnaire* as the main research instrument in my dissertation research addressing Social Capital and Six Sigma Professionals.

Tracy Cox has offered his contacts to provide a webmaster in order to distribute the survey electronically, unless you think it would be more appropriate to use hard copies.

Also, if you would be so kind, would you recommend some literature for me to review regarding the validity and/or reliability of this type instrument. I have already reviewed these works, and found them beneficial:

Burt, R. S. (1984). Network items and the General Social Survey. *Social Networks, 6,* 293-339.

Marsden, P. V. (1990). Network data and measurement. *Annual Review of Sociology, 16* (1), 435-463.

Regards,
Jerry

APPENDIX D: INFORMED CONSENT FORM

CONSENT TO ACT AS A RESEARCH PARTICIPANT

Introduction

Gerald Heidt, a Doctoral Candidate at the University of Phoenix and an independent researcher, has been given permission by the Vice President of BR Six Sigma, Supply Chain, and Chief Learning Officer and the Director of BR Six Sigma Institute to conduct a research study on the influence of Social Capital on Six Sigma professionals at the BR Company.

Interviewee:

I, _____, a representative of _____ have volunteered to participate in this research study. My participation in the study is entirely voluntary and my participation or non-participation will not be reported to the supervisory staff. I understand that

1. I may refuse to participate and/or withdraw at any time without consequences to my employment.
2. Research records and list of interviewees will be confidential.
3. Personal anonymity will be guaranteed.
4. Results of research data will be used for presentation and publications.
5. As the data is presented, I can choose to be identified as the source of that information for group discussion purposes.
6. Gerald Heidt (researcher) has explained this study to me and answered my questions. If I have other questions or research related issues, he can be reached through electronic mail at gheidt47@email.uophx.edu.

There are no other agreements, written or verbal, related to this study beyond that expressed in this consent and confidentiality form. I, the undersigned, understand the above explanation, and I give consent to my voluntary participation in this research.

Signature of the interviewee_____ Date_____

Signature of the researcher_____ Date_____

APPENDIX E: DIRECT REPORT DEMOGRAPHIC DATA

DIRECT REPORT DEMOGRAPHIC DATA

Participant	Gender	Age	Education	Business Unit	Functional Area	General Rank	Job Satisfaction	Project Type	Gross Benefit ($K)	Network Size
8011	F	41	B	TAS	Six Sigma	IC	7	Sustaining	2300	18
5989	M	54	M	TAS	Six Sigma	SM		Sustaining	1620	18
6426	M	55	B	TAS	Six Sigma	IC	7	Sustaining	1300	18
4406	M	50	B	SAC	Engineering	MM		Entrepreneurial	1250	17
2327	M	48	M	SMS	Six Sigma	MM	8	Entrepreneurial	1000	19
3222	M	49	M	SMS	Manufacturing	IC		Sustaining	1000	14
8287	M	46	M	JIS	Six Sigma	IC		Sustaining	33	21
101	M	53	M	TAS	Gen Management	IC		Sustaining	250	17
1250	M	45	M	SMS	Six Sigma	IC	9	Sustaining	1464	15
3366	M	42	M	SAC	Six Sigma	IC	7	Sustaining	264	17
9103	M	50	M	SAC	Six Sigma	IC	7	Sustaining	470	21
2857	M	42	D	JIS	Six Sigma	M	4	Entrepreneurial	6600	21
9789	M	50	M	STSC	Six Sigma	IC	4	Entrepreneurial	750	17

Participant	Gender	Age	Education	Business Unit	Functional Area	General Rank	Job Satisfaction	Project Type	Gross Benefit ($K)	Network Size
138	M		B	JIS	Engineering	M	9	Entrepreneurial	7100	21
8983	F	27	B	JIS	Six Sigma	M	7	Entrepreneurial	3844	19
7101	M	52	SC	TAS	Six Sigma	IC	7	Sustaining	1200	16
9583	F	43	M	JDS	Other	MM	1	Entrepreneurial	1248	21
3494	M	47	M	TAS	Program Management	IC		Entrepreneurial	507	15
7310	M	45	B	STSC	Six Sigma	MM	9	Entrepreneurial	1440	21
1186	M	60	M	JDS	Engineering	IC	8	Sustaining	2000	15
8391	F	40	D	OCS	Program Mgt	IC	8.5	Sustaining	190	15
464	F	51	B	TAS	Finance	IC	7	Entrepreneurial	3147	19
2166	F	50	B	SMS	Other	IC	7	Entrepreneurial	6009	21
104	M	53	B	JDS	Six Sigma	M		Entrepreneurial	4812	21
168	M	52	D	SMS	Engineering	M	9	Sustaining	1800	21
2163	F	45	M	JIS	Six Sigma	IC	7	Sustaining	1600	18

3180	F	32	M	TAS	Engineering	IC	6	Entrepreneurial	3416	18

Participant	Gender	Age	Education	Business Unit	Functional Area	General Rank	Job Satisfaction	Project Type	Gross Benefit ($K)	Network Size
996	M	49	M	JDS	Engineering	M	8	Entrepreneurial	987	21
1290	M	48	M	JDS	Six Sigma	IC	7	Sustaining	1250	16
8674	M	35	M	TAS	Six Sigma	IC	8	Sustaining	1400	15
8119	F	32	M	SMS	Six Sigma	IC	9	Sustaining	1700	15
2693	F	51	M	SMS	Six Sigma	IC	8	Entrepreneurial	5100	21

APPENDIX F: TYPICAL NETWORK ANALYSIS DATASET

DISPLAY

Width of field: MIN
# of decimals: MIN
Rows to display: all
Columns to display: all
Row partition:
Column partition:
Input dataset: C:\Program Files\Ucinet 6\DataFiles\A-2857R Dataset

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1		0.000	0.000	1.000	1.000	1.000	0.400	0.000	0.000	0.000	0.400	0.400	0.000	0.400	0.000	0.000	0.000	0.000	0.000	0.400	1.000
2	0.000		0.400	0.000	0.000	0.000	0.400	0.000	0.000	0.000	0.000	0.000	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
3	0.000	0.400		0.000	0.000	0.000	0.400	0.000	0.000	0.400	1.000	1.000	1.000	1.000	0.000	0.000	0.400	0.000	0.000	0.400	1.000
4	1.000	0.000	0.000		1.000	1.000	0.400	0.000	0.000	0.000	0.400	0.400	0.400	0.400	0.000	0.000	0.000	0.000	0.000	0.000	1.000
5	1.000	0.000	0.000	1.000		1.000	0.400	0.000	0.000	0.000	0.400	0.400	0.400	0.400	0.000	0.000	0.400	0.000	0.000	0.000	1.000
6	1.000	0.000	0.000	1.000	1.000		0.000	0.000	0.000	0.000	0.400	0.400	0.000	0.000	0.000	0.000	0.000	0.400	0.000	0.400	1.000
7	0.400	0.400	0.400	0.400	0.400	0.000		0.000	0.000	0.400	0.000	0.000	0.400	0.400	0.000	0.000	1.000	0.000	0.000	0.000	0.000
8	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	1.000	1.000
9	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	1.000
10	0.000	0.000	0.400	0.000	0.000	0.000	0.400	0.000	0.000		0.000	0.000	0.400	0.400	0.000	0.000	0.400	0.000	0.000	0.000	1.000
11	0.400	0.000	1.000	0.400	0.400	0.400	0.000	0.000	0.000	0.000		1.000	0.400	0.400	0.000	0.000	0.000	0.000	0.000	0.000	1.000
12	0.400	0.000	1.000	0.400	0.400	0.400	0.000	0.000	0.000	0.000	1.000		1.000	0.400	0.000	0.000	0.000	0.000	0.000	0.400	1.000
13	0.000	1.000	1.000	0.400	0.400	0.000	0.400	0.000	0.000	0.400	0.400	1.000		1.000	0.000	0.000	0.400	0.000	0.000	0.000	1.000
14	0.400	1.000	1.000	0.400	0.400	0.000	0.400	0.000	0.000	0.400	0.400	0.400	1.000		0.000	0.000	0.000	0.000	0.000	0.000	1.000
15	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000		0.400	0.000	0.000	0.000	0.000	1.000
16	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400		0.000	0.400	0.400	1.000	1.000
17	0.000	0.000	0.400	0.000	0.400	0.000	1.000	0.000	0.000	0.400	0.000	0.000	0.000	0.000	0.000	0.000		0.000	0.000	0.000	1.000
18	0.000	0.000	0.000	0.000	0.000	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.000		0.000	0.000	1.000
19	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.400	0.000	0.000		0.000	1.000
20	0.400	0.000	0.400	0.400	0.000	0.400	0.000	1.000	0.400	0.000	0.000	0.000	0.400	0.000	1.000	1.000	0.000	1.000	1.000		1.000
21	1.000	1.000	1.000	1.000	1.000	1.000	0.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	

Running time: 00:00:01
Output generated: 25 Jun 06 09:48:28