CONTINUOUS IMPROVEMENT AND OPERATIONS STRATEGY: FOCUS ON SIX SIGMA PROGRAMS

DISSERTATION

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By

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ABSTRACT

The main objective of this dissertation is to study the role of Six Sigma programs in deploying effective continuous improvement. Through three related essays we address three areas of inquiry focused on Six Sigma: (1) the place of Six Sigma in the evolution of continuous improvement programs, (2) organization level infrastructure that is critical for institutionalizing Six Sigma, and (3) practices used in Six Sigma projects for discovering process improvements.

The first essay uses concepts from Nelson and Winter's (1982) theory of evolutionary economics to present a conceptual model for the emergence of new continuous improvement programs such as Six Sigma. Based on its descriptions in the literature, Six Sigma appears to be a logical next-step in the evolution of continuous improvement programs. There are apparent differences compared to previous programs in the way Six Sigma is structured in organizations and in the way its team-projects target improvements.

In the second essay we employ the lens of the behavioral theory of the firm (Cyert and March, 1963) to derive a list of critical elements of organizational infrastructure for continuous improvement. Further, we analyze whether and how organizations that have deployed Six Sigma programs for continuous improvement cover these elements. We use empirical observations from interviews conducted with continuous improvement

executives from five organizations that have deployed Six Sigma programs. We find mixed results regarding coverage of infrastructure in these organizations. Although the prescriptive practitioner-targeted literature on Six Sigma covers most of the infrastructure elements, organizations are neglecting some important elements that are critical for effective continuous improvement.

The third essay empirically addresses the question of how knowledge creation activities (Nonaka, 1994) used in Six Sigma team-projects result in process improvements. Adapting existing scales for knowledge creation constructs, data on 92 Six Sigma projects is collected, and analyzed using hierarchical regression analyses. Hypotheses relating knowledge creation practices to Six Sigma project performance are partially supported.

Thus, the three essays provide insights into the place of Six Sigma in the evolution of continuous improvement programs, and organization-level infrastructure and project-level practices in Six Sigma programs.

Dedicated to:
Sowmya, whose love and inspiration made this possible
My family, for their support
The memory of my parents, Pushpadevi and Jankinath Anand
And God, to Whom I pray:

Where the mind is without fear and the head is held high,
Where knowledge is free,
Where the world has not been broken up into fragments
By narrow domestic walls,
Where words come out from the depth of truth,
Where tireless striving stretches its arms towards perfection,
Where the clear stream of reason has not lost its way
Into the dreary desert sand of dead habit,
Where the mind is led forward by Thee
Into ever-widening thought and action,
Into that heaven of freedom, my Father, let my country awake.

(Rabindranath Tagore, Geetanjali)

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Thank you!

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CHAPTER 1

INTRODUCTION

"It is important to recognize: what are selection criteria at one level are but trials of the criteria at the next higher, more fundamental, more encompassing, less frequently invoked level"

(Campbell, 1974; p. 421)

Continuous improvement programs such as total quality management and just-in-time management are prevalent in organizations (Swamidass et al., 2001; Voss, 2005). The main purpose of such programs is maintaining a sustained effort at improving the efficiency and effectiveness of work-processes (Imai, 1986; Liker and Choi, 1995). These programs consist of combinations of practices that aim to encourage and enable the participation of frontline personnel in process improvement (MacDuffie, 1995). Different combinations of work practices emerge from time to time as new continuous improvement programs (Cole, 1999). Six Sigma is one such continuous improvement program that has captured the interest of several organizations (Linderman et al., 2003). The purpose of this research is to study the rationale for Six Sigma programs. In the next three chapters (2-4) we address questions about what organizational and process improvement practices constitute Six Sigma programs, and how these practices, in turn, result in improvements in process- and organization-performance.

The proliferation of continuous improvement programs and the burgeoning number of consultants selling these programs sometimes cause Six Sigma to be portrayed as another fad undeserving of academic and practitioner attention (Miller et al., 2004). The purpose of the next chapter is to sift through the implications of a fads label and clarify the reasons for emergence and disappearance of continuous improvement programs from the limelight. As with any technologies and administrative practices that evolve over time, subsequent generations of improvement programs provide better methods for achieving their purpose. At the same time the scope, and therefore the purpose, of continuous improvement programs has expanded in response to changes in organizational environments.

We trace the evolution of past continuous improvement programs to assess patterns of such improvements and adaptations. To accomplish this, we develop a framework based on the evolutionary economic perspective (Nelson and Winter, 1982). We then use this framework to assess whether and how the Six Sigma program is the next step in the evolution of continuous improvement programs. This chapter sets the stage for the two chapters that follow, in which we focus on organization level infrastructure requirements and project execution practices in Six Sigma.

Chapter 3 is motivated by the changing roles of continuous improvement programs as a result of changes in organizational environments (Brown and Blackmon, 2005). We focus on the changing demands made on organizational infrastructure for continuous improvement programs. Such infrastructure is crucial for systematic planning of continuous improvement programs at the organization level as it ensures that improvements made through process-focused projects are in line with organizational objectives (Wruck and Jensen, 1998).

There is empirical evidence to support the notion that infrastructure is important for the success of continuous improvement programs (e.g. Flynn and Sakakibara, 1995; Samson and Terziovski, 1999). However, there is a gap between empirical evidence and theory to explain the importance of infrastructure for such programs. Toward studying infrastructure practices for Six Sigma programs we develop a general framework based on theoretical explanations for the relationships between continuous improvement infrastructure and program performance.

The success of Six Sigma programs depends to a large extent on motivating employees, training them and coordinating their efforts in projects as well as implementing changes resulting from projects. We apply our infrastructure framework for continuous improvement programs to Six Sigma. On the basis of existing practitioner-focused literature and interviews with continuous improvement executives from five organizations that have implemented Six Sigma programs, we assess the coverage of the elements of the continuous improvement infrastructure.

In Chapter 4 we empirically address the question of how activities in Six Sigma projects result in creating knowledge for improving targeted processes. We employ the knowledge creation framework of Nonaka (1994) that has previously been applied to research in new product development. The purpose of new product development projects is to use employee, customer and supplier knowledge to develop new products while the purpose of Six Sigma projects is to garner the knowledge of individuals for discovering process improvements. Thus, Nonaka's (1994) framework transfers well to Six Sigma process improvement projects (Linderman et al., 2004). Using data from ninety two Six Sigma projects we assess the effects of different knowledge creation mechanisms (Nonaka, 1994) on Six Sigma project performance.

Thus, in the following three chapters we move from an inter-organizational view of development of continuous improvement programs to an organization level scrutiny of infrastructure practices for such programs to a project level analysis of process improvements. In studying Six Sigma programs from these three views, we also suggest the use of these lenses to study continuous improvement programs in general.

CHAPTER 2

EVOLUTION OF CONTINUOUS IMPROVEMENT PROGRAMS AND SIX SIGMA

"I have called this principle, by which each slight variation, if useful, is preserved, by the term Natural Selection"

From: "The Origin of Species by Means of Natural Selection" by Charles Darwin (1889)

2.1. Introduction

Total Quality Management (TQM) and Business Process Reengineering (BPR) programs gained tremendous popularity as combinations of practices for continuous process improvement. However, after prevailing for some time these programs were dismissed by many as fads that mainly benefited the consultants who advocated them (Abrahamson, 2004; Miller et al, 2004). Despite the fate of such continuous improvement programs, new combinations of practices such as lean operations and agile supply chains continue to emerge and gain in popularity (see e.g. Gunasekaran, 2001; Swamidass, 2002; Womack and Jones, 2003). We examine the reasons and underlying mechanisms for the development of new continuous improvement (CI) programs and their subsequent entry and exit from the limelight.

History shows that even after fads fade from view they often leave a solid legacy of accomplishment and at least a subset of practices remain ingrained in organizations that embraced them. Therefore, instead of asking whether a new CI program's popularity will eventually wane, we should be asking whether its deployment holds any promise.

Does a new CI program address process improvement issues faced by a number of organizations that previous CI programs did not, and, does the CI program seem to work? If a CI program has incremental features that are more than superficial and there is some logic explaining why such novel features should work better, then it is worth-while to consider its deployments, and further, to establish determinants of successful deployments.

Six Sigma is one of the 'newer kids on the block' in the CI program arena and shares several common features with previous CI programs such as TQM and BPR. Six Sigma has already been skewered by Dilbert™ so its eventual post hoc dismissal as a fad seems assured. By applying evolutionary economics to trace the development of Six Sigma we gain insight into the gaps that Six Sigma is fulfilling in previous CI programs. We follow this up by highlighting the incremental features of the program that warrant investigation to determine whether such features are superficial or have some teeth.

2.1.1 The faddishness of CI programs:

CI programs are combinations of practices for conducting and coordinating ongoing process improvement and for sustaining the motivation and ability among employees to continually work toward such improvement (Benner and Tushman, 2003; Edmondson et al., 2001; Ittner and Larcker, 1997b). The genesis of a CI program is generally the result of an organization's internal efforts to identify combinations of practices to enhance its ongoing process improvement capability and its ability to sustain organization-wide interest in such process improvements. The search for a new combination of practices is initiated in response to changes in environmental demands such as increasing need for flexibility or to improve internal abilities such as continually reducing defects (Schonberger, 1994). It follows that the pioneer organization perceives existing CI programs to be inadequate or unsuited for its situation; such a perception may not necessarily be accurate.

In the event that a new combination of practices is tremendously successful it may gain recognition among other organizations as a CI program, in which case it typically acquires a popular label, for example, TQM and BPR. Following such publicity other organizations that are searching externally for better process improvement methods adopt the CI program while consultants offer deployment advice – it is then that the CI program acquires fad status. Adopting organizations typically do not adopt the CI program homogenously. They customize some of its constituent practices or practice-combinations and/or alter some of their incumbent ones in pursuit of better performance, which they may achieve to different extents.

After widespread proliferation of adoptions in the organizational population the popularity of the CI program peaks and declines. The decline in popularity frequently coincides with failures of several organizations in realizing benefits from the CI program. This passing of the fad is touted as evidence that the new CI program did not have any merit in the first place and therefore did not deserve the attention it was given. In debunking fads, the learning generated among organizational populations from its deployments and the subsequent absorption of fads' constituent practices into the next innovations in CI programs is completely ignored.

We investigate this notion that CI programs that come and go as fads do have beneficial effects, and provide credence to the life-cycle phenomenon using the theoretical lens of evolutionary economics (Nelson and Winter, 1982). Evolutionary economic theory describes the introduction of variations in practices, selection and retention of variations, and the incremental role of retained variations over the practices that they altered or replaced (Pandža et al., 2003). The theory also incorporates the relatedness of changes at the process, organizational and inter-organizational levels (Campbell, 1974; Cole and Scott, 2000; Dickson, 2003), thus providing us with a unified framework to study development of practices within organizations and their adoption and adaptation through CI programs across organizations.

Drawing upon the principles outlined in the theory of evolutionary economics we make the argument that innovative CI programs that are first widely adopted and then labeled as fads are generally beneficial (Ichniowski and Shaw, 2003; Staw and Epstein, 2000). We follow this assertion by outlining the characteristics of CI programs that increase their chances of success, measured as significant enhancements, in sustained process improvement. The theory of evolutionary economics points to three criteria that must be applied to assess successful adoption of a CI program in an organization and consequently, beneficial propagation among organizational populations: (1) incremental benefit of the CI program over previous work practice combinations; (2) logical relationship of its underlying practices to performance; and (3) presence of contextual and complementary organizational characteristics.

2.1.2. Application of the evolutionary framework to Six Sigma:

Six Sigma burst into the popular-organizational-practices scene after well publicized successful deployments by Larry Bossidy at AlliedSignal and Jack Welch at GE (Bartlett and Wozny, 2000; Linderman et al., 2003; Waage, 2003). Six Sigma is expected to suffer the same fate as any other CI program – burn brightly for a while and then fade and be replaced by the next popular CI program (Clifford, 2001; Costanzo, 2002). To support our assertions of legacy-values of fads, we trace the developments in quality-based CI programs, of which Six Sigma is the latest avatar. We then investigate the utility of Six Sigma by framing questions based on the evolutionary economic framework for further studies; in doing so, we also demonstrate an application of the framework to study emerging CI programs. The main question that we address is the extent to which Six Sigma programs add value to organizations beyond previous CI programs and how such value-add can be accomplished.

Our analysis of Six Sigma provides support for the notion that Six Sigma is part of a natural progression in CI programs (Thawani, 2004). In addition, by delineating the unique combinations of practices and structural implications of Six Sigma we confirm that it represents a noteworthy change from previous work practice bundles (Harry and Schroeder, 2000). Specifically, we make the case that Six Sigma prescribes a structured method for comprehensive implementation of principles and practices that have been only loosely suggested in a piecemeal manner under previous CI programs (Folaron, 2003).

2.1.3. <u>Organization of the chapter:</u>

The rest of the chapter is structured as follows: We begin, in section 2.2, by describing the nested relationships among routine execution of processes, application of process improvement practices and deployment of combinations of practices as CI programs in an organization. This sets the stage for studying the interrelated developments of practices in organizations and CI programs in organizational populations, which we accomplish in sections 2.3 and 2.4. In section 2.5, we describe Six Sigma and highlight its genesis and propagation through the evolutionary economics lens; we present testable propositions based on its existing track record to study adoptions and adaptations of the CI program. Six Sigma is portrayed as a result of a progression in quality-focused CI programs, particularly TQM, in section 2.6. In section 2.7, we tackle some of the pertinent questions we develop in sections 2.3 and 2.4 for assessing the value-add of a CI program, as applied to Six Sigma programs; propositions regarding the incremental benefits of Six Sigma are developed. Section 2.8 concludes the chapter.

2.2. Processes, process improvement and combinations of practices

2.2.1. <u>Nested relationships:</u>

In order to apply the theory of evolutionary economics to the recurring phenomenon of development and demise of CI programs among organizational populations we need to examine the role of improvement practices at the organizational level. A hierarchy of CI programs consisting of combinations of improvement practices (that are also constituents of generic CI programs), process improvement exercises and processes is depicted in Figure 2.1. Combinations of process improvement practices (that include generic CI programs adapted to an organization's specific context and needs) affect how ongoing process improvement is conducted – these practices establish, for example, team-structures, relationships between functional and hierarchical levels, training in improvement practices, primary improvement focus such as lower inventory or lower defect rates, and tools and techniques employed such as statistical process control and design of experiments. Process improvements discovered by employing these practices, in turn, result in established ways for executing processes – e.g. sequences of subtasks in assembling a car-door, metrics to be recorded at different steps in an operation, check-list for set-up changes, and rules for scheduling production.

2.2.2. Processes and process improvements:

Processes are designed sequences of tasks aimed at creating value adding transformations of inputs – material or information – to achieve intended outputs (Upton, 1996). For example, raw materials such as wood and iron fixtures go through several processes to create a chair, and information about the customer and aggregate risk-related data are used to deliver an automobile insurance policy. Process improvements are actions taken for improving organizational processes, e.g. improving the chair making process so that less raw material is consumed, or reducing the cycle time from proposal to delivery of an insurance policy. The need for making process improvements continually is imperative for the survival of organizations because of the need to respond rapidly to ever-changing environments in the face of stiff competition (Hayes and Pisano, 1994).

Even when generic technological or organizational processes are adopted externally, it is the in-house improvements in processes that provide unique or relatively hard-to-imitate advantages (Teece and Pisano, 1994).

2.2.3. Combinations of process improvement practices:

While improvements in processes may be sought through regularly executed and systematic projects, or via sporadic and chaotic efforts, process improvement practices dictate the procedure and methods for conducting these improvement exercises (Kathuria and Davis, 1999, McLachlin, 1997). Process improvement practices empower employees regularly working on processes to participate in exercises aimed at improving those very processes (Adler et al., 1999; Ittner and Larcker, 1997b). Process improvement practices incorporate an organizational learning perspective as they are aimed at making use of the knowledge of employees thereby enhancing the inimitability of organizational processes (Garvin, 1993a). Thus, for process improvement efforts to be effective, management needs to ensure, through the use of appropriate practices, that in addition to means and authority to participate in improvements, employees have a sustained level of interest toward seeking process improvements (Upton, 1996).

2.2.4. Enhancements in process improvement practices:

Just as employees at the process level are engaged in discovering and executing process improvements, at the organizational level, managements engage in discovering enhanced practices to encourage, coordinate and conduct process improvement exercises (Euske and Player, 1996; Zmud, 1984). Existing literature supports the idea of updating such organizational level practices and also provides empirical evidence of the cascading effects of improvement-practice enhancements on process performance (e.g. Barnett and Carroll, 1995; Hannan et al., 2003; Ittner and Larcker, 1997b; Zollo and Winter, 2002). Osterman (1994) used the term "innovative work practices" to describe new and improved models of organizing work incorporating employee-empowering practices such as broad job definitions, teams, job rotation, quality circles and TQM. Ettlie (1988) and Jelinek and Burstein (1982) highlighted the important role of such administrative structure innovations in supplementing technological innovations for competitive advantage. Bailey (1993) classified the characteristics of improved work organization among three components – motivation, skills and opportunities to participate. Appelbaum et al. (2000) studied the performance effects of workplace innovations in three industries – steel, apparel and medical electronics equipment and imaging. They found, among other things, empirical support for the positive effect of improved work practices on organizational commitment and job satisfaction among employees. While these studies emphasize the role of organizational practices for process improvements, there is a dearth of insight on the relationship between the evolutionary cycles of such practices and those of popular CI programs (Taylor and McAdam, 2004).

2.2.5. Combinations of practices as CI Programs:

Pil and MacDuffie (1996) noted that work organization practices were more effective when implemented as parts of larger bundles or systems that included complementary practices than piecemeal. They presented empirical support for their assertion; other researchers also supported the notion of bundles. We review some of this research as it is relevant to the formation of CI programs, which are combinations of practices that gain popularity. Shah and Ward (2003) provided empirical support for substantial performance effects of bundles of practices. Ichniowski and Shaw (1999) analyzed the differences between American and Japanese steel manufacturers and found that innovative work practices in general contribute to quality and productivity, more so when the entire bundle of practices is used. They found that US companies adopting limited employee-participation practices such as problem-solving teams and information sharing were less effective in improving process productivity than companies adopting the whole range of practices including extensive orientation of new employees, training throughout their careers, job-rotation, job-security and profit-sharing.

CI programs such as TQM and BPR are organizational enablers that enhance the capability of an organization for productive learning (Argyris, 1999b) and organizational performance (Ichniowski and Shaw, 1995). CI programs consist of employee involvement practices such as daily line-meetings, cross-training and use of statistical quality control (SQC); work organization practices such as line specific teams and cross-functional teams; and human resource management practices such as training and nontraditional reward systems. While different combinations of practices are aimed at pursuing different sets of ideals such as zero defects or one-piece-lot-sizes, they are ultimately steps toward common goals of organizational profitability and growth (Appelbaum et al., 2000). The tremendous empirical support that exists for the effectiveness of several CI programs such as TQM and JIT (e.g.: Cua et al., 2001;

Fullerton et al., 2003; Hendricks and Singhal, 2001; Kaynak, 2003; Samson and Terziovski, 1999; Taylor and Wright, 2003; Yeung et al., 2006) indicates that CI programs do exert positive influence.

Successive CI programs represent the progressive development of organizational practices for conducting, coordinating and sustaining process improvements; the updating of practices affects the survival and growth of an organization (see Figure 2.2). For example, the involvement of customers (Cristiano et al., 2000; Thomke and von Hippel, 2002) and suppliers (Dyer and Nobeoka, 2000; Petersen et al., 2005) in new product development processes is an organizational practice that has become imperative as customers become more sophisticated and products became more complex. Consequently, newer CI programs such as BPR and Design for Six Sigma (DFSS) include specific practices to deliberately involve customers and suppliers. Thus, even though CI programs may have a limited lifespan they do not appear to be ineffective as suggested by proponents of the fads theory.

2.2.6. <u>Scrutinizing the implications of a fads label:</u>

CI programs get labeled as fads when their popularity leads consultants and organizations to exploit them as universally applicable quick fixes or "magic sauces" that can solve virtually any problem. Most common criticisms related to the ineffectiveness of faddish programs (Abrahamson, 1991; Miller et al., 2004) are based on their following characteristics:

(1) Present oversimplified solutions that cause harm rather than provide benefits (Mitroff and Mohrman, 1987).

(2) Signal innovativeness or enable organizations mimic other adopters without adding any real value (DiMaggio and Powell, 1983).
(3) Lead organizations to move from one program to another without allowing enough time for the any one program to be effective (Lawler and Mohrman, 1985).
(4) Are thrust upon organizations as a result of a powerful player that sees benefits for itself (Power and Simon, 2004; Bloom and Perry, 2001).
(5) Do not really offer anything different than existing sets of principles and practices (Kihn, 2005).

Scrutiny of the first four characteristics listed above reveals that they are not really criticisms of the content of CI programs. They relate primarily to the circumstances and manner in which the CI programs are adopted (De Cock and Hipkin, 1997; Pfeffer, 2005). The fifth characteristic about the value adding potential of a CI program is one that relates directly to the content of the CI program. However, it poses a question about the CI program being distinctly different from existing CI programs and thereby having potential for incremental benefits over those available from existing CI programs (Gibson and Tesone, 2001).

Some researchers portray the finite nature of a CI program's life-cycle as evidence that that it was an ineffective fad and therefore should not have passed muster in the first place (e.g. Goeke and Offodile, 2004; Miller et al., 2004). An alternative perspective is that the set of practices may have been absorbed and integrated into a large number of organizations and in the next generation CI programs, and is therefore no longer a hot topic for discussion (Chiles and Choi, 2000; Cole, 1998; Westphal et al., 1997). These CI programs, much like technological innovations, may have had a constructive lifetime (Rosenberg, 1969) and represented a step in the progression of organizational work practices for process improvements.

Technological advances that are great for the period they are discovered may fade from subsequent view but pave the way for subsequent developments – a good example of this phenomenon in the context of aviation technology is provided by Miller and Sawers (1968) and cited by Nelson and Winter (1982). The advent of the propeller-engine powered DC-3 in the 1930s revolutionized commercial air travel with its newly developed capability of carrying approximately 30 passengers; the model was overshadowed by the jet-engine powered DC-8 and DC-9 in the late 1950s. These technological advances took place through interactions of lessons learnt; parallel developments in related technologies such as light and strong materials for fuselage, and wings and navigation equipment; the growing demands of customers, fueling and being fueled by new developments; and the growth of competition targeting the same demand base.

As new technologies represent incremental steps over preceding ones, so do administrative technologies (Nef and Dwivedi, 1985; Teece, 1980) including CI programs. Newer CI programs incorporate lessons learnt from previous CI programs (e.g. pull production and mass production), make adjustments for different work-cultures in their implementations (e.g. Toyota Production System implementations in the US), cater to growing customer needs (e.g. faster development of new products) and incorporate new technological advancements (e.g. the Internet).

Although investigations into the stages of life-cycles of CI programs are appropriate for analyzing differences between early and late adopters (e.g. Naveh et al., 2004; Segars and Grover, 1995) and for studying changes in CI programs over their popular life times (e.g. Mueller and Carter, 2005; Prajogo and Sohal, 2004), they are not suitable for assessing the effectiveness of CI programs. Toward that purpose, we need to address important questions related to characteristics of a CI program: 'what' is new, 'when' and 'why' it works, and 'how' should it be implemented so that it works as expected. As mentioned earlier, these questions relate to (1) any substantial changes in the content of a CI program over previous ones, (2) the rationale behind the CI program that can be used to attribute performance improvement to its adoption to, and (3) steps that organizations should take for appropriate adoption and adequate adaptation.

2.3. Evolutionary economic theory

2.3.1. Hierarchy of routines:

The interrelated development of practices and CI programs fits into the evolutionary economics framework, which incorporates a hierarchy of organization routines with higher order routines affecting how work is done at lower levels (Dickson, 2003). Evolutionary economic theory begins with the notion that organizations, at any given time, have certain routines (capabilities and decision rules) that are modified as a result of environmental events (exogenous factors) and deliberate improvement efforts (endogenous factors) (Nelson and Winter, 1982). "The generic term "routines" includes the forms, rules, procedures, conventions, strategies, and technologies around which organizations are constructed and through which they operate" (Levitt and March, 1988:

p. 320). Thus, routines encompass multiple levels of activities that are nested – e.g., as discussed in section 2.2, ways of executing processes are nested within practices for seeking and implementing process improvements (Campbell, 1974).

Adler et al. (1999: p. 45) used the terms creative ‘metaroutines’ or routines “for inventing new routines” referring to what we call ‘practices for process improvements’. Metaroutines signified the innovation-routines used by Toyota’s employees to improve established daily-work-type process-execution routines, distinguishing them from routines for executing processes and those for selecting among process-execution routines. Such sets of practices (metaroutines) have also been labeled production administrative structure (Jelinek and Burstein, 1982) and organizational innovation (Ettlie, 1988).

Thus, in our discussion of the theory of evolutionary economics, routines are practices for the conduct, coordination and sustaining of process improvements (Benner and Tushman, 2003) – we focus on changes and innovations in these practices through managers looking to enhance process improvement. Such practices in organizations and as part of CI programs are applicable across industries and different types of organizations; i.e., our discussion does not include technology-specific routines, such as those related to different routines for steel manufacturing used by traditional large steel mills and contemporary mini steel mills (Ettlie, 1988; Nilsson, 1995).

For all levels of routines, organizations seek and adopt innovations from the external environment in addition to making improvements internally; thus, organizations relate to the environment at different levels (Elenkov, 1997) as indicated in Figure 2.2. In determining the most effective practices to solve process problems (learning better ways to learn), organizations consider arrangements of relationships or structures for allocating resources and integrating workflows and broad sets of techniques (Argyris, 1977). Alterations or innovations in structures and techniques, which we refer to as practices, are made in light of the outcomes of earlier practices and in response to changing environments or contexts (Schön, 1975). Organizations that make appropriate and aligned internal and external innovations are successful; they are able to take advantage of environmental opportunities and survive environmental challenges including competition (Beer et al., 2005; Siggelkow, 2001). Those organizations that fail to update their routines decline and get winnowed out.

2.3.2. <u>Evolutions of practices and CI programs:</u>

Although the application of evolutionary economics transcends multiple levels, in this study we concentrate on two levels of changes, (1) in practice-combinations within organizations (Warglien, 2002), and (2) developments of CI programs across organizations (Bass, 1994). Figure 2.2 (shaded portion) and Figure 2.3 depict evolutionary mechanisms in these two focal areas. Before elaborating on the underlying evolutionary mechanisms at the two levels (Aldrich, 2000), we provide a brief description of the schematic in Figure 2.3.

Organizations create variations in their practice combinations – managers try out new ways of organizing work toward facilitating and encouraging process improvement. Variations in practices may be initiated by internal invention of novel practices or external adoption of existing practices. Variations will be selectively retained or eliminated based on whether they are useful or not and whether they survive despite divergent practices. Novel practices created as a result of variation in practices may also displace existing practices. Retained practices affect further variation – signified in Figure 2.3 by the feedback into variation of practices from retention. In addition, retained variations may become popular outside the originating organization, and if they represent significant changes, feed into the variation-selection-retention cycle of the set of CI programs that are publicized across organizational populations – depicted by the dotted arrow from retention of practices to variation of CI programs. The set of popular (retained) CI programs, in turn, adopted by individual organizations as externally inspired variation in practices. Thus, the inter-related cycle of practices and CI programs continues. In the following paragraphs we elaborate on the variation, selection and retention of organizational practices for conducting, coordinating and sustaining ongoing process-improvement.

2.3.3. Variation in organizational work practices:

Variations are akin to genetic mutations in the biological context, and, in the organizational context, refer to deliberate changes in incumbent work practices (Romanelli, 1991). Variations in practice-combinations involve departing from incumbent ways of conducting or organizing jobs such that the new ways are more conducive to making process improvements. For example, by introducing participative teams and transferring authority to such teams for making improvements in processes, an organization implements a new coordination system - - a practice - - that enables faster improvements. There are different parameters of variance and these are listed in Table 2.1 and explained in the following paragraphs.

2.3.3.1. <u>Search for variation:</u> Variations in work practices take place as a result of organizational members at and above the managerial level searching for better ways to conduct or organize processes at worker levels (Hannan et al., 2003; Zollo and Winter, 2002). Such search for variations in incumbent practices may be conducted internally, through ideas for change generated by organizational members, or externally, by studying other organizations and/or employing consultants (Henderson and Stern, 2004; Van de Ven and Poole, 1995). Thus, the result of the search may result in internally generated changes, or external adoption of practices or existing popular sets of practices (CI programs), completely or partially.

2.3.3.2. <u>Motivation for variation:</u> Variations are initiated due to internal or external pressures, and each of the motivators – internal and external – can either be based on justified cause-effect reasons such as higher efficiencies, or on superficial reasons, such as pressures for adoption (Abrahamson and Fairchild, 1999). Justified internally motivated variations are frequently spurred by persisting problems that are adversely affecting organizational performance (Kolesar, 1993; Li and Rajagopalan, 1998), e.g. a high defect-rate in several processes that the organization has failed to reduce or an inability to sustain improvements given current process-improvement practices. Alternatively, an organization may be spurred to vary practices proactively as a result of internal misalignments (Siggelkow, 2001). These misalignments may be the result of changes in strategic outlook such as a shift in the definition of defects and process improvement from one focusing on a cost-reduction perspective to an innovation-centric outlook. An even more proactive stance may be taken by organizations that generate impetus for change continually through a culture of promoting experimentation with new work practices at the managerial level (Smith et al., 2005; Teece et al., 1997). On the other hand, superficial internally motivated variations are caused by forces such as changes in top leadership (Tushman et al., 1986) or organizational mergers (Inkpen and Currall, 2004).

Justified externally motivated variations occur because of a need to align with external environment changes such as change in predominant technology that requires new ways of organizing practices, e.g. changes from large integrated steel mills to mini mills, or change in prevailing labor laws. Alternatively, in the case of superficial externally motivated variations, organizations may simply be imitating other organizations (DiMaggio and Powell, 1983). Such imitations may be induced by dominating suppliers or customers (Westphal et al., 1997), or by the association of a CI program with legitimacy and innovativeness among peer firms (Gibson and Tesone, 2001). For example, suppliers of Walmart adopted radio frequency identification (RFID) technology (McClenahen, 2005) following Walmart's dictate. Organizations have also been known to adopt enterprise resource planning (ERP) systems in order to portray their legitimacy among peer organizations (Benders et al., 2006). Apparent successes of a CI program in other organizations may cause an organization to adopt the CI program without analyzing fit within its own context (Abrahamson and Fairchild, 1999).

2.3.3.3. Extent of variation: Variations range from small incremental changes to existing work practices such as introducing cross functional teams, to fundamental changes such as moving from a bureaucratic top-down work coordination system to an organic participative-teams system (Abrahamson, 2004; Romanelli and Tushman, 1994). As a result of a search for radical variations, an organization may internally develop a novel and unconventional bundle of practices (for the time) that proves beneficial not just for the pioneer-organization but for other organizations as well. Such a bundle may gain popularity as the next CI program (Massini et al., 2002). On the other hand, the extent of variation or displacement in incumbent practices required for adopting a practice or CI program from outside the organization will be path-dependent as explained in the following section; even the capacity of the firm to search for incremental and radical changes (internally and externally) is affected by existing practices (Cohen and Levinthal, 1990).

2.3.4. Path dependency:

Incumbent process improvement practices serve as genes of an organization because they determine how the organization routinely improves its processes. In addition, as genes, their inherent characteristics (akin to DNA) affect whether and how practices change (i.e. how the genes morph). Thus, the existing makeup of practices makes both internal generation of changes and external adoption of practices path dependent.

The path dependency of change in process improvement practices has three main implications for the external adoption and absorption of CI programs by organizations.

First, it affects the ability of an organization to search for a new CI program contingent on the incumbent practices accumulated over time and consisting of practices adopted externally and developed internally (Cohen and Levinthal, 1990). Second, the CI program-adoption will often require modification of incumbent practices to aid the diffusion of the CI program (Nelson and Winter, 1982). The change required may necessitate destroying previous competencies in which case it would be a radical and revolutionary frame-breaking change as opposed to an evolutionary frame bending one needed for incremental modifications (Dewar and Dutton, 1986). For example, if the existing structure of a firm is bureaucratic then the adoption of a program like quality circles which requires meaningful participation of frontline workers will require foundational changes in the structure for the adoption to be effective. Another organization with a participative organizational structure will require less change to adopt the new set of practices. Finally, if the incumbent practices are steadfast, new practices that are being selected externally and may be part of a CI program will be altered to align with such incumbent practices. In this manner, incumbent practices, in addition to affecting internal and external searches for new practices also affect the manner in which the next mechanism in evolution – namely selection – plays out.

2.3.5. Selection:

A new gene or a mutated gene either survives by adjusting to the incumbent genes that surround it or by changing the surrounding genes to result in a match. In organizations, selection is the assessment of matches between incumbent and new practices and the ensuing struggle for survival between them (Nelson and Winter, 1982).

Thus, in a way, selection acts counter to variation because it represents a move toward homogeneity of practices. Depending on the conviction-level (for whatever underlying reason) of organization members for sticking to current practices versus changing to new ones, changes in practices initiated through variation may or may not take place.

There may be several reasons for organization members to resist change. Blind skepticism about the change and attitudes of inertia are two common examples of resistance that can have detrimental consequences as they hamper the organization's ability to keep up with environmental requirements (Pil and MacDuffie, 1996). On the other hand, the process of selection can also incorporate jostling toward alignment of practices so that complementary practices remain. Such alignment is beneficial and even essential in generating commitment for new practices so that they have a sustained impact – e.g. participative leadership can be beneficial for generating buy-in for new practices.

We must note here that a preoccupation with such alignment of practices can, in its wake, have detrimental effects on innovativeness as it encourages search for changes to be predominantly local – within the vicinity of incumbent practices (Benner and Tushman, 2003). However, this is where the next higher level of evolutionary agents, upper management needs to play a role in recognizing when a breakthrough change is needed, either by attempting a radical shift in-house or adopting a radically different program of practices externally. Nevertheless, any forced selection of practices because of non-performance related justifications, such as coercion by suppliers or blind adoption of fashionable programs, can lead to failure in generating benefits or the generation of limited benefits betraying the full potential of new practices.

It is also worth noting that the adaptation of practices from CI programs as a result of a play-out of the selection forces between incumbent and changed practices poses a problem for researchers trying to infer cause-effect connections between any CI program and organizational performance. Particularly, for a failed CI program, it is difficult to pin the cause of such failure to inherent weakness of the CI program or its idiosyncratic adoption in an organization. Hackman and Wagemen (1995) touched on this issue asserting that the spirit of TQM ceases to exist in its customized adoptions resulting in what is being adopted as anything but TQM.

2.3.6. Retention:

Retention is the propagation of genes that survive the selection process. In organizations, retention signifies spreading the selected practices so that different parts of the organization are applying standardized combinations of practices for generating process improvements (Garvin, 1993a; Edmondson et al., 2001). The retention of changed practices turns them into the new set of incumbent practices, until further change is initiated. Thus, retention dictates the nature of path dependency and the extent of change required for deploying another new practice or adopting a new CI program.

2.4. Evolution of CI programs

Patterns of variation, selection and retention in CI programs are related to evolutionary cycles of practices in individual organizations – practices implemented in organizations feed into and are fed by popular CI programs. In the following paragraphs we describe the manner in which the mechanisms of variation, selection and retention play out for CI programs.

2.4.1. CI program variation:

CI programs emerge from organizations that develop them; they are not invented by organizational theorists in laboratories using test tubes (Galbraith, 1980; Schön, 1975). The novel content in CI programs may be closely related to preceding CI programs or may be relatively divergent from them. Radically divergent CI programs materialize less frequently than those containing a recombination of existing practices or those supplementing the focus of existing CI programs. For example, while JIT represents a major shift in process improvement principles from job-lot manufacturing – one-piece flow versus maximizing capacity utilization – (Mullarkey et al., 1995); TQM combines the idea of customer focus (Sitkin et al., 1994) with the two percepts of employee empowerment and system view that existed in quality-control-circle programs (Lillrank and Kano, 1989).

2.4.2. CI program selection:

Selection of a CI program – increase or decrease in the size of a CI program's population, or a CI program's rise or fall in popularity among organizational and academic populations – is related to environmental factors affecting organizations. For example, changing customer expectations have required most organizational populations to shift their focus from tradeoffs among competitive priorities to accumulation of competitive capabilities (Rosenzweig and Roth, 2004); emerging CI programs such as lean operations (Shah and Ward, 2003) incorporate such a focus. Similarly, the word quality has changed its meaning from 'conformance to specifications' in the pre World War II era to today's broader definition of 'customer needs and requirements' (Reeves and Bednar, 1994; Takeuchi and Quelch, 1983). As a result, newer CI programs emphasize learning about customer needs in addition to controlling defects in manufacturing and delivery processes.

Technology and competing CI programs also influence emerging CI programs as these new CI programs represent a convergence of practices from previous CI programs and related technological advances (Challis et al., 2005; Voss, 2005). For example, lean manufacturing makes use of complementarities between inventory reduction practices of JIT, quality focused efforts of TQM and TPM, and flexible workforce focused efforts of HRM (Shah and Ward, 2003). Also, sophistication in information technology has lead to advances in emerging CI programs that incorporate its use resulting in enhanced benefits from deploying these CI programs (Preuss, 2003). Thus, in addition to selection of CI programs among organizational populations, practices within CI programs also get selected in and out. Practices that continue to provide benefits survive and are either retained in some form in the next generation of the same CI program (see Hines et al.'s (2004) description of the evolution of lean thinking) or appear as part of emerging CI programs (Bartezzaghi, 1999). Practices that are eliminated are those that either did not prove to be beneficial or lost their efficacy as a result of environmental changes.

Institutional factors such as coercion by large and powerful organizations also affect selection of CI programs resulting in some CI programs gaining popularity faster than others, and conversely in the decline of some CI programs (DiMaggio and Powell, 1983). For example, novel inventory practices for improving the efficiency of the supply chain are thrust upon suppliers by powerful players such as Walmart (McClenahen, 2005) and Chrysler (Purchasing, 7/13/1995). Conversely, there may be gems of innovative programs deployed by organizations that are modest or secretive about them and therefore such practices remain undiscovered. Knowledge entrepreneurs – consultants and academicians that sell CI program deployments – also affect the selection of CI programs. This phenomenon was described as management fashions by Abrahamson and Fairchild (1999) who provided a detailed description its occurrence in the context of quality circles.

2.4.3. <u>CI program retention:</u>

The retention and propagation of a CI program depends on whether it survives the selection process (See Figure 2.4). Moreover, the form in which a CI program is retained depends on the extent to which particular practices constituting the CI program are altered in the course of selection. While a CI program originally gets publicized because its deployment is seen as improving the ability for process improvement in innovator(s) and early adopters (Strang and Macy, 2001), different scenarios of retention CI program-retention can occur:

1. It does not survive long i.e. it does not gain popularity among organizational populations if it does not prove to be as beneficial as it was made out to be by the pioneer organization.
2. It gains in popularity resulting in growth in its population, i.e. propagates and spreads among a large number of organizations.

3. Further enhancements in the CI program consisting of additions and eliminations of practices and principles leads to the development of a related CI program as in the case of the development of TQM from Quality Circles.
4. A burgeoning CI program gets assimilated almost universally or at least recognized into the routine-practices of organizations, is therefore no longer externally recognized as novel and loses the extraordinary status of a CI program, e.g. incentive components of salaries.
5. An innovative CI program that contains practices that are incompatible with incumbent CI programs emerges, driving the incumbents into elimination. For instance, developments in flexible manufacturing reduced the importance of forecasting.
6. Environmental changes in customer demands, technology or government regulations leads to the reduction in the efficacy of the innovative CI program.

Six Sigma is a CI program that is currently popular among organizational populations but emerged through variation-selection-retention cycles at organizations such as Motorola and GE and is now being combined with lean creating a new hybrid CI program. Applying evolutionary economics to the emergence of Six Sigma helps focus on the origins and incremental elements of the CI program. In turn this helps assess the utility of Six Sigma. Studying the underlying reasons for adding these elements to existing CI programs and exploring the theoretical reasons for their relationship to process improvement are useful for both academicians and practitioners alike. In the next section we describe the Six Sigma CI program and map its evolution from previous quality-focused process improvement initiatives. As we apply the evolutionary perspective we also develop propositions to study contextual factors that affect its deployment and to assess the incremental contributions of Six Sigma.

2.5. Six Sigma and the evolution of practices and CI programs

2.5.1. Description of the Six Sigma CI program:

Six Sigma consists of a combination of practices that include tools and techniques used at the project execution level for systematic data-driven process improvements and a set structure for project- and organizational- level administration (Pyzdek, 2001). The process-improvement repertoire comprises technical tools such as statistical quality control (SQC) and design of experiments (DOE), as well as soft project- and change-management techniques such as process mapping, brainstorming, fool-proofing methods and visual dashboards (Hahn et al., 1999; Hoerl, 2001). Six Sigma is therefore aptly defined as a "…systematic method for strategic process improvement … that relies on…the scientific method to make dramatic reductions in customer defined defect rates" (Linderman et al., 2003: p. 195).

While consumers focus on quality of products (goods and services), organizations focus on the quality of processes involved in conceptualizing, making and delivering those products. These processes must create value for the company while catering to end-customer satisfaction. In Six Sigma, customer-focused improvement is targeted without losing sight of the wellbeing of the investors in the company (Harry and Schroeder, 2000). The emphasis on tangible and quantifiable answers in this definition reveals an unwavering commitment to the measurement of results and the belief that you cannot improve what you cannot measure.

Deployment of the Six Sigma program involves training employees at different levels in the organization to varying degrees in its tools and techniques (Hoerl, 2001).

Process improvements are mainly targeted through discrete team-projects guided by full-time experts called Black Belts. In addition to Black Belts, project teams typically consist of the process-owner of the main process being targeted for improvement and employees involved in the planning and day-to-day operations of the process. Thus, a Six Sigma project team may be cross-functional and transcend organizational levels, and its members may have had some level of Six Sigma training. Project teams are created for every project and disbanded after its completion, with the process owner and the project leader bearing responsibility for sustaining the implementation of resulting improvements. Every project is executed following the DMAIC framework consisting of the Define, Measure, Analyze, Improve and Control stages (Rasis et al., 2002). DMAIC is a formalized project-level application of the familiar Plan-Do-Check-Act cycle (Shewhart, 1939) and provides a standard structure for the execution of every project; a persistent focus on the customer is maintained through every stage of DMAIC.

2.5.2. <u>Evolution of Six Sigma:</u>

The Six Sigma statistic was introduced at Motorola first, in response to frustrating quality problems that the company was facing with its 'bandit' pager (Kumar and Gupta, 1993; Wiggenhorn, 1990). Motorola had a TQM program then (Poirier and Tokarz, 1996); the company undertook a radical shift in its attitude toward process quality and internally developed the DMAIC framework combined with the stringent variance-statistic for making process improvements. The Six Sigma program included several existing TQM practices such as cross-functional teams and customer involvement. The Six Sigma CI program was thus the result of an internal discovery of a combination of practices for process improvement that worked better than its preceding incumbent at instituting process improvement. The genesis of Six Sigma fits the evolutionary economics pattern of CI programs emerging from organizations searching for better combinations of practices.

The Six Sigma metric signifies driving down the variance of the process to an extent where a range of ± 6 standard deviations from the mean (center-line) falls within customer specifications; this translates to 3.4 defects per million opportunities (DPMO) (Bothe, 2002). Using this ultimate objective for every process, the program introduces practices for creating an organizational culture of scientific process improvement with continually stretched goals (Linderman et al., 2003). Although previous quality-focused initiatives incorporated variance-reduction techniques, the notions of such dramatic reductions and the use of the Six Sigma statistic for continually inspiring improvements are unique to the program. The first proposition is about the primary objective of Six Sigma programs that is reflected in the Six Sigma metric.

> Proposition 1: The primary objective of all Six Sigma deployments is dramatic reduction in process-variance.

AlliedSignal was one of the early adopters of Six Sigma and the company attributed tremendous success in process improvement executions to Six Sigma practices. Subsequently, GE adopted the program from Motorola and AlliedSignal. The initial adoption of Six Sigma at GE is known to be a personal initiative of Jack Welch after he heard about the success of the program at AlliedSignal from his friend Larry Bossidy, then CEO of AlliedSignal (Bartlett and Wozny, 2005). Since then, several such leader-driven deployments have since been made at companies such as Raytheon (Smith and Blakeslee, 2002) and 3M (McClenahen, 2004). These leaders justify the deployment of Six Sigma as a program for sustainable and breakthrough process improvement.

2.5.3. Contextual factors: There are several organizational factors affecting the deployment of Six Sigma. These factors dictate the reasons for deployment and the patterns of deployment of the CI program. The next six propositions deal with such contextual factors.

Before the advent of Six Sigma, the propagation of CI programs and standards such as TQM and ISO 9000 is known to have been caused in part by the coercion of small organizations by larger organizations. This also resulted in the belief that the spread of the rhetoric outweighed the reality of these programs and standards (Boiral, 2003). The spread in popularity of Six Sigma may follow this pattern of coercion- and rhetoric- based adoptions (Kleinert, 2005), which is the basis for our next proposition.

Proposition 2: In industries where major organizations have adopted Six Sigma, other organizations will follow either voluntarily or under pressure.

The Six Sigma deployment at GE was immediately preceded by the conduct of workout exercises – open forums for upper and middle management that created cultures of confronting problems head-on and of accountability (Tichy, 1989). These meetings ended up laying a good foundation for the deployment of Six Sigma. Further, GE adapted Six Sigma by making changes to the program, emphasizing not only the statistic and the DMAIC framework, but also on the softer implementation practices and motivational elements. Thus, GE made significant changes to the set of practices in the

CI program in addition to making alterations to its incumbent practices. Another example of Six Sigma adaptation is seen in some Information Systems divisions whose work is ordinarily structured as projects. The deployment of Six Sigma, in these divisions, is sometimes accomplished by incorporating the methodology and practices with existing projects. Thus, Six Sigma deployments involve making adjustments to some incumbent practices while varying some inherent elements of Six Sigma, resulting in the following proposition:

> <u>Proposition 3:</u> Deployment patterns of Six Sigma depend on incumbent practices – some incumbent practices and some adopted practices may be altered.

Six Sigma shares several principles and practices with predecessor CI programs such as JIT, BPR and lean operations (Antony et al., 2003; Sharma, 2003). An organization that has deployed one or more such related CI programs will need to make less dramatic changes to deploy Six Sigma than one that has not. It follows then that our next proposition has to do with the adoption of Six Sigma requiring different extents of deployment effort, depending on the incumbent set of practices.

> <u>Proposition 4:</u> The extent of change required to initiate deployment of Six Sigma ranges from incremental to radical, depending on incumbent process improvement practices.

Several Six Sigma deployments in organizations such as Boeing (Culbertson, 2006) and Xerox (Burt, 2005) incorporate elements of lean manufacturing. The contents of the two CI programs have merged (Furterer and Elshennawy, 2005; George, 2002); DMAIC is used to execute Six Sigma projects that have variance-reduction goals as well as lean projects aimed at waste-reduction. This is an indication of variation in the CI program, leading us to our sixth proposition for exploring developments in Six Sigma.

> Proposition 5: Six Sigma is taking the form of a hybrid CI program by incorporating the principles and practices of lean production.

There are constant debates about the suitability of the Six Sigma program for small organizations and organizations whose core competency is innovation (Brady, 2005). Prevailing perceptions are that Six Sigma needs too much investment to be deployed in small organizations (Davis, 2003) and that its improvement focus may stifle innovation (Brady, 2005). Benner and Tushman (2003) have posited that all process improvement programs take attention away from exploration of new ideas. These notions are the basis for two propositions speculating on the types of organizations for which Six Sigma deployments are more beneficial.

> Proposition 6: Six Sigma deployments are suitable primarily for large organizations.

> Proposition 7: Six Sigma deployments are suitable primarily for organizations whose primary focus is not radical innovation.

2.6. Six Sigma and quality focused CI programs

While our first seven propositions are about the inherent elements of the Six Sigma program and about the fit of the CI program with organizational contexts, we now turn to the questions of whether and how Six Sigma corrects deficiencies identified in previous CI programs. Academic interest should focus on analyzing whether Six Sigma has practices that provide incrementally better process improvement in organizations than previous CI programs. The following discussion is aimed at developing propositions about such incremental features of the Six Sigma program. One of the main contributions of Six Sigma is the introduction of an implementation structure that institutionalizes the idea of sustainable continuous improvement. Even though the principle of continuous improvement has existed prior to Six Sigma, there has been a lack of guidance on how it can be ingrained into the psyche of all employees and more important, how it can be sustained. The success of Toyota in accomplishing this task is exemplary – the culture of Toyota is often seen as being the facilitating and differentiating factor. Six Sigma provides a way of introducing the cultural DNA of the Toyota production system (Spear, 2004; Spear and Bowen 1999) into the genetic makeup of organizations. The principles of scientific management being followed in every action by every employee and the use of '*senseis*' as coaches at Toyota are paralleled under the aegis of Six Sigma, albeit in a more formalized manner.

Besides continuous improvement at Toyota, Japanese management practices (see e.g. Inkpen, 2005, Liker and Wu, 2000) have had a significant influence on the progression of quality focused CI programs in the United States. In addition, factors such as globalization, technological advancements and changing consumer needs have altered the makeup of quality-focused CI programs. Thus it is insightful to trace the progression of quality focused CI programs (for detailed historical perspectives of quality practices see Cole, 1999; and Yong and Wilkinson, 2002) culminating in an analysis of the incremental practices under the banner of Six Sigma.

2.6.1. Development of quality-focused CI programs:

Tracing the evolution of quality programs from Quality Circles thru TQM, Cole (1999) pointed out that under the old model preceding TQM, quality evolved within dedicated functional departments consisting of small numbers of quality experts reporting to manufacturing. The purpose of these quality experts was mainly defect detection. In the TQM model, the definition of quality was expanded to include customer oriented perspectives and therefore included the ability to efficiently make changes in response to customer needs (Giroux and Landry, 1998). The scope of quality became dynamic, necessitating the need for flexibility and resulting in a model that empowered employees. Organizations recognized the need for improving cross-functional co-ordination and maintaining a unified strategic outlook while continually making process improvements. The accumulation of these various principles under the expanded view of quality labeled TQM is classified among three main percepts: (a) focus on customer satisfaction, (b) continuous improvement and (3) total system view of the organization (Sitkin et al., 1994).

The development of TQM took place in parallel with industry changes in the areas of flexibility and cost reduction. Quality, which was earlier treated as a tradeoff with cost and /or flexibility started being treated as an omnipresent priority (Flynn and Flynn, 2004). The integration of TQM with just-in-time (JIT) and human resource management (HRM) practices lead to the birth of lean manufacturing (Cua et al., 2001; Shah and Ward, 2003). For academic research it became increasingly difficult to discriminate activities related to TQM from those related to JIT, total preventive maintenance (TPM) and HRM as evidenced from the various labels attached to quality, just-in-time manufacturing and lean manufacturing initiatives (Ahire et al., 1996, Koufteros et al., 1998). The definition and scope of TQM itself morphed and broadened over time (Hackman and Wageman, 1995).

An unintended consequence of the broadening of the scope of quality initiatives under TQM and the addition of organizational change agendas to quality programs was that the underlying structure and rigor were sacrificed. With decentralization, quality became everyone's responsibility and no one's. Cole (1999, p. 45) cites examples of companies like American Express and Corning to illustrate that as quality became every function's and business division's responsibility the importance of an exclusive quality department and leader declined. During this extended evolution of TQM, a number of gaps in the way organizations sought to implement the program became apparent (Poirier and Tokarz, 1996); these are listed in Table 2.2 along with the effects they had on organizational performance.

In fact, failures in TQM implementation in these areas are often attributed to lack of leadership (e.g. Beer, 2003; Leonard and McAdam, 2003). Under TQM implementations, organizational leaders failed to engender the commitment of employees and generate open discussions about the progress of quality from a holistic perspective going beyond cross-functional boundaries (Lemak et al., 2002). A closer look at the content of TQM, however, reveals that it fails to provide guidance about creating such a quality culture. In the absence of instituted practices it becomes difficult for leaders of large complex organizations operating in dynamic environments to continually motivate employees throughout the ranks to proactively seek out the overall organizational benefit while maintaining a systems view. The alternative avenue of intrinsic motivation (Hackman and Oldham, 1976) for generating employee enthusiasm through work characteristics alone has not proven to be effective, especially in Western firms (Senge, 1999).

A superimposed structure specifically for coordinating long-term organizational deployment and daily operational implementations of quality practices can go a long way in creating a sustained quality culture. This is empirically supported in the context of TQM; Douglas and Judge Jr. (2001) found structural elements to have significant moderating effects on the success of TQM. Six Sigma introduces structures for organizational and operational level implementation of practices and addresses this deficiency in TQM implementations (Antony, 2004; Pfeifer et al, 2004; Revere and Black, 2003).

Proposition 8: The underlying gaps in TQM deployments are addressed through Six Sigma in the following ways:

1. The structure of its program deployment – standardized training, systematic project selection and use of periodic quality system reviews provides a unified direction to the quality program
2. The DMAIC framework provides structure for project executions and ensures focus on proactive and data based changes related to customer value
3. The continuity maintained by the trained experts and the repository of project reports facilitates accumulation of learning and learning across projects.

These elements of management are critical for successful pursuit of well established quality principles and practices (Beer, 2003). In the next section we explore the incremental benefits that Six Sigma offers over previous quality-focused CI programs.

2.7. Incremental features and benefits of Six Sigma

Six Sigma not only fulfills gaps in TQM as described in the previous section, it also adds incremental features that represent an evolution toward better process improvement. Some of the innovative features of Six Sigma add useful elements to the three existing percepts of TQM – customer satisfaction, continuous improvement and system view. Further, we propose three additional percepts essential to capture the underlying philosophy of Six Sigma: interlinked project coordination, full time experts, and transfer of learning. The six percepts are described below, each followed by a proposition for an incremental effect of Six Sigma:

1. Customer Satisfaction: Six Sigma emphasizes the concept of total value to the customer by focusing on the total customer experience that includes, besides the conformance and performance quality of the product, the cost at which the product is delivered, the customization that is offered and the cycle time from the customer experiencing a need to receiving the product. Stakeholders in the organization that include stock holders, who care about their returns, and employees, who are internal process customers, are included under the domain of customer satisfaction.

   <u>Proposition 9:</u> The total customer value perspective in Six Sigma provides sustained long term process improvement.

2. Continuous Improvement: The insistence of pre specified goals for every project forces the team to assess the numerical value of the project in units such as dollars or defect rates or time. This ensures that every change that emerges as a result of the project is grounded in real data. The magnitude and type of goals also have psychological implications on team members (Linderman et al., 2003); on the one hand impossible goals can dishearten employees and on the other, stretch goals can motivate them to extend performance frontiers. Improvements from Six Sigma projects have to be approved by independent financial controllers and this provides a check against crediting project teams with illusionary and unreasonable credits for improvements. It also points to areas in which improvements are difficult. In order to guard against situations where short term benefits may be easy to achieve while long term benefits may be hard to sustain, some organizations give credit to project teams for improvements only after a suitable extended period.

   <u>Proposition 10:</u> The attention to setting concrete and independently verified goals for Six Sigma projects and their assessment after appropriate periods of time supports sustained long term process improvement.

3. System view: Six Sigma projects are led by full time Black Belts who have the authority to utilize resources from various functions during the course of the project execution as well as for the implementation of suggested changes (Edmondson, 2003). This supports cross-functional co-ordination. The relatively neutral posture of the Black Belt as an independent consultant also provides a

more objective assessment of total system benefits of any changes and guards against sub optimization of total system performance.

<u>Proposition 11:</u> The structure of Six Sigma project teams – with full time independent-from-process leaders and cross-functional members – assures a systems perspective in targeting process improvements.

4. Interlinked project co-ordination: Organization-wide coordination based on metrics is necessary for the long term success of quality initiatives (Beer, 2003). Six Sigma's structure referred to earlier, includes steering committees at various levels with interlinked participation, e.g. there are operational front-line employees included in the unit level steering committees and there are some top management officials that take part in middle level steering committees. This type of interlinked structure (Graham, 1995) for the coordination of projects helps maintain coordination among the different hierarchical levels in both directions – there is communication of ideas from front lines to the top management and that of overall strategic outlook in the opposite direction. The interlinked structure helps achieve the middle-up-down management that is critical for organizational knowledge creation (Nonaka and Takeuchi, 1996) and absorptive capacity (Van den Bosch et al., 1999). By superimposing this project co-ordination structure the speed and ability of absorbing changes in practices in response to the environment is enhanced.

Proposition 12: The top-down-bottom-up infrastructure for selection and coordination of Six Sigma projects requires environmental scanning at all organization levels and quickens the pace of process improvements.

5. Full time experts: The periodic training waves of Black Belts and Master Black Belts can be used to maintain a repertoire of the latest tools and techniques. The broad repertoire also provides the organization with dynamic capabilities to deal with operational level contingencies and changes. The frontline operational personnel can be trained or refreshed by Black Belts in the use of the tools of techniques, if required, as part of the implementation of individual project results.

   Proposition 13: The differential training provided to different levels of employees depending on their involvement in process involvement provides an efficient way of combining process-specific information and methodology expertise, resulting in better sustainability of process improvement efforts.

6. Accumulation and transfer of learning: Six Sigma projects have periodic reporting at "tollgates" during their executions; these typically coincide with the DMAIC stages. These reports are maintained in centralized databases by most organizations and they assist in the leveraging of insights from the projects across time and across different units. Using the example of a high technology medical equipment manufacturer Graham (1995) highlighted the importance of creating repositories of project information for getting sustained learning benefits from a quality program. Larger organizations especially consider such a database to be of great value and have "keyword search" software included so that their

employees all around the world can have access to the benefits of investments made in Six Sigma projects. Some organizations deploying Six Sigma have adopted the method of having the Black Belt on projects responsible for finding applications of their project results in their various divisions.

Proposition 14: The repertoire of project reports from multiple projects results in efficient sharing of best practices across the organization.

Six Sigma provides a structure to integrate and effectively follow principles and practices from previous initiatives like TQM and BPR. With such a large scope, there are differences in implementations that might be ideal for different environments; this is an area where further research and analysis are needed to discover important contingencies and appropriate implementations in the face of these different contingencies.

2.8. Conclusion

Six Sigma may be destined to follow the fate of previous CI programs; the excitement that it is presently generating may diminish with the passage of time and perhaps with the invention of the next CI program. However, this CI program has incremental features compared to previous quality focused CI programs that make it worthwhile of consideration by academicians and practitioners. These incremental features of Six Sigma will either be retained in the genetic makeup of the next CI program that arrives on the scene or they may be selected out in catering to environmental demands.

We began this chapter with a description of the evolution of practices in organizations and CI programs in organizational populations and created a framework relating the two evolutionary cycles. We then placed the development of Six Sigma within this framework. In drawing analogies between Six Sigma and previous CI programs, mainly TQM, we pointed out that though CI programs get selected out, some enduring aspects are retained in the genes of new CI programs. We followed this assertion with a listing of the novel features of Six Sigma, identifying voids in previous quality programs that Six Sigma fills.

Thus, we transitioned from a discussion of the usefulness of CI programs to one on the incremental features of Six Sigma that represent an evolution of quality and organization change ideas. The jury is still out on which of these features will endure into the next CI program, however we can safely say that the promise of Six Sigma results needs to be closely studied before dismissing it as old wine in a new bottle.

Parameters of variation	End points of Continuums	
Domain of search	Internal	External
Extent of variation	Incremental	Radical
Motivation for variation	Internally generated	External motivators
Justification for variation	Cause-effect	Superficial

Table 2.1
Parameters of Variation

Limitations in TQM implementations	**Effects**
Benefits expected to be long term and non measurable	No assessment of value for company
Training all in quality	No experts
No cross-functional coordination	Cross-purpose efforts
No transfer of learning	Duplication of efforts
No proactive scanning	Reactive stance

Table 2.2
Gaps in the pursuit of the TQM philosophy

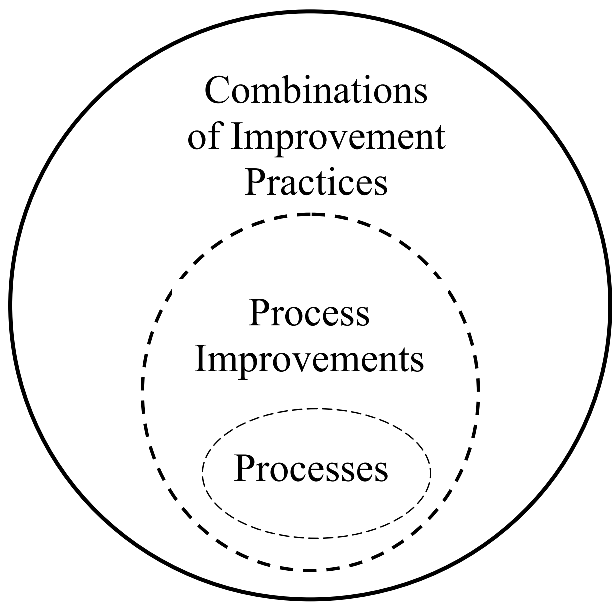

Figure 2.1

Nested relationships of processes, their ongoing improvements and combinations of practices for continuous process improvement

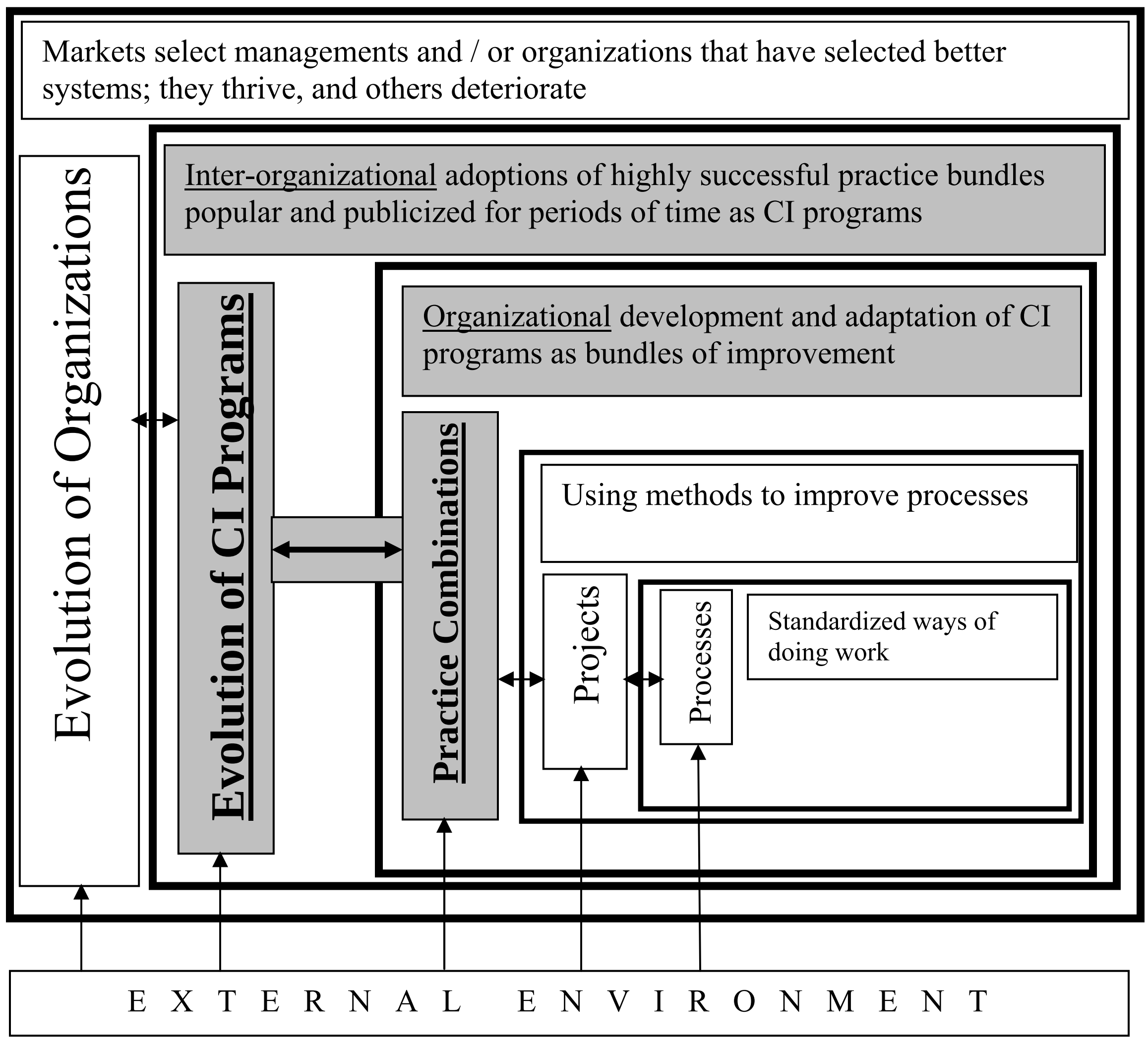

Figure 2.2
Effect of evolving CI programs on an organization's combinations of process improvement practices and role of evolving CI programs in the survival and growth (evolution) of organizations

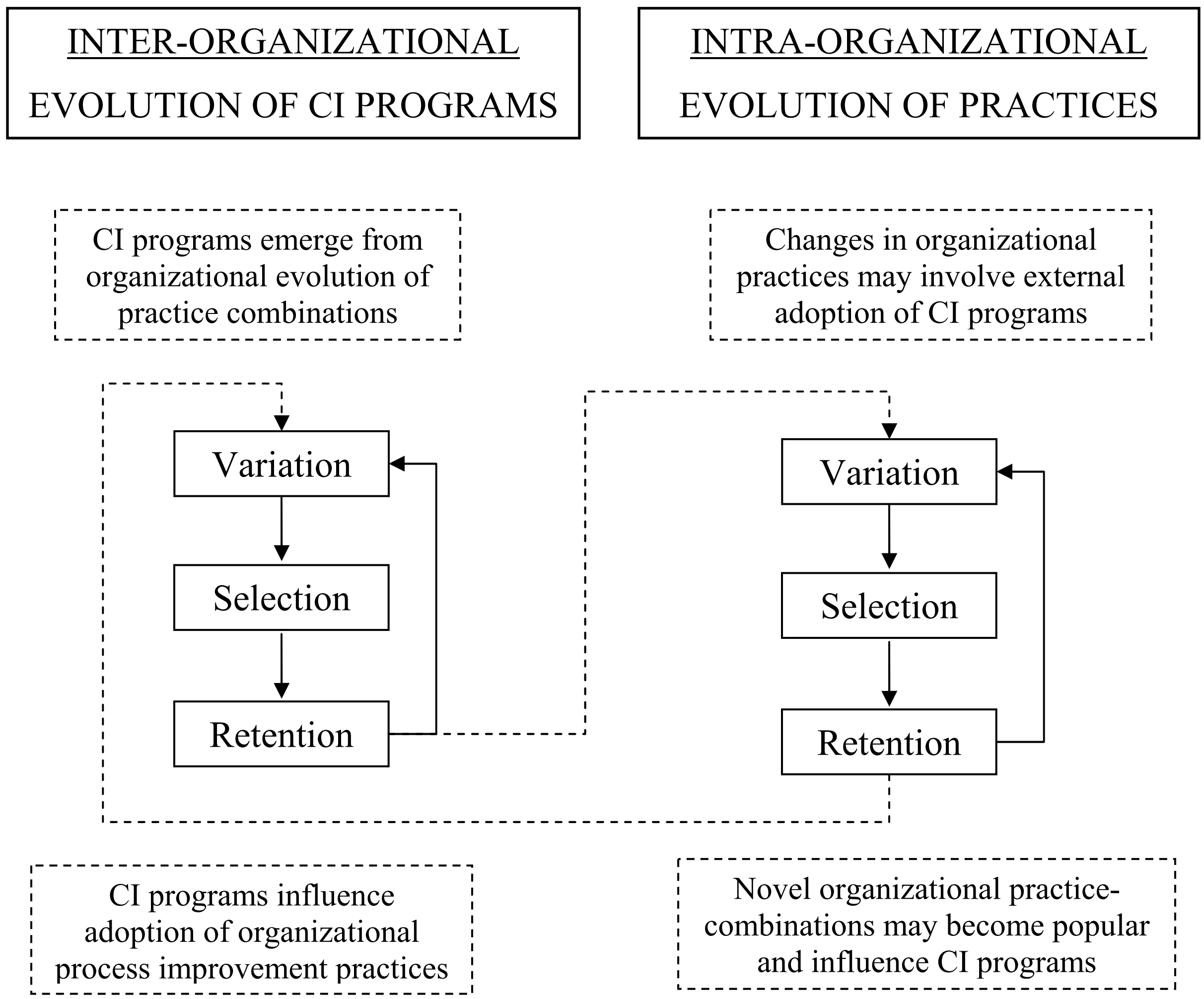

Figure 2.3
Interrelated evolution of CI programs among organizations and process improvement practices within organizations

CAUSE FOR VARIATION		LOCUS OF EVOLUTION	
		Intra-organizational	Inter-organizational
	Superficial	Failure	CI program as fad declines
	Justified	Radical variation becomes next CI program	CI program gets widely adopted and proliferates as fad
		Practices from CI programs are absorbed into generation of novel practices and bundles by pioneer and follower organizations	

Figure 2.4
Evolutionary paths of CI programs

CHAPTER 3

INFRASTRUCTURE FOR CONTINUOUS IMPROVEMENT: THEORETICAL FRAMEWORK AND APPLICATION TO SIX SIGMA PROGRAMS

"There are ways to certain defeat. First is not assessing numbers, second is lack of a clear system of punishments and rewards, third is failure in training, fourth is irrational overexcitement, fifth is ineffectiveness of law and order, and sixth is failure to choose the strong and resolute." From "The Art of War" by Sun Tzu; Chapter 10: "The Terrain"

3.1. Introduction

Continuous improvement is an ongoing activity aimed at improving company-wide performance through focused incremental changes in processes (Bessant and Caffyn, 1997; Wu and Chen, 2006). The role of continuous improvement has evolved in response to new environmental challenges faced by organizations (Bhuiyan and Baghel, 2005). A vast increase in the speed and intensity of environmental changes (Brown and Blackmon, 2005) has resulted in expanding the objectives of continuous improvement initiatives (Cole, 2002). Continually improving process flexibility and innovation capabilities now supplement traditional continuous improvement objectives of increasing efficiencies and reducing costs (Boer and Gersten, 2003). In addition to the expansion of their objectives, the prevalence of continuous improvement programs has also increased in manufacturing and services (Barsness et al., 1993; Swamidass et al., 2001). Today, continuous improvement (CI) programs such as lean management and business process re-engineering play an integral part in operational strategy formulation and implementation (Voss, 2005).

Research on CI programs incorporates project execution protocols such as kaizen blitzes and off-line team initiatives, and practices used to execute projects such as process mapping and statistical analyses. Theoretical inquiries into CI programs mainly focus on project execution protocols and practices because such features reflect the distinctive logic behind each CI program (e.g. Davy et al., 1992; Fullerton et al., 2003). For example, just-in-time management predominantly focuses on inventory reduction while total quality management starts with defect reduction. An additional area of CI that is critical is project planning – the selection and coordination of projects and preparation of the workforce to execute projects.

The absence of systematic planning for projects can result in prioritization of unimportant issues and prevalence of knee-jerk interferences from upper management (Wruck and Jensen, 1998). Such planning is critical for organizations to target the right level of improvement through CI programs – the middle-ground between superficial and too-ambitious improvements (Hackman and Wageman, 1995). Researchers have acknowledged the importance of such project-planning issues for CI programs (see e.g. Alexander et al., 2006; Flynn and Sakakibara, 1995; Kwak and Anbari, 2006; Powell, 1995; Samson and Terziovski, 1999). However, there has been limited inquiry into the theoretical basis for this common feature of all CI programs. Moreover, planning for the CI program is primarily the responsibility of the middle-management level and above while the execution of CI projects mostly occurs downwards from this level (Garvin, 1993b). Thus, planning issues of CI programs warrant separate inquiry from that into the execution of projects in each CI program, which has been of predominant interest.

For successful project planning in CI programs, it is essential for organizations to have in place infrastructure to support the execution of individual process improvement projects. In their research on just-in-time and total quality management programs Sakakibara et al. (1997) found infrastructure practices common to both programs to be significantly related to organizational performance. Irrespective of the brand of CI program in place there are common purposes that CI infrastructure needs to serve. It is important to identify the must-haves for such infrastructure necessary for selecting and coordinating projects and sustaining CI efforts (Bateman, 2005; Upton, 1996). In an effort to bridge the gap in the literature on this topic, this research focuses on theoretically developing an infrastructure framework for all CI programs. We begin by describing CI and identifying its role in organizations. Next, we identify different elements of CI infrastructure that work together in fulfilling the role of CI. Based on an extensive review of organizational theory and process improvement literatures we develop a conceptual framework of CI infrastructure. The constituent elements of this framework can be used as a diagnostic to help organizations assess and improve their CI initiatives – in a sense, improve their continuous improvement.

Six Sigma has recently gained popularity as a CI program that utilizes projects with specific goals aimed at reducing process-variations (de Mast, 2006; Gowen III and Tallon, 2005; Kwak and Anbari, 2006; Linderman et al., 2003). Project-goals are focused on adding value for customers through better customer service – lower costing, better quality and customized products delivered quickly and on time (Harry and Schroeder, 1999; Pande et al., 2000). Such value-add leads to better organizational performance (e.g. De Cock and Hipkin, 1997; Ittner and Larcker, 1997b).

As for all CI programs, infrastructure elements aimed at generating employee commitment, providing training in the scientific method, and enabling co-ordination of projects and tracking of knowledge created are critical for the success of Six Sigma deployments (Kwak and Anbari, 2006; Lloréns-Montes and Molina, 2006). However, this facet of Six Sigma is largely ignored in the shadow of the variance-reduction focus of its projects, and practices such as design-of-experiments and failure-mode-and-effect-analysis. As Six Sigma represents the current stage in continually evolving CI programs, a study of how CI infrastructure can enable translate discrete project results into organizational performance is timely.

Toward this purpose we collect information on Six Sigma infrastructure using semi-structured interviews with Six Sigma executives in five organizations and from descriptions of Six Sigma in the literature. We apply the framework that we develop in this chapter to assess whether and how elements of CI infrastructure help get more out of Six Sigma projects. In this way, we begin to address the important questions of organizational level practices of Six Sigma, and lay the theoretical groundwork for large scale studies of Six Sigma and other CI programs.

3.1.1. <u>Organization of the chapter:</u> In section 3.2 we describe the roles of CI programs based on definitions in the literature. In section 3.3 we develop a framework of infrastructure elements to support improvement projects in CI programs. Section 3.4 consists of a short description of the Six Sigma CI program and a description of our sample. In section 3.5 we relate the elements in our CI infrastructure framework from section 3.3 to practices used by the five firms in our sample. Section 3.6 concludes the chapter with implications for practitioners and academicians, and plans for future research.

3.2. Role of CI programs

While research on total quality management treats CI as a subset of the program (Sitkin et al., 1994) our use of the label CI includes programs such as quality circles, just-in-time, total quality management and Six Sigma that are aimed at continually improving processes. We adopt Boer et al.'s (2000) definition of CI as a planned and organized system for ongoing changes in processes toward enhancing organization-wide performance. The purpose of CI programs is constant organizational renewal achieved by institutionalizing a system for dynamic change in relation to environmental requirements (Delbridge and Barton, 2002; Savolainen, 1999). These changes are made with the involvement of frontline employees in systematic learning closer to the point where the processes being improved are operating (Bessant and Caffyn, 1997; Jorgensen et al., 2003). With the increasing role of frontline employees in designing their own work processes it is important to ensure that the dispersed changes being executed have a common direction (Garvin, 1993a). Thus, we can summarize the role of CI programs as (1) contributing to dynamic strategic capabilities (2) creating new knowledge and learning (3) aligning process improvement goals to overarching organizational objectives.

3.2.1. <u>Dynamic strategic initiatives:</u> A majority of organizations today operate in ever-changing environments; as a result responsiveness and dynamic capabilities have become the norm for survival and growth (Fliedner and Vokurka, 1997; Lei et al., 1996b; Nadler and Tushman, 1999). [See Business Week story, "Speed Demons" (March 27, 2006).] The maneuvers that organizations employ to utilize their capabilities in relation to their environments and to keep moving toward their goals are collectively referred to as strategy (Hambrick, 1980; Hambrick and Fredrickson, 2005; Rumelt, 1997). Conventional methods that assign the strategy formulation and implementation responsibilities to top management alone do not work well in ever-changing environments (Garvin, 1993b). First, because information needs to pass through several layers, it takes longer for upper management decisions to reach operational front-lines and this affects the speed and accuracy of the communication (Beer et al., 2005). Second, different organizational levels are impacted by different and multiple environmental factors (Cyert and March, 1963; Elenkov, 1997) making it difficult for upper management to keep track. Third, a conventional top-down structure inhibits any bottom-up communication about environmental changes (Wright and Snell, 1998).

Overcoming these weaknesses of conventional methods requires the displacement of traditional 'strategy-structure-systems' frameworks, characterized by formulation of strategy at the top levels with directed implementation at the front-lines controlled via relationship structures and reporting systems. Such bureaucratic frameworks have had to be replaced with organic 'purpose-process-people' types of frameworks that treat people as knowledge resources and encourage their participation in discovering better ways of executing processes to accomplish broad organizational purposes (Bartlett and Ghoshal, 1994; Bourgeois and Brodwin, 1984; Hart, 1992). Participative management styles that provide autonomy and facilitate proactive changes at middle and frontline levels (Parnell, 2005; Tourish, 2005; Wall, 2005) are needed for building dynamic capabilities necessary for long term success (Bessant et al., 2002; Ruef, 1997; Teece et al., 1997). In the words of Andy Grove (then CEO of Intel Corporation), "We need to soften the strategic focus at the top so that we can generate new possibilities from within the organization" (Bartlett and Ghoshal, 1994; p. 82).

CI programs can serve as a vehicle for achieving dynamic strategic capabilities through the involvement of middle and lower levels of management (Iansiti and Clark, 1994; MacDuffie, 1997; Mitki et al., 1997; Pfeffer, 2005; Schonberger, 1992). While employees continue to follow standardized work practices, they are encouraged to seek out and propose improvements in the processes they work on (Klein, 1991), thus targeting efficiency and creativity at the same time (Brown and Eisenhardt, 1997). Regardless of their varying primary operational objectives toward performance improvement such as inventory reduction or control of variation (Euske and Player, 1996) CI programs follow a common scheme of engaging frontline employees. By assigning employees a proactive role in operations strategy formulation and implementation, CI programs can create dynamic capabilities that are a source of sustainable competitive advantage (Lei et al., 1996b; Teece et al., 1997; Upton, 1996).

3.2.2. Learning: Frontline employees are trained in routine ways of operating processes, which include selecting among alternate paths of action in response to changes in operating conditions. Sometimes these routine ways of operating processes need to be changed to improve process performance. The changes that need to be made can be discovered through projects executed using CI protocols and practices, and involving employees working on the processes. The two nested activities – routine selection among alternate paths in a process and changes in the routine ways of operating the process – are referred to as single loop and double loop learning (Argyris and Schön, 1978; 1996). CI programs thus have a major role to play in double loop learning, also known as organizational learning or knowledge creation (Ahmed et al., 1999; Bhuiyan and Baghel, 2005; Linderman et al., 2003).

Fiol and Lyles (1985; p. 803) define organizational learning or knowledge management as "improving actions through better knowledge and understanding" and Argyris and Schön (1978) describe it as detection and correction of errors. These descriptions of organizational learning are congruent with the objectives of CI programs. Through training and reward systems CI programs can contribute the means and the encouragement for organizational learning (Ulrich et al., 1993). Further, efficient knowledge-sharing practices in CI programs can add to the ability of the organization to respond to environmental changes, thus enhancing its dynamic capabilities (Krogh et al., 2001; O'Dell and Grayson, 1998).

3.2.3. <u>Alignment:</u> As organizations make the shift from top-down management to more top-down-bottom-up combinations for strategy formulation and implementation, the need for mechanisms ensuring alignment of purpose arises (Volberda, 1996; Wright and Snell, 1998). Alignment warrants common understanding of strategic choices made by the organization (Daft and Weick, 1984; Garvin, 1993b). An overarching strategy within which lower level managers can participate is critical to achieving alignment of purpose (Adler, 1988).

CI programs can help not only to maintain a balance between efficiency and creativity and between standardization and innovation (Gibson and Birkinshaw, 2004; Nadler and Tushman, 1999), but also to maintain alignment of purpose and a systems view (Senge, 1990). Different autonomous frontline projects working toward a common purpose help prevent sub-optimization of organizational objectives. Further, CI practices that support and coordinate participative lower-management and frontlines can provide organizations the ability to maintain a cohesive front while making changes in response to environmental dynamism (Volberda, 1996). This ability may be fostered through mechanisms (Teece and Pisano, 1994) that coordinate various autonomous events such as kaizen blitzes, business process reengineering exercises, and projects under Six Sigma and total quality management.

3.3. Elements of CI infrastructure

In the light of the three roles of CI – dynamic strategic initiatives, learning, and alignment of objectives – we discuss the elements of CI infrastructure based on theoretical perspectives in the strategic- and organizational- management literatures. As depicted in Figure 3.1, CI is deployed through process improvement projects that are supported by organization-wide infrastructures for the selection, coordination and execution of projects over time. The infrastructure for CI provides the organizational support necessary for the cohesiveness and continuity of such projects (Guha et al., 1997; Upton, 1996; Wu and Chen, 2006).

Previous studies of CI programs that have included selected elements of infrastructure in analyzing the effectiveness of programs have focused primarily on the unique package consisting of project-execution protocols and tools and techniques that each program advocated (e.g. Davy et al., 1992; Fullerton et al., 2003; Shah and Ward, 2003; Yasin et al., 1997). In doing so, infrastructure questions are overshadowed by project-execution related questions, and the theoretical basis of infrastructure is not adequately addressed. We intend to provide a theoretically derived framework consisting of elements that are commonly applicable across different CI programs (see Figure 3.2). As the infrastructure for CI is an organization-level question, we consider it exclusively and separately from questions of process-level project-executions (Garvin, 1993b). We concentrate, in this study, solely on what Sakakibara et al. (1997) called "common infrastructure practices" in their study of just-in-time and total quality management programs and Cua et al. (2001) labeled "human- and strategic- oriented common practices" in their assessment of total quality management, just-in-time and total preventive maintenance practices.

The elements of the infrastructure framework that we develop can serve as a checklist for academics and practitioners assessing effectiveness of CI programs. We contend that the roles of CI can be achieved more successfully by following the framework, elements of which are derived from the behavioral theory of the firm (Cyert and March, 1963) and enhancements to the theory focusing on proactive organizational learning (Carter, 1971; Fiol and Lyles, 1985). The broad idea of the CI infrastructure framework is for organizations to arrange and manage their operations in relation to the environment and gain competitive advantage by using current capabilities and resources, and building new ones.

The infrastructure of CI programs provides an atmosphere that encourages experimentation, while ensuring a controlled and structured approach, resulting in a type of "controlled chaos" (Quinn, 1985) that is essential for CI (Gilson et al., 2005). In serving as a forum for experimentation it facilitates the convergence of diverse skills and perspectives of project team members. By encouraging and facilitating proactive and team-oriented problem solving the CI infrastructure facilitates insights for better products and processes enabling organizations to address the multi-functional issues of complex processes in an integrated system wide manner (Prahalad & Hamel, 1990; Senge, 1990).

Thus, our framework reflects the objective of CI infrastructure: to provide the motivation and means to continually pursue learning while maintaining a dynamic and unified strategic outlook (Grant, 1996b; Kraatz and Zajac, 2001; Lant and Mezias, 1992; Neave and Peterson, 1980). Based on the perspectives of CI infrastructure viewed from the theoretical lens of behavioral theory we can group the elements of CI infrastructure into three categories – ends, ways and means (Fast, 1997). CI infrastructure helps define organizational and project goals that can be categorized as *ends*; it facilitates achievement of these ends via implementation practices that can be categorized as *ways*; and it includes investments to support *ways*, and these areas of investment can be categorized as *means* (see Figure 3.2 and Table 3.1).

3.3.1. Ends: Ends refer to multi-level organizational goals including overall organizational purpose, departmental objectives, sub-process objectives, and CI project goals. Organizations implementing CI programs formulate strategy as "a pattern in a stream of decisions" (Mintzberg, 1978; p. 935) with top management providing a vision that guides the formulation of goals at middle and lower managerial levels (Nonaka, 1988). Biases of managers and employees at different levels may affect their interpretations of organizational goals in turn affecting their formulation of goals for their domain (Carter, 1971; Cohen et al., 1972). With a view to avoiding formulation of incongruent goals, CI infrastructure elements that form the *ends* category provide support for determination of goals at different levels in keeping with the overall strategic vision.

3.3.1.1. Organizational direction: In organizations that adopt CI programs, employees and middle management are not only responsible for making processes improvements (Bateman, 2005), they are also expected to suggest broader changes in the strategies at the next higher level (Bartlett and Ghoshal, 1994; Hart, 1982; Imai, 1986). By providing structures that interlink vertical organizational levels (Jelinek, 1979), CI infrastructure can help middle and lower level managers take active part in not just implementation but also the formulation of the underlying strategic goals of the CI program (Beer et al., 2005; Forrester, 2000a). Systematic linkages underlying these CI infrastructure elements are designed to not only communicate the strategic imperatives but also to generate debate and discussion toward formulation of strategy (Lyles, 1981; Nonaka, 1988). A coordination system that encourages employee initiative in setting goals while involving upper management can steer the direction of the program while assuring employee commitment through involvement (Hart, 1992; Lawler, 1982).

3.3.1.2. Goals determination and validation: For determination of targets for process improvements and for performance assessments, it is important to incorporate learning-benefits that will accrue for the long term and to assure alignment with overall objectives of the CI program. It is also as crucial to gain the conviction of team members toward project goals and assessments, and the trust of the rest of the organization in these metrics (Evans, 2004; Tennant and Roberts, 2001). This can be facilitated by installing a system of coordination of project teams with a controller department for appraisal of project goals and results. Project results may also be tied to the assessment of the performance of team members, although such practices would need to account for the potential of encouraging risk-averse behaviors and selection of ‘safe’ projects thereby discouraging knowledge-sharing (Mohrman et al., 2002).

3.3.1.3. Ambidexterity: Through the selection and prioritization of projects based upon their goals, middle and upper management have the ability to guide the CI program. Toward this purpose management can oversee a mix of control and learning (Sitkin et al., 1994) and exploitation- and exploration- focused projects, thus giving the CI program an ambidextrous quality (Crossan and Berdrow, 2003; Jansen et al., 2005). CI programs have been criticized for concentrating too much on improvements in existing processes leading to exploitation-oriented changes, thereby stifling creativity and suppressing radical improvements that require exploration-oriented efforts (Benner and Tushman, 2002). Upper management has a wider view of the organization and is therefore in a better position to combat such a bias through their continued involvement in coordination of projects.

3.3.1.4. Visibility of the program: Leadership commitment to a CI program can be demonstrated, not only through their own time and resource commitments but also by including the CI program in any important discussions and speeches and by its inclusion in performance appraisals. Further, leadership commitment can be legitimized through direct connections between the CI infrastructure and human resource management practices for selection and promotion. Embedding the message of broad objectives through personal involvement and repeated mention, combined with continual reference to assessments can be more effective for achieving buy-in than any financial and numerical goals (Bartlett and Ghoshal, 1995).

3.3.2. Ways: CI infrastructure elements included in this category provide direction regarding courses of action toward CI objectives. These elements focus mainly on implementing decisions toward the goals which are the focus of the *ends* category. While elements in the *ends* category facilitate setting of goals, CI infrastructure elements in the *ways* category facilitate achievement of those goals. Behavioral theory extensions that provide insights on methods for involving different organizational levels in implementation decisions (Bourgeois and Brodwin, 1984; Carter, 1971; Hays and Hill, 2001; Schultz et al., 2003) serve as the basis for elements in this categorization. The knowledge based theory of the firm (Grant, 1996b; Nonaka, 1994) and organizational learning theory (Argyris and Schön, 1978) follow the behavioral view and shed light on organizational factors that support individual learning toward organizational objectives.

3.3.2.1. Environmental scanning: Toward supporting a dynamic strategic initiative for the CI program it is important for the CI infrastructure to engage employees in scanning the environment so they can capitalize on any opportunities (Crossan and Berdrow, 2003). Organizations interact with their environments at multiple levels – organizational, business unit, department, and process (Elenkov, 1997). For example, at the overall organizational level, there are regulators and major competitors to manage, while the departments and process levels interact with suppliers and customers. Scanning at all levels improves the organization's capacity to react to or even preempt environmental changes that pose risks or provide opportunities. CI infrastructure elements that facilitate and reward scanning, serve as encouragement for proactive seeking of opportunities and threats.

In addition, cascading organizational goals into divisional and other sub-unit goals with clear connections between different levels through *ends* elements facilitates scanning at different levels. Clear goals provide employees with a context in which they can interpret the effects of the environment. On the other hand, in the absence of meaningful goals at their levels these employees would not have parameters to guide them resulting in chaotic scanning behaviors (Cohen et al., 1972).

3.3.2.2. Constant-change culture: CI programs work by engaging employees in double loop learning, described earlier (Argyris and Schön, 1978), which involves challenging existing ways of executing processes and improving them. Employees working on processes are themselves responsible for seeking out improvement opportunities and implementing changes (Sitkin et al., 1994; Upton, 1996). In CI, continually occurring changes may be triggered from among multiple organizational levels as opposed to intermittent changes that are typically initiated by top management in response to major events that affects the whole organization (Campbell, 2000; Quy Nguyen and Mintzberg, 2003). Thus, it is important for middle management to be good at sustaining change-management. By incorporating training for project managers in change-management and by encouraging and rewarding employee initiatives toward change, elements of CI infrastructure can generate a culture that is conducive to ongoing change (Barrett, 1995; Verona and Ravasi, 2003).

3.3.2.3. Parallel participation structures: Parallel participation structures such as matrix organizations, off-line teams and line-specific quality circles facilitate intra-organizational co-ordination among multiple functions (Mitki et al., 1997; Shenhar, 2001), and are therefore suitable for CI programs that take a process view of organizations. Such lateral structures (Galbraith, 1994; Joyce et al., 1997) give project leaders the ability to make changes quickly compared to existing hierarchical structures (Beer et al., 2005; Hatten and Rosenthal, 1999; Mitki et al., 1997; Wruck and Jensen, 1998). CI infrastructure includes the design and administration of such superimposed structures, including inherent authority and responsibility configurations. In addition, CI infrastructure facilitates these arrangements by providing resources such as venues and technological support for their activities. Such infrastructure for projects, combined with support for ongoing informal interaction among employees (Grant, 1996a; Jansen et al.,

2005) integrates knowledge resources throughout the organization (Kogut and Zander, 1992) increasing the benefits of the CI program.

3.3.2.4. Ensuring systems view: When deploying any CI initiative it is critical for organizations to guard against proliferation of myopic process-specific improvements that are at cross-purposes with each other and are therefore compromising organization-wide performance. Such myopia results from two sources – one, the inability of groups to see beyond their process, and two, even when they can detect any ill-effects, a rewards systems designed so that it is in their selfish interests to ignore the misalignment of objectives (Ackoff, 1994). To combat these, a rational project-selection system that assesses goals with a systems view, combined with an appropriate reward system, is important (Senge, 1990). Including these elements in the CI infrastructure can ensure the selection of projects that add value for the organization instead of targeting improvement for improvement sake (Bateman, 2005; Mohrman et al., 2002; Wall, 2005).

Customer focus is a tenet of all CI programs (Delbridge and Barton, 2002; Sitkin et al., 1994) and even if an internal process is being improved, the value added for the customer of the process, and for the ultimate customer of the goods and services being delivered, is the main focus. By facilitating involvement of customers and suppliers in projects, infrastructure mechanisms that bring together diverse interest groups in a team can also ensure that problems are truly being addressed instead of being transferred outside organizational boundaries.

3.3.2.5. Standardized processes: Process improvements resulting from CI projects, once proven, are inducted into the process as standardized practice and propagated throughout similar processes in the organization (Spear, 2004; Spear and Bowen, 1999). Such standardized processes provide a valid baseline for any further improvements and facilitate root cause analyses for problem- or improvement- identification (Taylor and Wright, 2006). Standardized processes also provide relevant experience to employees working on the processes on the basis of which rich data about the process and ways of improving the process can emerge (MacDuffie, 1997). Thus, infrastructure practices supporting standardized processes for everyday process-execution can facilitate CI project ideas and executions.

3.3.2.6. Standardized improvement methodology: A rigorous scientific method for solving problems and making improvements inculcates systematic learning (Garvin, 1993a; Forrester, 2000b; Spear and Bowen, 1999). A common process improvement methodology adopted by all levels of employees promotes common understanding of changes and facilitates commitment toward such change (MacDuffie, 1997). In addition, the knowledge created does not remain married to a person or project-team but can be utilized organization-wide and over time.

Different CI programs have different protocols for executing improvement-projects. The presence of such standardized methodologies enables employees from different functions and multiple vertical organization levels to participate in cross-functional projects with common knowledge about the sequence of steps (Bateman, 2005; Henderson and Clark, 1990). In Nelson and Winter's (1982) parlance, a standardized improvement methodology consists of 'search routines' or established ways of making investigations (Henderson and Cockburn, 1994) as part of projects. CI infrastructure practices that facilitate the use of such project-improvement frameworks help establish a sequence of process improvements that is useful for sustaining the CI initiative.

3.3.3. Means: Depending on the makeup of an organization's resource endowments, such endowments can serve as facilitators or inhibitors of change in response to environmental challenges (Kraatz and Zajac, 2001). Resources required to support actions towards *ends* and to sustain the continuation of ongoing improvements are included in the *means* category. CI infrastructure elements in the *ways* category that relate to coordination structures require investments in *means* elements of infrastructure. Investments geared toward preparing employees for organizational learning form the basis for the *means* categorization of CI infrastructure elements.

3.3.3.1. Training: Training in the use of the scientific method enables employees to meaningfully participate in the execution of projects and in the implementation of the resulting changes in processes (Hatch and Dyer, 2004). Training employees across departments and levels as a group also helps build camaraderie (Upton, 1996). Voluntary participation in different training programs combined with the offer of chances to participate in improvement projects that have concrete payoffs serve as intrinsic and extrinsic motivators for employees.

Investments in training programs reflect the level of top-management commitment to the CI program. Different levels of training for employees may prepare them for leading projects and participating in them. Investments in CI infrastructure may also be needed apart from projects-related training for training employees to put changes into practice, to collect metrics on processes and to identify enhancement-opportunities in processes in the course of their everyday work.

3.3.3.2. Tools repertoire: In the spirit of CI, the repertoire of tools that are part of the methodology can be updated by incorporating internal and external developments. Most CI programs involve in-house experts who are responsible for ongoing training of employees in the CI methodology and who serve as internal consultants providing guidance and training on projects as and when needed (Palo and Padhi, 2005). These experts can also be assigned the responsibility and provided the resources for maintaining an updated body of knowledge related to the CI methodology. Such investments in CI infrastructure can facilitate the absorption of incremental aspects of newly developed CI programs – organizations can avoid a reinvention of the wheel or a major incremental change when a new CI program is adopted.

3.3.3.3. Roles, designations and career paths for experts: Unambiguous levels of authority and responsibility for team leaders and team members facilitate interest in participation in the CI program. Such clarity can be especially helpful in the light of dual reporting relationships that are necessitated in matrix and other parallel types of structures that are instituted as part of most CI programs. Career paths for employees who get trained and also schemes for their promotion and re-induction into managerial roles if the training process is prolonged help sustain the CI initiative. As with training, resource commitments toward promotions reflect the leadership's commitment and intended direction for the CI program.

3.3.3.4. Information technology support: Information systems for collecting data, designing studies, and conducting analyses are infrastructure elements that are critical for CI projects; process control systems are important for ongoing process control (Davenport and Beers, 1995). In addition, knowledge repository databases conducive to entering timely information and conducting convenient key word searches can prove to be useful in the long term (Cross and Baird, 2000). Using such repositories exemplar results from a project can be highlighted organization-wide; insights from projects can be utilized to benchmark similar processes. Sharing of the codified or explicit knowledge can serve as a starting point for tacit knowledge sharing through referrals and social interactions (Mohrman et al., 2002). Knowledge repositories can also support historical reviews of success and failures in projects to learn from them (Garvin, 1993a).

3.4. Six Sigma programs

The Six Sigma program has gained tremendous popularity as a CI program in all types of organizations – manufacturing, service and non-profit (Gowen III and Tallon, 2005). Six Sigma is defined as "A comprehensive and flexible system for achieving, sustaining and maximizing business success . . . uniquely driven by a close understanding of customer needs, disciplined use of facts, data and statistical analysis, and diligent attention to managing, improving and reinventing business processes" (Pande et al., 2000). Six Sigma has process-variance reduction as its predominant focus with project goals tied to overall organizational strategic goals (Linderman et al., 2003). Six Sigma projects are implemented by teams that include frontline employees using a scientific method to discover process improvements. Training for Six Sigma creates experts at different levels commonly referred to as Belts and described in Table 3.2. Six Sigma projects often involve analysis of external environmental factors and internal contextual conditions to ensure alignment with both (de Mast, 2006). Thus Six Sigma is geared to fulfill the three CI program roles of dynamic strategic initiative, learning and alignment discussed in section 3.2.

3.4.1. Semi structured interviews: With a view to assessing how organizational level infrastructure elements are being targeted in Six Sigma programs we contacted five organizations from among twenty nine for which we had contact information for the top Six Sigma or Continuous Improvement executives. These were selected to get a range of size and some variety in the business areas – the five organizations have revenues ranging from one billion to over twenty billion, with industries ranging from industrial services to healthcare. Interviews with management executives from these organizations were recorded and transcribed. A semi-structured format was used with a list of broad questions that were e mailed to the interviewees before hand (see Table 3.3). In order to secure participation we assured the executives of anonymity for themselves and their organizations. We briefly describe the organizations in our sample, all of which are publicly traded companies.

1. Company Alpha is a healthcare related manufacturer with over fifty thousand employees and annual revenues of over twenty billion. Their Six Sigma program had been deployed about two years ago, at the time the two interviews were conducted, one with a director, and another with a manager of continuous improvement.

2. Gamma Company is an industrial services company with annual revenues of over three billion and facilities and customers in North America, employing over 30,000 people. They are market leaders in their main customer segment. The company had deployed Six Sigma about four years prior to the time the interview was conducted. Five Master Black Belts were interviewed in this company; in addition, internal presentations were also made available.
3. Epsilon Company is a chemicals manufacturer with headquarters in the United States and an international presence spanning more than twenty countries. Their annual turnover is over seven billion dollars and they employ over 12,000 employees. During the time the interview was conducted with a Black Belt in the company, the Six Sigma program was five years old.
4. Company Mu is a manufacturer of medical equipment with facilities in over hundred countries worldwide and annual revenues over ten billion dollars. The Vice President of quality provided information about their three-year old program through two telephone interviews.
5. The Iota Company is an industrial high technology solutions manufacturer with an international presence and over one billion dollars in sales. With over 4,000 employees, they first deployed Six Sigma just over six years ago at the time of the telephone interview, conducted with the director of global continuous improvement.

3.5. CI infrastructure coverage in Six Sigma programs

Based on our semi-structured interviews with Six Sigma executives we describe the treatment of infrastructure elements in their deployments. Through directed questions (Table 3.3) we gathered information on whether these Six Sigma executives consider the elements of the infrastructure as important and how they achieve the underlying purposes under each element. We tried to capture the executives' perceptions of the effectiveness of their methods. We also observe how organizational level CI infrastructure elements are covered in descriptions of the Six Sigma program in practitioner-oriented books (De Feo and Barnard, 2004; George, 2002; Harry and Schroeder, 1999; Pande et al., 2000). Table 3.1 provides a summary of CI infrastructure that can be used to reflect on the elements as we describe them in relation to Six Sigma programs.

All five organizations in our sample had previously deployed CI initiatives before adopting Six Sigma – total quality management, Crosby's (1980) principles, short interval scheduling (Smith, 1968) and the Baldridge award criteria (NIST, 2006). The main reasons for adoption of Six Sigma provided by these firms were the systematic and rigorous project execution structure: define-measure-analyze-improve-control (DMAIC), the potential for breakthrough improvement, and the administrative structure for the program with designated roles for Black Belt experts. One executive listed four main factors ("four X's") for effective deployment as (1) methodology, (2) people, (3) infrastructure, and (4) project selection. The sample organizations considered CI infrastructure to be an important aspect of program deployment in addition to its clear and rigorous project-execution framework.

3.5.1. Ends:

3.5.1.1. Organizational direction: Questions related to organizational direction were aimed at finding out whether the organizations in our sample are implementing top-down and bottom-up coordination mechanisms toward combining strategy formulation and implementation. We found that all organizations in our sample used systems of multi-level steering committees with interlinked membership to coordinate the direction of their programs. The highest planning body consisting mainly of upper management is the 'executive council' or the 'executive steering committee'. In addition to being members of the executive council, each of the upper management members individually participates in coordinating councils or steering committees at the next business or division level. This interlinking or interlocking pattern of an upper council member being part of a lower council is followed through the different levels of Six Sigma up to the Black Belts and Green Belts working on projects. This coordination approach is similar to the Japanese 'Hoshin Kanri' policy deployment system that requires every subordinate level to show how it is aligned to the plan above it, creating a linkage between every functional strategy, tactic and metric and the overall organizational strategy (Akao, 1991, Witcher and Butterworth, 2001).

Tollgate reviews for different stages of projects represented the lower end of this system. In Gamma Company, for example, these are held periodically and combined for all projects being conducted by a Master Black Belt. This is convenient for them as their Black Belts and Master Black Belts are located in a common central location. In Mu Company, with projects and project leaders spread internationally, the tollgate reviews for projects are conducted by Black Belts. Master Black Belts and Deployment Champions access these reports through a centralized reporting system and database. The Iota Company gives more of a free hand to its over thirty business units – they believe that trying to manage it at the corporate level does not add much value because of the diversity of their businesses. Thus, the management of the project portfolio is handled by a business director of who is an experienced Black Belt. Subsequent coordination at the next level consisting only of high level checks and progress of selected key projects takes place through conversations between the directors of continuous improvement of each business and the global director of continuous improvement.

We learned that the goals of the Six Sigma program changed with the maturity of the program in the case of the Epsilon Company. Their initial rollout of the program was confined to manufacturing operations and after two years, they expanded its application to transactional problems such as rationalizing the number of payment terms and reducing response time for complaints. According to internal documentation that the Gamma Company shared with us, their plan is to take Six Sigma gradually from achievement of internal process capability to outside the organization, so customers sense its effects and ultimately have 100% of their employees use the DMAIC way of thinking in the way they do their daily work.

In summary, the predominant roles of this CI infrastructure element in our sample of organizations appear to be that of (1) generating ideas from middle management toward implementation of organizational strategy, and (2) working toward inculcating a Six Sigma culture in daily work. We did not find evidence in these organizations of influencing higher level strategy formulation through Six Sigma program efforts at the middle or lower levels. Any bottom-up contribution manifested itself only in the form of project ideas submitted for approval.

3.5.1.2. Goals determination and validation:

The next infrastructure element for assessing our empirical sample consists of goals set for individual projects and results obtained – independent validation of goals to ensure buy-in from team members and the rest of the organization. Setting of project goals is connected to sourcing and selection of projects ideas because projects with goals unsuited to strategy may be weaned out at the selection stage. The main sources of project ideas in the five organizations are business leaders, Black Belts and Green Belts. Mu and Gamma Companies train business leaders to be Champions and part of their training includes project selection methods using flow charts and idea generation tools. According to the Mu Company executive, "… there's … a side of the coin that says, make sure you pick a good project, and there's the side of the coin that says, pick a project that the business cares about." With the same idea, Company Alpha has designed their project tracking system to create an effort-benefit matrix for every project connecting the project objectives and efforts to weighted strategic goals that are supplied by business leaders. The effort-benefit ratio is used to select and prioritize projects. Their criteria for Six Sigma framework suitability also include a targeted completion time of three to four months – other organizations in our sample have similar standards. These comments signify that a deliberate effort needs to be made to keep these two objectives in mind – relation to business strategy objectives and suitability for the use of the DMAIC methodology.

The Mu Company executive added that a good Six Sigma project has a clear defect-related target that can be explained in a short elevator-ride talk but the defect should not be of the magnitude of “world hunger”. Projects should be doable in a period of four to six months. In the Gamma Company each project is required to have a strategic implication ‘Y’ (this terminology is inspired by the causality equation $Y = f(X)$) that indicates primarily how the project seeks to improve the process for the process customer and ultimately for the organization – through defect reduction, cost improvements, easier ordering or added features. Thus, in each of the organizations we found the use of infrastructure mechanisms to ensure that projects selected have goals suited to organizational strategy and that once selected, the goals for projects are set such that the team remains focused on overarching strategic objective.

Literature on Six Sigma stresses the importance of defining specific goals for every project in place of amorphous general objectives such as zero defects or zero inventories (Pande et al., 2000). Mu Company has “governance systems” to ensure that project goals are reasonable – the tracking system requires signoff from a finance function employee before it can move ahead from the define phase in DMAIC. The other four organizations also use similar independent controller functions to approve project goals and their achievements. Not all projects have dollar metrics; some have operational metrics such as cycle time. We observed that the sigma metric was not prevalent in these organizations. Epsilon Company used a change in sigma metric to compare before and after project performance of the process but the project champions – the Vice Presidents of Divisions – did not care about sigma metrics and instead wanted to see bottom line (profits) and top line (costs) results in dollars.

"…it is not a hard must-make goal.... Most times they end up surpassing the goal by a lot but they are not held to it. It is to populate the tracking system…and get the conversation started." This quote from Mu Company points to an apparent disconnect between setting-up of specific project goals and assessment of results. Another company – Epsilon – does not approve project goals unless the expected payoff is at least one million dollars – the project Black Belt has to back the proposal with data and convince the financial committee. However, after implementation, it did not matter much if the dollar objective is over- or under- shot as long as the project was satisfactorily completed – i.e. the Black Belt was able to show based on documentation and analyses a concerted effort at solving the problem. Company Gamma projects have goals divided between one-time balance sheet goals and recurring profit and loss statement goals; however, they also, do not judge the success of a project by achievement of its goal as long as there is some improvement from the project and there is data to back the same. Company Iota assesses Black Belt performance annually at the business level by including rate of project completion, effectiveness of projects and long term value of lessons learnt.

In conclusion, the organizations appear to pay a lot of attention to two aspects of project goals: (1) selection of projects after a priori assessment of the objectives of the project, and (2) determining goals for projects and value of results. However, there does not appear to be a serious attempt to assess the level of goals-achievement after projects are completed. This raises some question about Six Sigma deployments, mainly about the unrealized potential for process improvements and the long run effects of satisficing when learning stops after some improvement (Winter, 2000).

3.5.1.3. Ambidexterity: At the organizational level, middle and upper management can generate 'structural ambidexterity' (Gibson and Birkinshaw, 2004) by selecting projects with exploitive and explorative objectives in conjunction with organizational strategy (Mader, 2004). Exploitive projects focus on improving current ways of executing processes while explorative projects primarily relate to designing new processes. Six Sigma programs employ two different standardized project-execution frameworks to differentiate the emphasis in exploitive versus exploratory projects – the 'DMAIC' or 'define-measure-analyze-improve-control' framework for process improvements and the 'define-measure-analyze-design-verify' or 'DMADV' framework for designing new processes (De Feo and Barnard, 2004).

The emphasis on the suitability of projects for DMAIC described in the preceding subsection shows that the infrastructure of the organizations we sampled is geared toward selecting process improvement projects leaving out process design projects. A common feature of all five organizations is that none of them have formally deployed Design for Six Sigma programs. Only Company Iota has some specific training for product engineering employees in process design tools; they do not, however, have different project selection mechanisms and metrics for Design for Six Sigma. The idea is for their engineers to incorporate Six Sigma in their process designs.

When asked about how they address the possibility of getting preoccupied with improvement when a process deserves a redesign, the executives had different responses. Mu Company believes that with three years into their Six Sigma deployment they are not ready for the DMADV framework. So if an odd project idea comes up where the process warrants a redesign, they "steer away" from it. The important part is recognizing when a project is not DMAIC worthy and for that they stress the importance of project selection criteria when training their executives as champions. A similar response was given by Gamma Company that in the absence of a Design for Six Sigma program they refer situations needing new process designs to marketing, and research and development departments. The Black Belt from Gamma recalled one incident of a team that had tremendous difficulty completing a project when after starting with a DMAIC framework the team realized that the process needed a redesign. Iota Company leaves it to the champions and Black Belts to make the call about dismantling a completely broken process and starting anew. For process design projects their Black Belts adjust and use the appropriate tools and techniques within the common DMAIC framework.

While they have not deployed Design for Six Sigma, all five organizations incorporate lean principles within the Six Sigma program. Using the common DMAIC framework for its underlying scientific management notion these companies execute lean and Six Sigma projects differently. Calling the lean projects "Kaizen" and "Just Do It" projects these companies mostly assign the projects that "do not require a deep dive" to Green Belts. These projects do not have the elaborate reporting requirements of the traditional Six Sigma projects and have a much shorter duration. In order to recognize the need for a lean project the project selection abilities of the champions and the Black Belts are crucial. Iota Company uses a value stream transformation view of continuous improvement – "… as we go from a current state to a future state transformation of a value stream, we find variation in the process that has to be driven out in order to achieve a really good flow of values…" Lean and Six Sigma projects emerge from this view.

Thus, it is apparent that the sampled organizations have recognized that there is not a one-size-fits-all project implementation methodology and so it is important to match projects to methodologies. An interesting question that remains unanswered because of the mix of organizations in our sample is whether the same employees can adjust to working on process improvement and process design projects when there is a Design for Six Sigma program deployed in parallel. A comparison of the executions of the two frameworks and the expertise and attitude required for each would be useful toward this purpose.

3.5.1.4. <u>Visibility of the program:</u> In three of the five organizations in our sample the Six Sigma initiative was introduced at the behest of upper management. Therefore, the program was accorded prominence in communications from them. In Company Mu the CI program executives routinely track the number of job postings that listed Six Sigma training or experience as a requirement or preference – at the time of the interview the metric was at 33%. The program also gets noticed by investment analysts. So the mode of increasing the importance of the program in Mu is from the ground up – letting the performance speak for itself. They also follow a strategy of making the Black Belt certification a special earned privilege. Departments that send employees for training are charged a fee, certification standards are strictly maintained through examinations and training project completion requirements and Black Belts are awarded medallions on certification. Thus, visibility for the program is generated by a combination of the interest of upper management demonstrated through conversations and resource commitments, and by efforts toward maintaining momentum at the grassroots level.

3.5.2. Ways:

3.5.2.1. Environment scanning: Upper management makes assessments of the overall business environment and the economy to determine broad strategic goals for the Six Sigma program (De Feo and Barnard, 2004; p. 315). In doing so they utilize information received from their functional, divisional and departmental heads who continually scan the environment at their levels and who, in turn, process information from the frontlines. While the steering committee hierarchy described earlier supports multi-level environmental scanning, the organizations in our sample use additional mechanisms to ensure that environmental changes at different levels are accounted for.

Company Mu benchmarks with other organizations in their line of business and, toward that purpose, encourages business executives and middle managers to interact with their counterparts at other organizations. They also use their project tracking data base for internal and external benchmarking. Company Gamma uses dashboards of metrics for daily management of processes (Lareau, 2003) and to assess the effects of any changes in external factors such as customer needs or supplier quality. In addition to infrastructure mechanisms for scanning the environment as an ongoing exercise, there is infrastructure support provided for capturing the voice of the customer as part of project execution.

Other than dashboards that measure explicit targeted information, we did not find evidence from our interviews of any mechanisms to facilitate intrinsically motivated scanning by employees who operate the processes. The sampled organizations did not make use of suggestion boxes and rewards for suggestions. Thus, although measures to facilitate scanning at the managerial and higher levers are apparent, these organizations seem to be missing out on capturing the insights of the people working on their processes continually. Informal opportunities of socializing among process operators and middle management can help capture the tacit knowledge of grassroots workers regarding environmental variables outside the organization and contextual variables inside it.

3.5.2.2. Constant-change culture:

GE, the company that popularized Six Sigma, extensively used work-out meetings before deployment and even during the initial stages of deployment. These cross-functional meetings were structured to get employees involved and to create momentum for continuing change (Tichy and Sherman, 1993). The companies in our sample hold similar workshops from time to time that encourage a free flow of ideas. These meetings achieve the dual objectives of removing fear of suggesting change and preparing employees to expect ongoing change for process improvement (Zimmerer and Yasin, 1998).

Company Iota uses a value stream view to stress the need for constantly transforming value streams using lean tools to eliminate waste and Six Sigma tools to reduce variation while incorporating voices of the customer, process, employee and business. The executive from Company Iota observed that he judges the authenticity of the change culture in a business by asking himself "…if we sold that business off today, and we kept the management team…would they continue on the operational excellence course they are on, or would they immediately dump it…"

The Company Alpha executive also believes that inspiring people to continually create change is a big part of Six Sigma and should be accomplished in the initial period of deployment. In their industry especially the culture has been to check quality into products and therefore creating a culture of continual process improvement is a challenge that requires special effort. They have accomplished this by selling continuous improvement to their champions and training their champions in leading and managing change. Their strategy for inspiring continuous improvement is creating demand-pull by letting functional leaders and ultimately front-line employees see the value-add in participating in CI.

Black Belt training curriculum in all five sample organizations includes training in leadership, team involvement and change management. Competence in these areas enables Black Belts to combat inertia during project executions and in implementing results from projects. Although the standard of 3.4 defects per million opportunities (DPMO) is emphasized in Six Sigma as a symbol of a continuing drive toward improvement of changing process requirements, it did not seem to be at the forefront in any of our sample organizations. However, the organizations were strict about insisting on valid and accurate data, which is a prerequisite for any justifiable change. The main weapon for creating a change culture according to our respondents is having all employees trained to some level in Six Sigma.

3.5.2.3. Parallel participation structures: All five organizations followed the traditional model of Six Sigma deployment comprising offline teams that temporarily come together for the duration of their projects (Appelbaum et al., 2000). The organizations cited the addition of this project management framework as a fundamental difference between traditional quality management programs and Six Sigma, and as one of the main reasons for their adoption of the Six Sigma program. This type of participation structure combined with the practice of an independent but internal facilitator in charge of the project explicitly applies the notions of employee participation and CI (Rees, 1998; Juran and Godfrey, 1999).

3.5.2.4. Ensuring systems view: When participating in a project to discover better ways of running processes, the target incorporates holistic goals of the business unit or the organization, incorporating necessary functional tradeoffs. Company Epsilon experienced problems with conflicting functional objectives in a past project – aligning the objectives considerably prolonged the project. Taking lessons from that project, their Black Belts now ensure that for projects with functional tradeoffs they use data to convince the functions upfront about the organizational objectives. They follow this up with necessary adjustments to functional assessment targets. The Company Iota executive responded to the question of alignment by saying that the very nature of Six

Sigma project teams brings out alignment issues in the open and that is valuable. Once the different functions see the big picture of the value stream tradeoffs they work together through any essential tradeoffs and establish the right metrics and process changes toward the benefit of the entire value stream.

Being part of the Six Sigma structure and independent from any line, staff or division, Black Belts are perceived as being fair by the cross-functional team (Holland et al., 2000; Randel and Jaussi, 2003). Moreover, by making the project's goals the focal point for all team members, any selfish functional agendas that may sub optimize the total process are naturally subordinated (Sethi, 2000). Value stream mapping was cited by our interviewees as an effective way for project teams and project coordination committees to participate in constructing the system-wide perspective.

Company Mu has extended the concept of the systems view outside their organizational boundaries. They proactively involve suppliers in their Six Sigma activities and even provide them training so that suppliers can participate as project-team members or provide input in the form of data for projects and ongoing assessments. The extended value chain perspective (Ittner and Larcker, 1997a) prevents the transfer of problems to upstream processes instead of addressing them. Company Gamma includes the "voice of the customer" in sourcing projects to ensure that they include the other end of the value chain and not transfer problems downstream. Thus, the pattern of responsibility distribution in Six Sigma projects with an independent project leader and the data and visualization tools in the Six Sigma quiver are facilitators of systems thinking in projects.

3.5.2.5. Standardized processes: Standardized processes are crucial as inputs and outputs of Six Sigma projects – they facilitate the assessment of "before and after" performances of projects. Company Gamma and Company Mu revealed that at times their Black Belts did not find processes to be at a satisfactory level of standardization to execute the "measure" stage in DMAIC. In such projects, process standardization had to be accomplished as part of the project execution before establishing relevant metrics and gathering data. Such instances of processes and metrics requiring standardization as part of "measure" occurred more frequently in the business transactions projects as compared to manufacturing operations projects.

The Black Belt from Company Gamma also described a project where the standardization of a process was accomplished in the "control" stage. It involved preparing a "standard operating procedure" for employee training as a deliverable of the project. Company Mu had a different take as compared to the others on ways to ensure compliance for a new procedure established as a result of a project. While other organizations use dashboards of metrics as signals for the status and performance of processes, in the Mu Company, it is imperative that the procedure be mistake-proofed at the end of a project so that there is no need for follow-up observations to ensure that the change is sustained. "…if you have got a lot of SPC charts in your control phase, it means you did not design the problem out … you did not poka-yoke it…" Thus, although the five organizations in our sample realize the criticality of standardized processes, they were at different stages in working toward achieving higher levels of standardization in the course of executing projects.

3.5.2.6. <u>Standardized improvement methodology:</u> The ‘define-measure-analyze-improve-control’ steps in the ‘DMAIC’ framework constitute a standard procedure that is followed in every Six Sigma process improvement project. Each of the organizations considered these stages sacrosanct as they considered the DMAIC steps for project execution to be fundamental to the Six Sigma program. The framework ensures a relentless focus on the customer, reliance on data, and use of the scientific method. The companies also stressed the importance of tollgate reviews conducted at transitions between each step in the framework to review the project’s progress.

Respondents observed that the steps are not as linear as they appear from the title of the framework. For example, the project charter prepared in the “define” stage had to be altered at times when the team realized, after getting to the “measure” stage, that the problem targeted was larger than originally described. The five organizations also differed in their opinion on Six Sigma tools and techniques used in each stage. While Company Gamma has a set of tools that are encouraged for usage in each of the DMAIC stages, Companies Iota and Mu are opposed to the notion of recommended tools. The executive from Mu believes that careful selection to ensure projects are suitable to apply DMAIC is more crucial – if that is accomplished correctly, the Black Belts, with their training, will use the appropriate tools in the different DMAIC stages. Once again, the importance of this infrastructure element is recognized by organizations in our sample; there are, however, some differences in execution.

3.5.3. Means:

3.5.3.1. Training: An important part of Six Sigma is measurement of processes to enable control of variation. Training at the process level enables employees to record valid measurements and even use tools like trend charts and control charts to track variation (Knowles et al., 2004). The Black Belt from Company Epsilon that we interviewed has frequently had to train process operators as part of the control stage in project execution. However, the majority of training in Six Sigma programs is toward preparing employees for participating in and leading projects. This training in the scientific methodology is done at different expertise-levels, commonly represented by Belts (Linderman et al., 2003). We describe the training content reflecting the belt-wise hierarchy generally followed across Six Sigma programs (also see Table 3.2).

Black Belts and Green Belts are commonly used to indicate the higher and lower levels of competence in the methodology and tools and techniques. (Organizations and consultants have also derived interim Belts such as Yellow and Brown representing different levels of competence in applying the methodology). Black Belts head team projects and for the period that they fulfill this role, cease to have any other line or staff responsibilities, whereas Green Belts continue to work in their routine jobs and lead less complicated projects or participate in Black Belt projects. Training for the Black Belts includes technical skills such as statistics, optimization, simulation and survey design, and soft skills such as team management and conducting meetings. Before they can start heading projects independently, Black Belts are typically required to conduct one or two projects under the guidance of their teacher, who is designated as a Master Black Belt.

Green Belts get a shorter version of the Black Belt training and head simpler projects or participate as team members on other Black Belt projects. ‘Project champion’ or ‘project sponsor’ training is provided to executives in charge of processes who sponsor improvement projects related to their processes and take part in tollgate meetings as well as steering committees. Champion training includes tools such as decision flowcharts to help in project selection. The standardized training system makes it easy to select team members based on their Six Sigma credentials and the education of all trainees in a common set of basics of Six Sigma facilitates communication among all levels of employees.

Company Mu has an extensive system in place to centrally coordinate its Six Sigma training conducted in multiple worldwide locations. Business leaders send employees for different levels of training and their divisions are charged a weekly rate for the number of employees they assign. The training imparted at Mu for Black and Green Belt certification is identical except for a full time certification project that Black Belts have to manage. The training schedule is divided over three full-time weeks of DM, A and IC with gaps of six weeks between them. The curriculum includes tools and techniques of lean principles in addition to Six Sigma. The other companies use similar training schedules except their curricula for Green Belt training are shorter versions of those for Black Belts.

Company Alpha, Mu and Gamma initially conducted their Six Sigma training in waves and used external consultants, gradually moving the training in-house, conducted by Master Black Belts. Each of the sample organizations used a mix of voluntary enrollment for training and nominations by middle management. All five organizations place particular emphasis on selection of highly motivated and skilled employees ("high potentials") for training to ensure maximum benefit from the investment.

3.5.3.2. Tools repertoire: As an implementation methodology based on the scientific method, Six Sigma process improvement employs a vast body of tools and techniques (Deming, 1986; Juran and Godfrey, 1999). Black Belts are imparted a repertoire of tools during training from which they select and use relevant ones in individual projects. Master Black Belts in addition to being trainers for other Belts also have the role of consultants in advising other Belts on their projects. The body of knowledge for implementing the scientific method is continually expanding as a result of advancements in tools and techniques and due to increasing complexities of businesses (Hahn and Hill, 1999).

Company Mu holds an annual summit where Master Black Belts and selected Black Belts from its worldwide operations get updated on the latest tools and techniques. The organization has been so successful in regularly updating their training material and regimen that they are preparing to sell their training services externally, in partnership with an academic institution.

Although on the surface the five organizations in our sample seem to follow similar training methodologies and content, it would be interesting to compare their training and certification rigor. We did not have access to the training material in each of these organizations to make such a comparison.

3.5.3.3. Roles, designations and career paths for experts: Career path options for Green Belts include further training to become Black Belts, or continuing to perform functional responsibilities and participating in projects. Black Belts work in the roles of full-time project leaders for a period of two to three years after which they are re-absorbed into their functions or get promoted as Master Black Belts. In addition to developing expertise in the methodology the full time project leader stint ingrains a cross-functional and systems perspective in employees returning to functional responsibilities.

Company Mu has grades and salary levels defined in their human resource management system for each of the Belts. Iota does annual human resource reviews of performance and potential for all Black Belts. In companies Iota and Alpha, Black Belts returning to full time functional or divisional responsibilities after two to three year stints as full time project leaders are offered a promotion. Company Iota is flexible with Black Belts staying in their full-time project-leader position for longer than the two-three year stipulation; they have also had occasions, mainly with Black Belts in engineering positions who were not interested in taking up the higher managerial level positions offered after completion of their Black Belt stint. Overall, the organizations in our sample seemed to follow the generic pattern of roles and responsibilities and career advancement opportunities for the different belts.

3.5.3.4. Information technology support: Database management and analysis tools are essential in Six Sigma programs for routine tracking of processes and for project executions. In addition, communication and systems integration tools are used for swift and accurate dissemination of information (Martínez-Lorente et al., 2004). Project tracking software is used to keep real time track of progress by team members and management (Linderman et al., 2003). Repositories of project reports are made available in databases equipped with keyword searches to share knowledge and leverage lessons learnt (Sabherwal and Sabherwal, 2005). Thus, information technology is an imperative in Six Sigma at the process, project and organizational level.

All the organizations in our sample use information technology systems for process and project tracking and to make available reports after projects are completed. The organizations intend for their databases of project reports to be used for sharing knowledge across different divisions and locations. The idea is for Black Belts and Champions to refer to the repository of reports representing lessons learnt so that the proverbial wheel is not reinvented when similar problems arise. Each of the five organizations expressed disappointment with the extent they were able to achieve such synergy.

The Company Mu executive observed, "There's no way you can poka-yoke the process…it is a human push process, you just hope that the belt has the wherewithal to go in and search for other projects. Quite honestly, one of the best ways to do that is to rigorously schedule project reviews." Company Gamma finds that some times their Black Belts use the database for tracking progress during execution but do not populate the data base at completion. They are planning to offer incentives for Black Belts to leverage their project across the organization by finding similar problems to the ones they may have tackled in their projects. On the other hand, Company Epsilon finds it hard to change Black Belts' beliefs that even when problems and projects appear similar there are unique characteristics of each situation that make leveraging pointless.

The evidence from our sample of five organizations shows that information technology is being used extensively for execution of projects and for routine tracking of process performances as well as for checks on project progress. However, organizations have not found a way of taking advantage of the valuable project reports that they accumulate over the years and across different locations and divisions.

3.5.4. Summary of empirical evidence: The differences in approach of organizations toward each of the infrastructure elements appear to reflect the differences in their reasons for initially adopting the Six Sigma program. Each organization appears to target areas of infrastructure in which they are deficient and which represent their organization's vision. Company Epsilon adopted Six Sigma for breakthrough improvements – they already had a quality culture established over the years with previous initiatives. Therefore while they adopted the goal focused DMAIC methodology, they did not have to put in too much effort toward establishing a change culture. In Company Gamma, CI initiatives before Six Sigma were localized and so their aim is to create a scientific management culture by training 100% of their workforce to some level. Mu Company required an initiative that allowed the different businesses to make improvements through employee involvement in local settings. However, they centrally control the infrastructure to ensure that the different decentralized efforts remain consistent.

3.6. Conclusion

Reflecting on the importance of organizational infrastructure for nurturing productive individual initiative, W. Edwards Deming (1993) remarked, “Put a good person in a bad system and the bad system wins, no contest.” Our attempt in this chapter was to delineate the characteristics of an organizational system that is conducive to sustained organizational learning. An infrastructure provides a vehicle for upper management to put their commitment for CI into action and to provide direction to the program while giving middle management freedom in executing projects and contributing to the strategic push of the organization. We developed a framework of infrastructure practices that support CI consisting of a web of relationships among elements categorized as ends, ways and means. In addition to the criticality of these individual elements there are interdependencies among them that organizations pursuing CI cannot afford to ignore.

With the idea of validating our framework we applied it to Six Sigma programs, relying on descriptions of the program in the literature and observations of deployments in five organizations. We found that normative Six Sigma prescribed in the practitioner literature covers the elements of CI. Both infrastructure and project execution methodology are critical in Six Sigma – the methodology for project executions is closely tied with the way projects are selected and coordinated, and people are trained. The Six Sigma executives that we interviewed affirmed the importance of the infrastructure elements and also shed light on some ways in which they address the infrastructure requirements of their programs.

From our interviews we observe that organizations adopt Six Sigma with different underlying motives. Depending on the existing state of CI maturity in their organizations they steer the Six Sigma program in different directions using infrastructure practices. Also, through different stages of maturity in their Six Sigma deployment they alter their infrastructure practices to change the focus of their CI initiative.

The insights that we gained from applying our framework to Six Sigma raise questions that we intend to pursue in future research. Contextual matching of practices with the vision of the organization and with the level of maturity of CI are issues about which insights can be useful for academicians and practitioners. An understanding of performance implications of CI infrastructure practices that incorporate different patterns of matching can be of considerable value. Our infrastructure framework, in its current form, can be used as the basis for diagnosing the coverage of relevant questions in organizations and for constructing scales for large scale empirical studies on the topic.

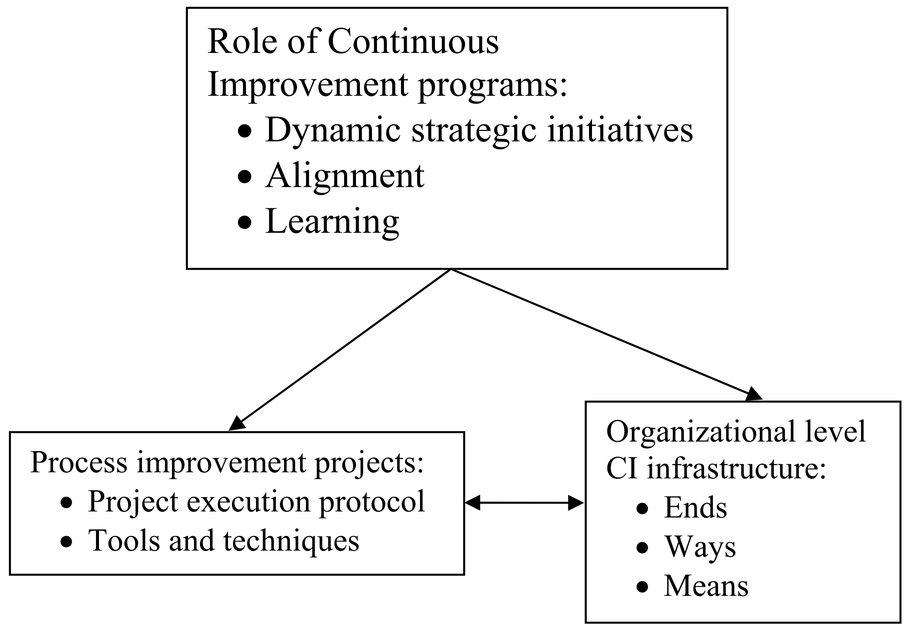

Figure 3.1
CI Programs – Roles, projects and infrastructure

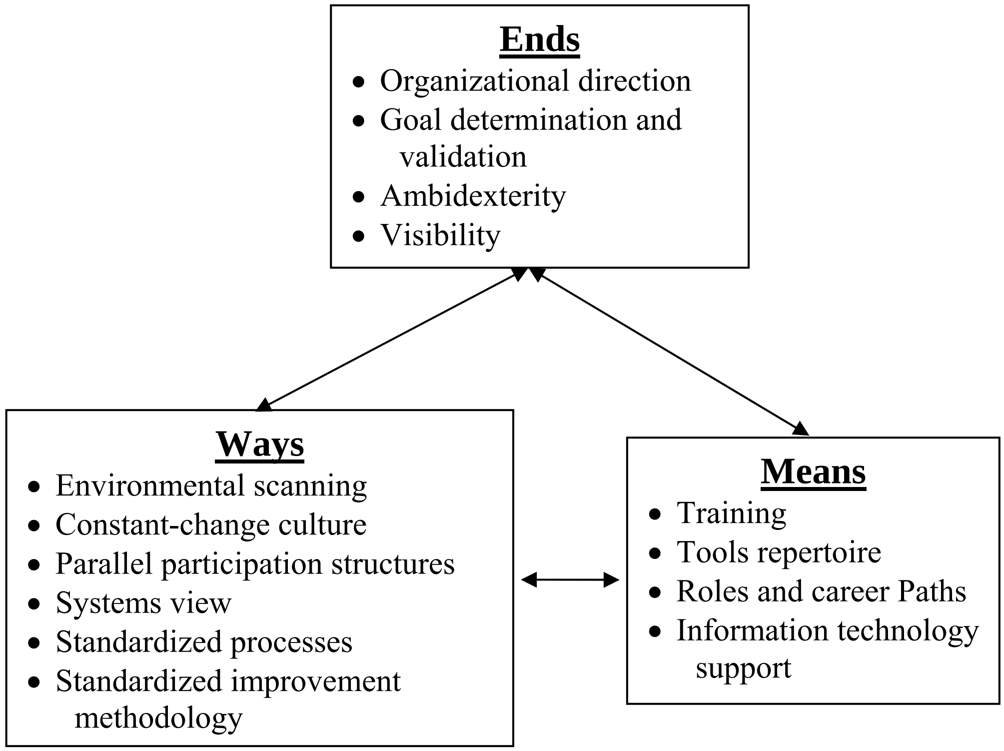

Figure 3.2
Infrastructure for CI

Element	Function
Ends	Determine multi-level goals while maintaining unified strategic outlook
Organizational Direction	Facilitate mid and lower level managers participation in strategy formulation and implementation
Goal determination and validation	Assure project goal congruence with strategic objectives and set and validate goals and results independently
Ambidexterity	Incorporate stability and change objectives and exploration and exploitation oriented projects
Visibility	Maintain focus on CI initiative
Ways	Institute practices and structures gearing implementations toward *ends*
Environmental Scanning	Encourage proactive scanning for opportunities and threats
Constant Change Culture	Prepare employees for constant change and reorientations
Parallel Participation Structures	Superimpose lateral structures for cross-functional cooperation
Systems View	Avoid sub-optimization of organizational performance for functional goals
Standardized Processes	Enable measurement and comparison for improvement projects
Standardized Imp. Methodology	Provide common scientific method for improvement and facilitate participation
Means	Provide resources toward *ways* to achieve *ends*
Training	Enable participation in CI projects
Tools Repertoire	Update body of knowledge and provide training when appropriate
Roles and Career Paths	Clarify reporting structures and paths for personal development
Information Technology Support	Support process-measurement needs and provide repository of project reports

Table 3.1
CI infrastructure elements

<u>Master Black Belts</u> Train all other Belts and Champions Coach Black Belts Participate in steering committees
<u>Black Belts</u> Experts in methodology and tools and techniques Lead team projects Work full time in the role
<u>Green Belts</u> Lead less complicated projects Participate in Black Belt projects Continue to work in routine jobs
<u>Champions</u> Executives in charge of processes Sponsor improvement projects Select team members in conjunction with Black Belts Participate in tollgate meetings and in steering committees

Table 3.2
Six Sigma training certification levels

1.	Who took the initiative to adopt Six Sigma in the company, and when and why?
2.	Was there a previous quality initiative?
3.	Where do project ideas come from?
4.	As part of projects, do teams study other divisions or organizations?
5.	How are projects selected and coordinated?
6.	Is there a DFSS program in place?
7.	Please describe the administration structure for projects?
8.	Who selects team members in a Six Sigma team?
9.	To what extent are Six Sigma teams cross-functional?
10.	How are project results assessed?
11.	Are process customers and suppliers included in teams?
12.	How strictly are standard operating procedures followed?
13.	Is data on processes collected regularly e.g. cycle time of an order, or time to respond to customer query, or tracking of customer sat data?
14.	Is the DMAIC framework strictly followed in project executions?
15.	How is project-documentation maintained?
16.	What are the different Belt levels of Six Sigma training?
17.	How are candidates selected to undergo training?
18.	What are the responsibilities of Master Black Belts?
19.	What are the career paths for BBs?
20.	What role does IT play at the routine process level, project level and organizational level?
21.	How are goals for projects decided?
22.	Is there a project tracker used to track project execution?
23.	Are reports from completed projects stored in a database and accessible to others?
24.	What is the general perception about the Six Sigma program among employees?

Table 3.3
Questions for semi-structured interviews with Six Sigma executives

CHAPTER 4

SIX SIGMA PROJECTS AS AVENUES OF KNOWLEDGE CREATION

"If knowledge is an essential resource for establishing competitive advantage, then management should identify, generate, deploy, and develop knowledge" Drucker (1993)

4.1. Introduction

There is substantial anecdotal evidence linking Six Sigma to better organizational performance. However, to date there has been limited theoretical inquiry exploring and explaining the relationship. Six Sigma programs are implemented primarily through multiple projects that employ a common structured methodology. We therefore focus on Six Sigma projects and examine them as avenues to utilize team-members' knowledge for discovering process improvements.

A discussion of the underlying theoretical basis for Six Sigma projects was presented by Linderman et al. (2003). Their perspective is that the existence of stretch goals (Shalley et al., 1987) combined with providing adequate means for their achievement (Kanfer and Ackerman, 1989) contributes to the success of projects. We build on the arguments of Linderman et al. (2003) and delve deeper into their notion of "means for achievement of project goals".

In order to achieve high project performance, different project management practices (both tools and techniques) are used to extract and combine team members' knowledge. This results in achievement of project goals and higher organizational performance (Linderman et al., 2004). We focus on the very mechanisms that result in value creation within Six Sigma projects. In so doing we address 'how' new knowledge is created by the execution of Six Sigma projects and 'why' Six Sigma projects result in improvements (Whetten, 1989).

4.1.1. Focus on projects:

Organizations are defined as "goal-directed, boundary-maintaining, and socially-constructed" administrative units that incorporate work-processes converting inputs into outputs (Aldrich, 2000; p.2). Thus, an organization can be a company or a strategic business unit within the company that acts in a unified manner (Drucker, 1993). An organization may deploy continuous improvement programs and these programs usually consist of multiple process improvement projects (see Figure 4.1). Process improvement projects are executed using a combination of practices (tools and techniques) and aimed at improving particular aspects of processes.

Participative continuous improvement programs such as Six Sigma are implemented at two levels – project and organization (Bartlett and Wozny, 2005; Un and Cuervo-Cazurra, 2004). Consistent and complementary efforts at both levels are necessary for sustainable process improvements (Garvin, 1993b; Lok et al., 2005; Upton, 1996). While task specific project teams are crucial (Juran and Godfrey, 1999; Linderman et al., 2003; MacDuffie, 1995), overarching project co-ordination mechanisms at the organization level also play an important part in process improvement (Batemen, 2005; Forrester and Drexler, 1999). Thus, Six Sigma can be studied at either the project or organization level of analysis.

In this research on Six Sigma we concentrate on the project level of analysis. There is little empirical research on the role of project teams in process improvement and unanswered questions remain regarding the underlying mechanisms at work in process improvement projects. We address these questions in the context of Six Sigma process improvement projects by investigating the relationships of the tools and techniques with project performance. In addition to the academic contribution, our research has implications for practitioners because it provides guidance for the selection of appropriate tools and techniques most appropriate to the type of project and the environment in which the project is executed.

4.1.2. <u>Organization of the chapter:</u>

We begin by providing a description of Six Sigma in section 4.2. On the basis of prescriptive practitioner-oriented books on Six Sigma, accounts of its deployments and academic literature on the subject, we define Six Sigma conceptually, thus providing context for the rest of the analysis. In section 4.3, we incorporate knowledge management theory (Spender and Grant, 1996; Argyris and Schön, 1978; 1996) to explain the underlying mechanisms that make Six Sigma projects beneficial to organizations. In section 4.4, we adapt Nonaka's (1994) knowledge creation mechanisms to the context of project-execution practices (Linderman et al., 2004) and Six Sigma. Section 4.5, titled 'conceptual framework', presents our research hypotheses. In section

4.6, we describe our instrument development and empirical methodology. We then present analyses in section 4.7, statistically validating the survey scales and testing the hypothesized relationships of practices and project performance. Finally, section 4.8 consists of a discussion of the implications of our results, followed by limitations of the study and concluding remarks.

4.2. Unraveling Six Sigma

The essence of the Six Sigma program is in reducing process variation. Specifically, the label Six Sigma implies the reduction and control of process variance to such an extent that even when the output varies up to six standard deviations on either side of the process mean it complies with upper and lower customer specifications (Pande et al., 2000). This standard corresponds to a defect level of 3.4 per million opportunities, and a defect-free yield rate of 99.99966%. The Six Sigma metric originated at Motorola as a way to compare performance across disparate processes – e.g. the performance of a die casting process can be compared with that of a parts-ordering process using the common metric of Sigma level. The metric also signifies a spirit of continuous improvement toward Six Sigma level process performance.

Though it originated in the 1980s as a means to measure and reduce defects, numerous descriptions of Six Sigma program implementations indicate that its scope goes further than statistical control. For example, Pande et al. (2000) describe Six Sigma as:

> "… a comprehensive and flexible system for achieving business success. Six Sigma is uniquely driven by a close understanding of customer needs, disciplined use of facts, data and statistical analysis, and diligent attention to managing, improving and reinventing business processes."

Linderman et al. (2003) offer a similar definition:

> "Six Sigma is an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic changes in customer defined defect rates."

The Six Sigma program establishes a process improvement initiative that is sustained over time with the objective of continually improving performance – improving efficiencies and making other process changes in response to customer requirements. Process improvements are sought by employing the scientific method, commonly framed as the 'define-measure-analyze-improve-control' (DMAIC) steps, in Six Sigma team projects (a short description of the steps in the DMAIC framework is presented in Table 4.1). This standard framework is designed to assure that a project stays focused on its goal; it further facilitates the involvement of team members through a common understanding of its steps. Although the two definitions of Six Sigma programs presented earlier also refer to the design and development of *new* processes, we limit ourselves to the study of Six Sigma projects for improvements of *existing* processes. The Six Sigma program, for designing new processes, prescribes an alternative project implementation framework and a different set of tools and techniques that is beyond the scope of our purpose in this research.

4.2.1. Project management methodology:

Six Sigma program implementations involve training employees to different extents in its practices (that is, its tools and techniques). This aspect is reflected in a hierarchy of "Belts" awarded. Master Black Belts are the highest level experts who serve as full-time consultants in the methodology and practices. Master Black Belts do not manage process improvement projects although they may advise Black Belts, as needed, on particular projects. Then follow the Black, Green, Yellow, etc. belts reflecting reducing levels of proven competence in using the methodology and practices. Black Belts are certified upon completion of an extensive (typically four-week) training program, passing an examination, and leadership of two significant process improvement projects.

Black Belts have full time Six Sigma project responsibilities, i.e. they do not have other line and staff responsibilities usually for the two or three years that they fulfill the role of project leaders (Harry and Schroeder, 2000; Kumar and Gupta, 1993). Continuous improvement through the Six Sigma program takes place in the form of process improvement projects that are guided by Black Belts or Green Belts depending on the complexity of a project. The needs for process improvement originate from different organization levels and functional departments involved in the process, and from customers and suppliers. These needs are the sources of Six Sigma projects.

The process owner who has a stake in the process being improved also participates as part of the project team. Process owners may be trained for their role as Six Sigma project 'champions'. The rest of the team consists of employees across functional lines that are connected to the affected process. Some team members are those who routinely work on or manage the targeted process (e.g. an insurance sales agent or supervisor), and others routinely work in supporting the process (e.g. an information technology expert who provides support to the insurance claims process). All project team members may not be trained in Six Sigma practices. The project leader (Black or

Green Belt) and process owner (project champion) jointly select the team. The project leader leads the execution of the project taking into account the Six Sigma expertise-levels of team members. Consequently, the project leader may need to train team members in the use of certain tools and techniques required for the execution of the project. The framework of DMAIC includes 'control' as its last step signifying the need to sustain results by ensuring that employees who regularly work on the processes adopt the improvements discovered.

4.2.2. Importance of teams:

Participative project teams are an integral part of Six Sigma programs for five key reasons:

1. Participative teams ensure utilization of the potential of frontline employees in generating novel improvement ideas (Bharadwaj and Menon, 2000; Nilsson, 1995).
2. The involvement of middle management level Black Belts, and the connection through these Black Belts to upper management, keeps the organizational big picture within sight. A middle-up-down approach helps to focus on broad strategic goals while utilizing the creative abilities of front-line employees (Nonaka and Takeuchi, 1996).
3. Participative teams secure buy-in and eventually sustainability from frontline employees who are responsible for the day-to-day implementation of the findings (Benson et al., 1994).

4. Cross-functional participation provides a system-wide view of the improvement initiative. It also guards against selfish functional optimization at the expense of system-wide performance (Sitkin et al., 1994). Quality guru Deming (1983) highlighted the importance of such "appreciation of the system" as part of his system of profound knowledge™.
5. Most critically, participative teams facilitate the balancing of the paradoxical principles of empowerment and conformance (Tatikonda and Rosenthal, 2000). Improvements are generated with the involvement of people doing the work, many times originating because of the initiative of the front-line employees. However, they follow a scientific method of hypothesis-testing, and once proven, are standardized for that type of work, until another improvement is suggested (Klein, 1989; Spear and Bowen, 1999).

4.2.3. <u>Defects and quality:</u>

The concepts of *defects* and *quality* are central to Six Sigma as they affect the domain covered by its projects. Six Sigma projects are aimed at reducing the occurrence of *defects* in processes. The resulting increase in *quality* of process-output is intended to raise customer satisfaction. The meaning of *quality*, and as a result, the implication for *defect* reduction through process *improvement*, has evolved. From being limited to preventing operational failures of products (goods and services) the scope of process *improvement* has expanded to include multidimensional notions of *quality* (see Garvin's (1987) eight dimensions and Parasuraman et al.'s (1988) eight facets). For example, an automobile purchase now is blended with ancillary services such as financing, supporting websites, provision of preferred repair shops, and various types of warranties. Customer definitions of *quality* include, among others, dimensions of product ordering and delivery. In addition, customers are expecting higher *quality* in multiple areas, such as higher customization and lower cost, instead of accepting compromises in what were once considered competing dimensions.

With the increasing complexity of products and the expanding definition of *quality* over time, the number of processes involved in their design, production, and delivery has exploded. For example, computer designers incorporate network cards and web-cams when designing notebook computers, the installation of which adds manufacturing processes. Customer choices in each of these features further add complexity in the ordering and delivery processes. Each of the processes provides opportunities to please customers (improve *quality*) and chances to create *defects* (reduce *quality*) across multiple dimensions.

Six Sigma projects are aimed at reducing *defects* in all types of processes ranging from marketing and sales, to production of goods and services, and provision of after-sales services. They also cover ancillary processes that support the core processes of an organization, e.g. processes in accounting and procurement in a manufacturing organization. Under the expanded definition of *quality*, *defect*-free also means catering to more customer requirements at lower prices than the competition, and being responsive. A deficiency in any feature that the customer expects is termed a *defect*, while an *improvement* is one that adds value for the customer and possibly even surprises the customer by exceeding expectations. Thus, an *improvement* can come from, among other sources, reduced occurrences of failures, increased flexibility in a process allowing customization of output, faster and more consistent delivery times, and reduced costs that may or may not be translated into lower prices. Consequently, when determining process *improvement* goals and executing Six Sigma process *improvement* projects, multiple perspectives of *quality* are included under the umbrella of value-addition for the customer.

4.3. Knowledge, knowledge creation and process improvement

Knowledge is internalized information about cause-effect relationships that is the result of learning and experience (Fiol and Lyles, 1985; Nonaka and Takeuchi, 1995). Knowledge creation or organizational learning is defined as the detection of errors and anomalies, investigation of causal relationships, and corrections made in light of the results (Argyris and Schön, 1978). (The terms knowledge creation and organizational learning are closely related and used almost interchangeably in the literature [Argote et al., 2003; Easterby-Smith and Lyles, 2003]). Process improvement projects are executed to gain knowledge about ways to reduce defects and improve quality of the process-output for the customer (Juran and Godfrey, 1999; Lapré et al., 2000; Mukherjee et al., 1998).

Process improvement projects aim to create knowledge by discovering causal relationships through planned experimentation using front-line participative practices (Ethiraj and Levinthal, 2004; Un and Cuervo-Cazurra, 2004). Putting the knowledge gained through projects into action can lead to better operational performance (Garvin, 1993a; Linderman et al., 2004; McAdam and Leonard, 2001; Wruck and Jensen, 1998).

Thus, knowledge based theories are appropriate lenses to understand the logic of continuous improvement programs and the associated combinations of process improvement practices they prescribe.

4.3.1. Knowledge based theory of competitive advantage:

The knowledge based view of business strategy supports the notion that knowledge can be a valuable resource for competitive advantage; see, e.g. Argote et al. (2003), Baum and Ingram (1998), Cyert and March (1963), Kogut and Zander (1992), Lei et al. (1996a), Nonaka et al. (2000) and Spender (1996). Thus, capabilities to manage and create knowledge can provide sustainable competitive advantage (Argyris, 1999a; de Geus, 1988; Prahalad and Hamel, 1990; Hatch and Dyer, 2004; Hayes et al., 1988). We invoke the knowledge based theory because Six Sigma programs can contribute to competitive advantage by institutionalizing continuous improvement of processes (de Mast, J., 2006). (Selected research papers in organizational learning and knowledge management are described in Tables 4.2-4.5). Though an extensive amount of research has been conducted on knowledge management, there has been limited research on process improvement using these concepts (Linderman et al., 2004) (Table 4.6).

Most organizational knowledge originates in individuals (Spender and Grant, 1996). Individual knowledge must then be synthesized, integrated and preserved to create organizational knowledge that in turn provides strategic competitive advantage (Nonaka, 1994). Thus, environments that facilitate interaction among individuals in turn facilitate organizational knowledge creation (Reagans et al., 2005). Teams created for specific purposes such as new product development and process improvement can create knowledge more efficiently and effectively in the presence of practices that facilitate interactions among team-members (de Jong et al., 2005; Huang and Newell, 2003; Okhuyen and Eisenhardt, 2002). The Six Sigma continuous improvement program contains one such organizational design involving empowered teams, and tools and techniques that the team members use, for making process improvements (Argyris, 1999a). The question that we seek to address is how do the learning activities included in Six Sigma result in creating knowledge about process improvement.

This question needs to be addressed at two levels – the organization level, at which decisions regarding knowledge creation enablers (e.g. new patterns of relationships among employees, resource deployment in training and information systems, etc.) are made; and the project team level, at which tools and techniques are used to address the specific problems being targeted (Gold et al., 2001; Un and Cuervo-Cazurra, 2004). Six Sigma program implementations at the organization level include project selection and steering committees for linkages between strategic and operational levels. These serve to support and coordinate front-line improvement projects. In the present research, we concentrate on studying knowledge creation at the project level as we are interested in assessing the efficacy of different categories of tools and techniques for Six Sigma project success.

4.3.2. Classification of knowledge – tacit and explicit

Knowledge is commonly classified using two schemes: (1) based on whether the knowledge addresses the questions of ‘know-what’ (dealing with facts, concepts, and generalizations) or ‘know-how and -why’ (dealing with skills, procedures and processes);

and (2) based on whether the knowledge is tacit or explicit (Edmondson et al., 2003). The two classifications are related in that while ‘know-what’ knowledge is mostly explicit, ‘know -how and -why’ has both tacit and explicit elements. We adopt the tacit-explicit classification because of its focused view of types of knowledge that may apply in Six Sigma project contexts.

Tacit knowledge is non-numerical and non-linguistic knowledge that is difficult to articulate. It is context specific (Nonaka, 1994) and is transferred mainly through social interactions (Baumard, 1999; Polanyi, 1966). Language is an excellent example of tacit knowledge; often we speak a language without being able to articulate the grammatical and syntactical rules governing it. Tacit knowledge is that part of knowledge that is more than we can tell (Polanyi, 1966) and therefore contributes to stickiness of information required for problem solving, making it difficult to gather, transfer and utilize (von Hippel, 1994). It is because of these aspects that it is difficult for organizations to garner tacit individual knowledge. It is also because of its difficult-to-codify nature that tacit knowledge provides inimitable capabilities (Barney, 1995).

Interactions in the context of team meetings help draw out ideas and improvisations in standard procedures. Employees would not have ordinarily expressed such ideas because they were not even aware of their existence and / or relevance. By building mutual understanding among team members such hidden tacit knowledge is harvested. Although some elements of tacit knowledge may be codified, at least partially, with some effort, there are other elements that absolutely cannot be separated from the context and are transmittable only through learning-by-doing and personal training (Edmondson et al., 2003).

Explicit knowledge, on the other hand, is conducive to codification and documentation. Transfer of explicit types of knowledge can take place in impersonal ways – through written instructions and diagrams. Although explicit knowledge has been the predominant focus in the conventional management of large organizations, tacit knowledge must be captured to provide strategic advantage through inimitability and adaptability (Brown and Duguid, 2000; Duguid, 2005; Spender and Grant, 1996b). Learning-oriented practices of continuous improvement programs that incorporate tacit knowledge about customer needs and work practices must be emphasized along with control-oriented practices (Sitkin et al., 1994).

In related previous research Mukherjee et al (1998) addressed the question of knowledge creation through process improvement projects in the context of TQM programs. Restricting the scope of their study to technological knowledge, they found *operational* and *conceptual* learning to be significant predictors of project performance. While *operational* learning involves superficially learning how to run a process and how to react to certain changes, *conceptual* learning involves gaining deeper knowledge of cause-effect relationships resulting in the formulation of theories. Mukherjee et al.'s (1998) treatment of these variables was limited to "explicit knowledge" contexts. Our research differs from theirs in two ways: (1) we employ the knowledge creation framework of Nonaka (1994) that incorporates the role of "tacit knowledge", to gain insights into the patterns of knowledge creation (Linderman et al., 2004); (2) we study knowledge creation in the context of Six Sigma projects which have incremental features when compared to TQM projects, mainly project-specific off-line teams facilitated by full time project leaders (Harry and Schroeder, 2000; Kumar and Gupta, 1993). Thus we propose knowledge creation theory as an effective lens for viewing the efficacy of Six Sigma (de Treville et al., 2005), and assess the argument that tacit knowledge creation is essential for process improvements (Baumard, 1999; Kulkki and Kosensen, 2001; Nonaka, 1991).

4.4. Knowledge creation mechanisms

4.4.1 Nonaka's (1994) framework of knowledge creation:

Nonaka's (1994) framework of knowledge creation includes both tacit and explicit knowledge; it describes the process of knowledge creation as continually occurring cycles of conversions between these two knowledge types (see Figure 4.2). The framework provides a good explanation for the knowledge creation mechanics underlying Six Sigma practices (tools and techniques) in generating results for improvement projects (see Figure 4.3). Tools and techniques used in Six Sigma team projects are aimed at bringing together the knowledge of employees across the value chain (Florida and Kenney, 1990) to generate continuous improvements in products and processes. To understand knowledge creation in the context of Six Sigma projects, we now describe Nonaka's (1994) mechanisms of knowledge creation and do so from both the team-level and process improvement perspectives (Fong, 2003; Gold et al., 2001; Johnson and Johnston, 2004; Linderman et al., 2004; Sabherwal and Becerra-Fernandez, 2005). As shown in Figures 4.2 and 4.3, Nonaka's (1994) framework consists of four knowledge creation mechanisms and Six Sigma practices can be categorized among these four mechanisms.

4.4.1.1. Socialization (Tacit → Tacit):

The socialization mechanism combines individual knowledge and expertise and creates a common understanding about the process being investigated (Fiol, 1994; Nonaka et al., 1994; Weick and Roberts, 1993). The group-level tacit knowledge that is the outcome of this mechanism is not concrete enough to be expressed in comprehensible written or picture forms. Socialization practices enable individuals to express to each other ideas in light of their experiences – in some ways, it brings to the group an individual's ideas about the process that they may not have even considered relevant had they stayed in a vacuum. Socialization practices generally require physical proximity and joint action (Sabherwal and Becerra-Fernandez, 2003) – even the verbalization of ideas is subject to immediate absorption and response by others.

The socialization mechanism in projects is targeted by the inclusion of individuals from across functional, hierarchical and organizational boundaries (suppliers and customers) in the team, and by their attendance in team meetings. Socialization practices predominantly occur in the early portion of the DMAIC methodology for Six Sigma projects, when project goals are decided based on multiple stakeholders, processes are studied from different points of view and possible triggers for defects are discussed. Socialization practices in Six Sigma include idea generation and meeting facilitation techniques. These bring out individual ideas and enable them to incorporate other individuals' perspectives in coming up with possible ideas for the cause of the defect being targeted and ways to correct it.

Besides project-level practices, the socialization mechanism is targeted via informal organization-level activities such as company picnics, and by creating environments such as common drinking fountains and dining areas that encourage casual discussions about processes. In addition there are formal organization-level practices such as job rotation (Kane et al., 2005) and apprenticeships that play a role in the conversion of both explicit and tacit knowledge to tacit knowledge – thus, some practices serve dual purposes of socialization and internalization (explicit → tacit). Socialization practices are time-consuming but are more rich in information and effective in the sense that the interchange of ideas among team members to generate new ideas is not hindered in any way by communication barriers. There is nothing lost in translation into language or pictures, and any clarifications needed are immediately obtained.

4.4.1.2. <u>Externalization (Tacit → Explicit):</u>

While socialization enables process stakeholders to synthesize tacit ideas and generate more tacit ideas, the externalization mechanism enables explicit expression of these tacit ideas in the form of language and visual schemata that can be communicated. Externalization practices convert tacit knowledge (held by individuals and the group) into explicit forms such as written descriptions, objective numbers, or pictures and diagrams. Externalization practices enable individuals to express, summarize and view explicitly the knowledge they have created jointly through the exchange and synthesis of tacit knowledge, thus creating common understanding. Further, externalization practices assign explicit measurements to subjective performance attributes thus facilitating assessment, comparison and scientific experimentation.

4.4.1.3. Combination (Explicit → Explicit):

Through the combination mechanism of knowledge creation explicit knowledge becomes justified knowledge for project team members, i.e. team members see explicit relationships between sets of process elements through data analysis and measurement of critical metrics. Combination practices combine explicit knowledge, reconfiguring and systematizing it to result in new explicit knowledge (Linderman et al., 2004). Combination practices involve sorting, adding, combining and categorizing explicit knowledge (Zhang et al., 2004). Some of the outputs from externalization (tacit → explicit) practices naturally become inputs for combination practices, e.g. the explicit face given to a tacit knowledge feature like customer satisfaction is input for analyses of explicit factors affecting it and for comparing performance over a period of time.

4.4.1.4. Internalization (Explicit → Tacit):

The internalization mechanism constitutes the embodiment of explicit knowledge gained by individuals in the activities they perform as part of the process. Internalization practices consist of learning-by-doing activities like training on the job and observation of someone applying the explicit knowledge in doing their job. In the context of Six Sigma practices internalization practices include the use of explicit signaling mechanisms like control charts and error-proofing (poka yoke) mechanisms. These tools provide an explicit signal of the need for either tacit on-the-job corrections or the need for team meetings to brainstorm and come up with ideas about what may be wrong, why it went wrong and how it may be corrected.

Internalization practices, depending on the extent of the defect or an improvement signaled by explicit data, may involve a tacit error correction by the frontline or require the initialization of a new Six Sigma project to solve the problem. In such instances the problem will probably be addressed first by socialization mechanisms, thus starting a new loop in the continuous learning cycle. Using the broad definition of quality adopted in Six Sigma projects, such a defect may be a deficiency in a product or service or may represent a new and/or more demanding customer requirement. Nevertheless, the direction of internalization activities is from explicit knowledge to activities that involve the use of specialized knowledge that is tacit. As evident from these descriptions, such mechanisms will predominantly come into play in the Control stages of Six Sigma projects, when the knowledge about ways to improve and sustain improvement is being utilized.

4.4.2. <u>Six Sigma Practices as knowledge creation mechanisms:</u>

There is considerable overlap among different authors' definitions of the four knowledge creation mechanisms. The overlap occurs because the knowledge creation mechanisms deal with conversions within and between tacit and explicit knowledge. These two categories of knowledge are not exclusive; they exist along a continuum (Edmondson et al., 2003). As a result there can be overlap between pairs of conversion mechanisms at the boundaries of their classifications. Especially for externalization (tacit

→ explicit) and internalization (explicit → tacit) in which the input for and the output from the mechanism are different, it can be difficult to say whether the conversion mechanism being referred to is a compound of two mechanisms or a single mechanism. For example, when dealing with a practice such as process mapping, we have to examine whether there are two underlying mechanisms being employed or if it is a single mechanism converting tacit knowledge to explicit knowledge. As a two-mechanism tool, process mapping converts tacit to tacit knowledge via discussions among process stakeholders, and tacit to explicit knowledge through depiction in the process map as a diagram. As a one mechanism tool, it converts tacit ideas into an explicit diagram.

In the light of this confusion, we categorize Six Sigma practices into the four knowledge-creation mechanisms based solely on the type of knowledge that is input (tacit or explicit) and the type of knowledge that is created (tacit or explicit) through that practice. Using this basis some Six Sigma practices have to be classified differently based on the stage in the DMAIC framework that they are employed. For example, an SPC chart used in the define or measure stage to discover possible causes of problems is an externalization practice - using the tacit knowledge of team members to determine variables that must be charted, while at the control stage, it is a combination practice - using data to assess the variance of the process. Our attempt at classifying Six Sigma practices by knowledge creation mechanisms is similar to that of Linderman et al. (2004) who present a classification of total quality management practices. A classification of some Six Sigma practices into knowledge creation mechanisms is presented in Figure 4.3.

4.5. Conceptual Framework:

As we explain here, it is important that a knowledge creation initiative incorporate practices covering all four knowledge creation mechanisms. Considerable empirical support exists to back up this assertion in the area of new product development (e.g. Johnson and Johnston, 2004; Nonaka et al., 2005; Smith et al., 2005; Zhang et al., 2004). However, the claim has not been investigated in the context of process improvement programs such as Six Sigma (Linderman et al., 2004).

In this section we lay out our conceptual framework relating the coverage of the four knowledge creation mechanisms in Six Sigma projects to project performance. We develop four testable hypotheses that we test in the next two sections. Figure 4.4 shows our conceptual model including all hypothesized relationships.

Our first two hypotheses deal with the effect of knowledge creation mechanisms on project performance. Our first and central hypothesis is that Six Sigma projects that cover all four mechanisms of knowledge creation achieve higher levels of project success compared to those that ignore any of the mechanisms.

> <u>Hypothesis 1.</u> All four knowledge creation mechanisms – socialization (tacit → tacit), externalization (tacit → explicit), combination (explicit → explicit) and internalization (explicit → tacit) contribute positively to Six Sigma project performance.

Our second hypothesis is that the inclusion of tacit knowledge through socialization (tacit → tacit) and externalization (tacit → explicit) practices adds marginal value over and above that created by concentrating solely on utilizing explicit knowledge (Baumard, 1999; Cohen and Levinthal, 1990; Kulkki and Kosensen, 2000; Nonaka et al., 2005). The criticality of capturing tacit knowledge is brought home by the fact that the main cause of the Challenger disaster was due to the lack of tacit knowledge sharing among engineers and managers involved in fine tuning the shuttle's design (Starbuck and Milliken, 1988). The importance of tacit knowledge is also recognized by managers; a 2000 Delphi study found that they believed 42% of organizational knowledge is situated in employees' brains (Frappaolo and Wilson, 2000). Thus, tacit knowledge is critical for process improvements and day-to-day knowledge management just as it is critical for new product and process design (Benner and Tushman, 2002, 2003; Dyck et al.2005; Sabherwal and Becerra-Fernandez, 2005). There has been limited inquiry, however, into the utilization of tacit knowledge for improvement of existing processes (Linderman et al., 2004).

> <u>Hypothesis 2.</u> Socialization (tacit → tacit) and externalization (tacit → explicit) contribute significantly and positively to Six Sigma project performance after accounting for the effects of combination (explicit → explicit) and internalization (explicit → tacit).

We also propose that the relative effectiveness of the four knowledge creation mechanisms is different for different categories of improvement projects. There is a tendency of organizations adopting any new initiative such as Six Sigma to treat it as universalistic, ignoring the different requirements of different classes of problems.

Overzealous execution is common for innovative work practice bundles (Ketokivi and Schroeder, 2004) such as TQM (Hackman and Wageman, 1995) and JIT (Young, 1992) leading to problems of unsuccessful implementations and decline in popularity of these initiatives. Thus, it is important to consider the question whether the four knowledge creation mechanisms are equally related to the success of all types of Six Sigma projects.

Just as the universalistic perspective is problematic for organizations, over-aggregation of data is also a problem in empirical investigations and leads to misattributions of performance effects (Hambrick and Lei, 1985). Contextual factors such as task uncertainty, industry category and life-cycle stage are contingency variables that affect the implementation of business strategies and organizational structures (Dewar and Werbel, 1979; Govindarajan, 1988; Lawrence and Lorsch, 1967; Van de Ven and Drazin, 1985). Contingencies have also been found to be important in explaining the success of operations strategy decisions at the organization level; e.g. adoption of lean principles (Hines et al., 2004; Shah and Ward, 2003), TQM (Birkinshaw et al., 2002; Dreyfus et al., 2004), JIT (Selto et al., 1995), manufacturing flexibility (Kathuria and Partovi, 1999), new product development (Kusunoki et al., 1998), and advanced manufacturing technology (Boyer et al, 1996; Das and Jayaram, 2003). These studies highlight the importance of contingencies for proposing relationships using management theory.

At the project level of implementation, several studies have discussed and empirically tested the effects of contingency factors. The effectiveness of management practices used in new product development projects was found to be dependent upon technological uncertainty and scope of the project (Shenhar et al., 2002). Success of platform and derivative projects, classified on the basis of different stages in the product family stream for which products were being developed, was affected differently by the use of interdependent technologies and other technological and managerial factors (Tatikonda, 1999). Late-stage inter-functional co-operation in product development projects positively affected their success but was not a significant predictor of success in low-innovation projects (Olson et al., 2001). On the other hand, early-stage inter-functional cooperation had a positive effect on low-innovation projects while it had a negative effect on innovative projects (Olson et al., 2001). Learning-before-doing was found to be more effective in developing processes for traditional chemical-based pharmaceuticals, while simultaneous learning and development was more found to be more appropriate for biotechnology-based pharmaceuticals (Pisano, 1994).

Six Sigma projects deal with a range of problems that can be assessed on a continuum of less to more exploitation of current capabilities. In new product development studies, exploration and exploitation refer to the two extreme cases of developing a radically different design for a product and one that is only a slight incremental change over the previous design (Olson et al., 2001; Tatikonda, 1999). Although all process improvements fall in the category of exploitation of current processes, they can be classified based on a more granular assessment of levels of exploitation. Projects that deal with more amorphous improvement objectives like improvement of customer satisfaction have considerably different task environments than do manufacturing processes-defect-reduction projects that have more concrete goals. The former projects fall on the scale of low exploitation (tending toward exploration) while the latter involve a higher degree of exploitation of current capabilities.

Making specific manufacturing defect reductions requires leveraging existing knowledge to a greater extent than when creating new concepts. Projects related to making improvements in already highly standardized processes are conducive to measurement of explicit and detailed metrics. Thus, the use of tools and techniques to analyze explicit knowledge to discover improvements are appropriate for situations where controlling a defect is the question that dominates over generating new learning (Sitkin et al., 1994). Further, the explicit knowledge gained needs to be utilized to produce the desired results. Practices that facilitate the absorption of such explicit knowledge such that it becomes 'automatic' are critical for projects dealing with defect reductions. Our third hypothesis deals with Six Sigma practices that use explicit knowledge, either recombining it and creating more explicit knowledge (combination: explicit → explicit), or using the explicit knowledge in action and creating tacit knowledge (internalization: explicit → tacit).

> <u>Hypothesis 3.</u> For Six Sigma projects entailing already standardized processes, mechanisms that make use of explicit knowledge – [combination (explicit → explicit) and internalization (explicit → tacit)] will have greater beneficial effects on Six Sigma project performance.

The fourth hypothesis addresses contingency effects for the success of Six Sigma projects. In developing it, we apply existing research in the area of cross-functional work teams. We propose that projects that cover several processes predominantly require the use of tacit knowledge through socialization (tacit → tacit) and externalization (tacit → explicit) mechanisms. For projects covering several processes it is important to facilitate collaboration among employees (Mohamed et al., 2005; Yasumoto and Fujimoto, 2005). Thus, socialization (tacit → tacit) and externalization (tacit → explicit) mechanisms that enable individuals to contribute to the team are especially important for the performance of such projects (Reagans et al., 2005). The need for socialization (tacit → tacit) and externalization (tacit → explicit) practices to integrate the knowledge of individuals is greater for projects involving several processes.

> <u>Hypothesis 4.</u> For Six Sigma projects that cover several processes, mechanisms for the synthesis of tacit knowledge – socialization (tacit → tacit) and the conversion of tacit to explicit knowledge – combination (tacit → explicit) will have greater beneficial effects on Six Sigma project performance.

4.6. Methodology

We test the hypothesized linkages between knowledge creation mechanisms and Six Sigma project performance using data collected from U.S. organizations utilizing Six Sigma programs. These data are collected using surveys administered via the Internet. The unit of analysis is a Six Sigma Black Belt project completed within the last three years, and respondents providing the data are Black Belts, in their capacity as leaders of projects for which they are providing data. Regression analyses are conducted to test the hypotheses using as measures, scales adapted from previous research and validated using statistical techniques.

4.6.1. Sample:

Project-level data is not reported publicly by any organization and moreover, is considered highly sensitive and confidential. Thus, we had to adopt an approach different from the conventional method of contacting organizations on any particular mailing list used in most empirical studies involving business unit or finer-grained data. To conduct an efficient search for organizations that would be willing to participate, we used three avenues to find Six Sigma implementing organizations that we could approach: (1) we obtained contact information for organizations known to the Center for Operational Excellence at the Ohio State University, (2) we received support from the Joseph M. Juran Center for Leadership in Quality at the University of Minnesota in the form of referrals sent to Six Sigma executives in a few of their member companies and (3) we cold-called some local companies in and around Columbus, Ohio that we had information on as having implemented Six Sigma.

We only contacted organizations that had implemented Six Sigma for at least three years prior and invited them to participate in the study, requesting data on projects completed within the last three years. In return for their participation, we offered these organizations a customized report of the results, which included, in addition to analysis of the overall sample, analysis of the projects solely by their organization. We contacted a total of 27 organizations. There were two main issues that we needed to convince executives in these organizations about to get them to participate: (1) maintaining confidentiality of the information they provided, and (2) minimizing time spent by multiple respondents from the organization for interviews and for responding to the survey. A total of five organizations gave us permission to contact their Black Belts; the others cited data confidentiality and time concerns as reasons for refusing to participate. A few organizations were going through major changes in upper management or a revamping their Six Sigma programs and therefore could not participate, despite indicating interest.

4.6.2. Data collection:

After getting approval from top management (COO, CEO or Director of Continuous Improvement) of the five organizations that consented to participate, we started by conducting personal interviews with a few Master Black Belts, Black Belts and Six Sigma or Quality Initiative management executives in these companies to get agreement to participate in the research project and to gather some information about their Six Sigma deployment. These interviews were also used to refine our perceptual scales and for identifying items that we could or could not include due to confidentiality. During these interviews participating organizations took the opportunity to convey additional questions that they would like included in the research instrument. Such questions were included as part of the customization of the study for each organization.

From each of the participating organizations, we collected data on projects via surveys administered over the Internet to project-leading Black Belts. Each record in the data represents one project for which Black Belts responded retrospectively. The survey consisted of objective questions such as start and end dates of projects, team members and their designations, project leaders' Six Sigma experience-levels, and project pay-offs. Perceptual questions were used to assess constructs such as extent of use of each of the four knowledge creation mechanisms and results of projects. An Internet link was set up to collect data in a Fisher College of Business server at the Ohio State University. The link for each organization was mailed to Black Belts by a Six Sigma executive in that organization, with instructions and a time period of two weeks to respond; a reminder was sent after the two week period, extending the response-period by an additional two weeks. A sample of the email invitation sent for participation is shown in Appendix A.

Despite the targeted mailing, executive support for the data collection effort and reminder to respond, response from Black Belts was difficult in most organizations, although of the five organizations, one did have a comparatively excellent response rate of 75%. We use a statistical technique, described later, to ameliorate concerns of mono-method bias (Podsakoff and Organ, 1986). We received data on a total of 92 projects.

4.6.3 Scales for knowledge creation mechanisms:

Researchers have constructed scales to measure the use of knowledge creation mechanisms proposed by Nonaka (1994). However, there are inherent differences between knowledge creation for new product and process development, for which most of the existing scales were created (Zhang et al., 2004; Johnson and Johnston, 2004), and that for process improvement, which is the focus here. Similarly, some knowledge-creation scales were created for organization-level analyses (Johnson and Johnston, 2004; Lee and Choi, 2003) and are therefore not completely suitable for our research, which is at the project team level of analysis. Therefore, we adapted items mainly from scales constructed by Becerra-Fernandez and Sabherwal (2001) because these scales did not involve new product development and concentrated on ongoing work in sub-units at the Kennedy Space Center.

In this research the four knowledge creation scales were designed to assess the extent to which the four mechanisms – – socialization (tacit → tacit), externalization (tacit → explicit), combination (explicit → explicit) and internalization (explicit → tacit) – – are being employed in a Six Sigma project. Different practices (tools and techniques) used in these projects are aimed at creating knowledge via conversions between tacit and explicit types represented by the four mechanisms and so the items address the use of these different practices. We presented our adapted scales to nine Six Sigma practitioners (Master Black Belts, Black Belts and Consultants) to solicit their opinions about the wordings of items. We then discussed the underlying purpose of these scales and refined them following respondents' suggestions. We also presented these scales, as part of the complete questionnaire and along with definitions of knowledge creation mechanisms, to seven operations management academicians with experience in process improvement and/or project level research and incorporated their insights altering the items in the scales accordingly.

In this way a preliminary instrument for knowledge creation was developed. We subjected these scales to a modified Q-sort analysis (Moore and Benbasat, 1991; Nahm et al., 2000; Perreault and Leigh, 1989; Rust and Cooil, 1994) to confirm their face validity (Ahire and Devaraj, 2001; Flynn et al., 1994). This exercise involved presenting definitions for the four knowledge creation mechanisms along with a set of items in jumbled order. Respondents were asked to allocate each item-statement to the knowledge mechanism it referred to, according to its definition.

We conducted this exercise in two phases. The first phase was executed among twelve doctoral students from the operations management, human resource management and business strategy management at the Fisher College of Business, The Ohio State University. Following refinements in the items suggested by these doctoral students we conducted the exercise among a class of 29 second-year MBA students at the Fisher College of Business. These students were enrolled in an MBA elective class on Six Sigma and the exercise was conducted in the fifth week of a ten-week quarter, so that the students had some knowledge about Six Sigma projects.

There were four different versions of the list of items; each version listing the items in different jumbled order (see Appendix B for the definitions provided to the students and one version of the jumbled list). The results of the Q-sort are presented in Appendix C, which shows the scale items and the percentage of respondents that classified it in each of the four categories, and one additional category for “unsure.” As indicated in the table in Appendix C, for 13 of the 18 items, 71% or more of the respondents correctly classified the item into its matching knowledge creation mechanism category; three additional items had 63% or higher accurate classification. One item was allocated to two different categories by 46% and 33% of the respondents indicating that it was not a clear indicator for any one of the two mechanisms and was therefore dropped from the scale. In this way, we ended up with seventeen scale-items for the four knowledge creation scales. The items are measured using a five point scale for extent to which practices were used; the end-points of the scale are 'not at all' and 'to an extremely large extent'.

4.6.4. Scale for project performance:

Project performance signifies the level of success attained from the execution of a Six Sigma project. Any scale for assessing project performance should cover the multiple facets of project-level success (Griffin and Page, 1996). We used a five-item scale to measure Six Sigma project performance. The first item in the scale measures the extent to which the improvement goals of the project were achieved (Mukherjee et al., 1998). A Six Sigma project may result in a yield-increase, cost-reduction, cycle-time-reduction, or sales-increase, or more than one of these. These results are achieved through improvements made to the process. Thus, the second item in our project performance scale measures the extent to which the process improved as a result of the project. During discussions with Six Sigma practitioners the importance of two dimensions relating project results to organizational benefits emerged: (1) immediate benefits incurred and (2) long term benefits expected as a result of the project. The third and fourth items of the scale reflect these dimensions. Because the Six Sigma methodology emphasizes the establishment of causal relationships, the fifth item in our scale measures the extent to which cause-effect relationships were established through the execution of the project (Mukherjee et al., 1998). The complete five-point scale with different scale-point labels is shown in Table 4.7.

4.6.5. Scales for contextual and control variables:

Our third and fourth hypotheses posit that the effects of knowledge creation mechanisms on Six Sigma project performance are contingent upon the context of projects. The two contextual elements included in these contingency hypotheses are: (1) the extent to which the process was standardized before the improvement project was executed and (2) the extent to which other processes related to the focal process of the project were studied during the execution of the project. These contextual elements are measured as single-item variables on five-point scales ranging from 'not at all' to 'an extremely large extent'. We refer to these two contextual elements as 'standardized process' and 'related processes' in short.

We also collected objective information on the number of people on the project-team and the years of Six Sigma experience of the Black Belt at the start of the project. These metrics are used to control for confounding effects in the relationships between knowledge creation mechanisms and Six Sigma project performance (de Jong et al., 2005).

4.7. Analyses and results

4.7.1. Scale reliability and construct validity:

Scale-items measuring the use of knowledge creation mechanisms in Six Sigma projects were derived from previous knowledge management literature. This provided content validity for the knowledge creation scales. Q-sort analysis used to test the relatedness of scale-items to knowledge creation mechanisms provided further support for the content validity of these scales. The Six Sigma project performance scale was based on project management literature and insights from Six Sigma practitioners. In this way the content validity of all five multi-item scales was established.

As data on knowledge creation and Six Sigma project performance were collected from a single respondent per project, we conducted a Harman's one-factor test to detect the presence of mono-method bias (Podsakoff and Organ, 1986). Using SPSS 11.0 to conduct an exploratory factor analysis without specifying the number of factors, the resulting un-rotated solution had six factors with eigen-values greater than one and highest item loadings on four different factors. This result provides credence to the belief that the variance in the scale-items exists because of reasons other than mono-method bias.

For the four knowledge creation scales we conducted statistical analyses and made adjustments to ensure the convergence of within-scale items as one scale and the divergence of each scale from the other three scales (Ahire and Devaraj, 2001; Flynn et al., 1999). While such adjustments were made based on our sample and using statistical tests, we remained conscious of the completeness and parsimony of the underlying theoretical construct being measured by each scale. Cronbach's alpha reliability coefficients (Nunally and Bernstein, 1994) were computed and single-scale principal components analyses (PCA) were conducted using SPSS 14.0, and confirmatory factor analysis (CFA) was conducted using the RAMONA model in SYSTAT 11.0. Because missing values can result in model misspecification of the CFA and because list-wise deletions would have resulted in a substantial reduction in the sample size, we imputed 72 values using regression (Little and Rubin, 1987). These imputed values represent less than 3% of the total values in the dataset.

Following commonly used guidelines of 0.70 for Cronbach's alpha scores and 0.50 for factor loadings (Hair et al., 1998), we eliminated one item from each of the four knowledge creation scales (SOC1, EXT3, COM1 and INT1). Thus the total number of items used to measure knowledge creation reduced from 17 to 13. After this modification, all four knowledge creation scales have Cronbach's alpha coefficients that exceed 0.70. (Table 4.8).

A CFA model for the 13 items loading on four correlated scales is fitted (Figure 4.5). The fit of the model is assessed using multiple fit measures as advocated (Hair et al., 1998); fit statistics for our model are shown in Table 4.9. The Chi-squared adjusted for degrees of freedom is between 1 and 2 (Hair et al., 1998) and the root mean square error of approximation (RMSEA) is 0.04, indicating close fit (MacCallum et al., 1996). We reran the model using LISREL 8.4 (Joreskog & Sorbom, 2004) to confirm the results and to get additional fit statistics – the NFI, NNFI, GFI and CFI are at or above the recommended cutoff of 0.90; the AGFI is short but close at 0.84. The path loadings shown in Table 4.10 are all statistically significant at $p \leq 0.01$ and are above the recommended cutoff of 0.50 except for EXT4 which is at 0.47. In addition to the CFA, we also conducted within scale principal component analyses (PCA) for each of the scales – all four PCAs resulted in factor loadings greater than 0.71 on single factors, substantially greater than the recommended cutoff of 0.40 (Hair et al., 1998).

The performance scale is made up of five items. It has a Cronbach's alpha coefficient of 0.68, slightly below the recommended cutoff of 0.70. It loaded on a single factor when its five items were subjected to a PCA; the smallest factor loading is 0.62.

For subsequent analyses, the score on each of the five multi-item scales for knowledge creation and performance was computed as the average score of items constituting that scale. The means and standard deviations of these five multi-item scales are presented in Table 4.8 and the correlations among these scales are shown in Table 4.11. Three of the knowledge creation constructs are significantly correlated with performance, externalization has a non-significant correlation of 9% with project performance. All four knowledge creation constructs are significantly correlated with each other with measures ranging from 23% to 57%.

4.7.2. <u>Regression estimation and results:</u>

Prior to estimating multiple regression equations to test our hypotheses we assessed the kurtosis and skewness of the six independent variables – two control variable and four knowledge creation variables, and one dependent variable – Six Sigma project performance. Two variables - team size and Black Belt experience - had significantly high kurtosis (5.15 and 10.90) and skweness (3.29 and 1.85); we therefore used log transformations for both variables in subsequent regression analyses. The absolute value of skewness and kurtosis for all other variables is less than 0.60 and 0.72 respectively.

4.7.2.1 <u>Hypotheses 1 and 2:</u> We proposed that the four knowledge creation mechanisms would have a direct and positive impact on Six Sigma project performance, as outlined in hypotheses 1 and 2. For the first hypothesis to be supported, all four knowledge creation mechanisms must explain significant variance in Six Sigma project performance. The second hypothesis would be supported if there is significant incremental variance in Six Sigma project performance being explained by socialization (tacit→tacit) and externalization (tacit→explicit) i.e. knowledge creation mechanisms utilizing tacit knowledge, after accounting for variance explained by combination (explicit→explicit) and internalization (explicit→tacit) i.e. mechanisms utilizing explicit knowledge.

The first two hypotheses are tested through a common hierarchical regression analysis (Cohen et al., 2003) by entering two knowledge creation variables, one pair at a time, in two steps – (1) combination (explicit→explicit) and internalization (explicit→tacit), followed by (2) socialization (tacit→tacit) and externalization (tacit→explicit). These two steps are referred to as steps 2 and 3 in Table 4.12. Variation inflation factor (VIF) scores are computed for all coefficients to assess multicollinerity; scores ≥5 are considered unacceptable (Hair et al., 1998).

The R^2 and the F statistic for the complete regression model in the third step and the coefficients for the independent variables are the metrics of interest to test the first hypothesis. The change in R^2 and the F statistic for the change between step 2 and 3 provide tests for the second hypothesis. Table 4.12 shows the results obtained from the hierarchical regression analysis. Predictors entered into the regression equation in the first step – controls for team size and Black Belt experience – do not explain a significant amount of variance in the dependent variable – Six Sigma project performance (b = 0.06, *ns*, and b = - 0.12, *ns* for log-team size and log-BB experience respectively). The addition of the two knowledge creation variables in the second step results in a significant amount of additional variance explained (change in $R^2 = 0.18$, F for the step = 9.31, $p \leq .001$). The F statistic for the equation is significant and the R^2 value is 20% indicating variance in the dependent variable explained by the four independent variables (Table 4.12: column 2, F = 5.18, $p \leq 0.01$). Of the two independent variables of interest, internalization (explicit→tacit) is positively and significantly associated with Six Sigma project performance (b = 0.29, $p \leq 0.05$) while combination (explicit→ explicit) is not, although its effect is in the right direction (b = 0.20, p = 0.11).

In the third step of the equation (Table 4.12: column 3), the addition of socialization (tacit→tacit) and externalization (tacit→explicit) as independent variables results in significant additional variance explained in Six Sigma project performance (change in $R^2 = 0.04$, F for the step = 2.39, $p \leq .10$). One of the knowledge creation mechanism variables added in the third step has a significant coefficient (socialization: b = 0.23, $p \leq 0.05$), while the other does not have a significant impact (externalization: b = - 0.16, *ns*) and the effect is in the opposite direction. The coefficients for combination and internalization do not change substantially between the second and the third steps. The overall R^2 is 24% (F = 4.40, $p \leq 0.01$) and adjusted for number of parameters estimated, is 19%. The highest VIF score among the six predictors is 1.75, substantially lower than the recommended cutoff of 5, indicating that multicollinearity is not a problem.

Thus, from the results shown in column 3 of Table 4.12, hypothesis one is partially supported. A significant amount of variance in Six Sigma project performance is explained by the four knowledge creation variables and higher values of socialization and internalization are associated with higher project performance. Hypothesis two, regarding the incremental effect of tacit knowledge utilizing knowledge creation mechanisms – socialization (tacit→tacit) and externalization (tacit→explicit) – is also partially supported with significant amount of incremental variance explained by the addition of the two variables to the regression equation. The coefficient for socialization (tacit→tacit) is significant as expected; however, the coefficient for internalization (tacit→explicit) is not significant and has a negative sign.

4.7.2.2 Hypotheses 3 and 4: Our third and fourth hypotheses propose that the impact of knowledge creation mechanisms on Six Sigma project performance is contingent upon the levels of contextual variables. In order to test these hypotheses of 'fit as moderation' (Venkatraman, 1989) we needed to compute multiplicative interaction terms of the 'causal' knowledge creation variables and the 'moderator' contextual variables. Computing such interaction terms we estimated two different regressions equations, one for each contextual variable – standardized process and related processes.

Before computing multiplicative interaction terms the scores for knowledge creation and the two contextual variables were centered by subtracting the means to ameliorate multicollinearity (Aiken and West, 1991; Irwin and McClelland, 2001). The resulting deviation scores were then used as independent variables to assess the main effects of the four knowledge creation mechanisms as well as to compute the multiplicative interaction terms. For testing hypothesis three, two multiplicative interaction terms were computed as cross-products of (1) standardized process * combination (explicit→explicit) and (2) standardized process * internalization (explicit→tacit). Similarly, for hypothesis four, scores for (1) related processes * socialization (tacit→tacit) and (2) related processes and externalization (tacit→explicit) were computed.

Table 4.13 shows the results of the two hierarchical regression equations estimated for assessing the effects of the two sets of interactions. In each of the two equations the addition of the interaction terms as predictors in the third step does not result in a significant amount of incremental variance being explained (Table 4.13, Column 3, F for the step = 0.98, *ns*; Column 6, F for the step = 0.28, *ns*). Thus, our third and fourth hypotheses regarding moderating effects of standardized process and related processes are not supported.

4.8. Discussion

4.8.1. Implications:

While our first two hypotheses deal with universal effects of knowledge creation mechanisms on Six Sigma project performance, our third and fourth hypotheses address contingency effects of the existing nature of the process at the start of the project and the cross-process scope of the project. Regression analyses partially support our first two universal-effects hypotheses, while the two contingency hypotheses are not supported.

4.8.1.1. Hypotheses 1 and 2:

Our first hypothesis states that all four types of conversions between tacit and explicit types of knowledge are important for the success of Six Sigma projects. The first regression model with all four knowledge creation mechanisms entered as predictors indicates that socialization (tacit→tacit knowledge conversion) and internalization (explicit→tacit knowledge conversion) significantly explain Six Sigma project success. This result implies that for organizations using Six Sigma projects to engineer process improvements, it is not sufficient to rely solely on practices that codify knowledge, i.e. create explicit knowledge - softer practices that personalize the knowledge by making it tacit are critical. This result is in line with assertions made by McMahon et al. (2004) using the personalization-codification dichotomy (first proposed by Hansen et al., 1999) that organizations must not neglect the creation of tacit knowledge.

The effect of combination (explicit→ explicit) on Six Sigma project performance is not statistically significant at the conventional levels. However, we must be cautious about interpreting this as the lack of importance of the explicit knowledge converting mechanism. The results may be an indication that practices under this mechanism are not as critical within the domain of a Six Sigma project. Perhaps practices for creating explicit knowledge from explicit sources of knowledge (combination: explicit→ explicit) are executed continually outside the scope of discrete Six Sigma projects. The generation and use of real time explicit information from high-technology sources such as computers and automated gauges may result in less importance being placed on such explicit-knowledge creating activities within the execution of a project. These combination (explicit→ explicit) activities may be taking place on a routine basis within the administration of processes. The lack of significant effect of practices for the conversion of tacit knowledge to explicit knowledge, covered under the externalization (tacit→explicit) mechanism also affects our interpretation of hypothesis 2 and is discussed in the following paragraphs.

Our second hypothesis focuses on the incremental effect of socialization (tacit→tacit) and externalization (tacit→explicit) practices – both utilizing tacit knowledge – to Six Sigma project performance. Although the effect of externalization on Six Sigma project performance was not found to be significant, adding the two variables did explain a significant amount of variance in project success. Nonaka et al.'s (1994) assertion that capturing tacit knowledge is critical is, therefore, supported.

The coefficient for externalization (tacit→explicit) in the regression was non-significant and had a negative sign. Given that externalization was the only one of the four mechanisms to have a non-significant bivariate correlation ($r = 0.09$) with performance, we speculate that the negative non-significant coefficient may have occurred for two reasons based on our conversations with Master Black Belts and continuous improvement executives. First, Six Sigma Black Belts are under time pressure to complete their projects – the number of projects that they have to complete ranges from six to eight per year. As a result, they tend to cut short steps that do not have a direct impact on their current project. The codification of findings is one such activity, that Master Black Belts and continuous improvement executives observed, gets compromised. The fact that organizations have to put in place checks that relate entering of project results in the database to crediting the Black Belt with project completion are proof of the occurrence of such laxity.

Second, to the extent that Black Belts do make the effort to codify changes made as a result of project-findings, these codifications have the potential of providing long term benefits to the targeted process. The codified findings may also benefit other processes, which is one of the reasons for such codification in the first place. Such possible benefits are not captured by the performance measure we use. Moreover, our analysis is not designed to capture organizational performance-benefits from projects. Thus, a more comprehensive measure of performance, including lagged performance metrics and effects on other processes organization-wide may capture the benefits of externalization (tacit→explicit) practices.

4.8.1.2. Hypotheses 3 and 4:

The contingency view of knowledge creation through Six Sigma projects was not supported for the two contextual variables we included in our analyses. We failed to find support for our assertion that for processes with higher degrees of standardization, explicit knowledge utilizing practices – combination (explicit→explicit) and internalization (explicit→tacit) – have a greater effect on Six Sigma project performance. Similarly, we did not find significant moderation effects for the extent to which related processes were being studied in the projects on the socialization (tacit→tacit)-project performance and externalization (tacit→explicit)-project performance relationships.

The organizations in our sample have deployed the Six Sigma program over the past five years. The vast majority of projects that they have completed started with non-standardized processes; 71% of the responses for the project standardization question scored the item on 1 and 2 – lower numbers indicating lesser degree of standardization. Perhaps a higher proportion of projects with higher degrees of standardization would have resulted in the occurrence of the interaction. In the current sample the mechanisms using explicit knowledge are significantly important for *all* the projects as indicated by the significant coefficient for internalization (explicit→tacit) and the nearly significant coefficient for combination (explicit→explicit) in Table 4.12.

The absence of the second set of interaction effects of related processes with socialization (tacit→tacit) and externalization (tacit→explicit) is perhaps a manifestation of the dominating effects of organization level infrastructure practices of Six Sigma programs. Such infrastructure practices may obviate the need for any special and extra efforts toward socialization (tacit→tacit) and externalization (tacit→explicit) in the execution of multi-process projects beyond the levels of such practices needed in all types of projects. For example, the general work atmosphere in the organization may encourage employees to have informal discussions with each other across processes and functions. Thus incremental effort for socialization (tacit→tacit) and externalization (tacit→explicit) over and above the level of these practices ordinarily employed in project-executions may not be necessary even if the projects cover several related processes.

4.8.2. Limitations:

The results of our analyses must be viewed in the context of some inherent limitations of the study. First, the relatively modest small sample size is a concern both for the number of paths being estimated in the confirmatory factor analysis and for the estimation of the regression equations. Second, the use of a single respondent for scales measuring practices used in projects and project performance is far from ideal. Third, the single item measures for the contextual variables raise questions of validity of the measure. Fourth, the differences in the infrastructure practices of the five organizations included in the sample are not accounted for in assessing project performance.

4.8.3. Conclusion:

Our study shows that process improvement through Six Sigma projects involves the creation of knowledge. Thus, the underlying basis for practices employed in Six Sigma projects is knowledge creation through the transformation of knowledge from tacit to explicit and vice versa and through the transfer of both types of knowledge from individuals to teams. Particularly, the transfer of tacit knowledge from individuals to teams through socialization (tacit→tacit) practices in Six Sigma projects increases their performance level significantly. Thus, it is important for Black Belts as project leaders to include social interactions among project-team members and people related to the process as part of project executions.

Further, Black Belts must not only be trained in sophisticated analytical techniques, they should also gain expertise in practices for generating ideas and encouraging their sharing among team members. Techniques such as brainstorming sessions and nominal group technique must not be overlooked. Six Sigma project success is also significantly explained by practices for conversion of explicit knowledge to tacit knowledge (internalization) pointing to the criticality of training of employees for transfer of knowledge gained from project execution to routine process implementation. Thus, our research shows that creation of tacit knowledge, which is the determinant of success levels of innovation in organizations (Cavusgil et al., 2003), is also an important factor for the success levels of improvements in existing processes.

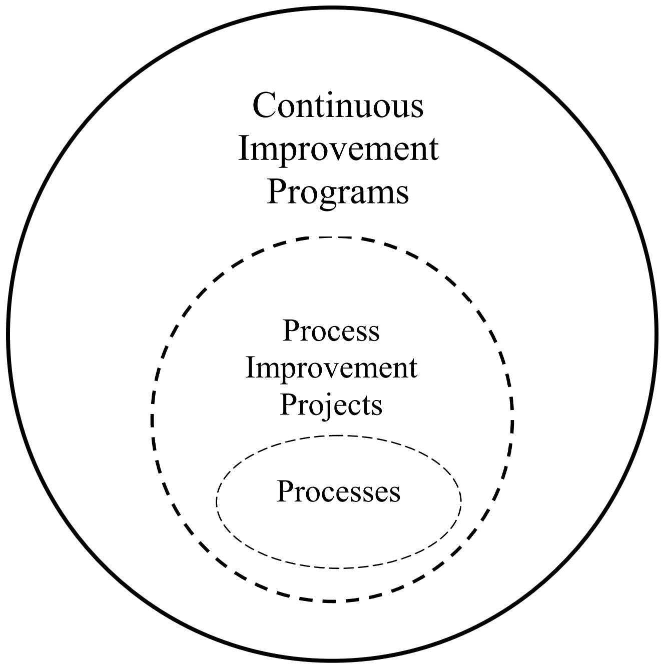

Figure 4.1
Continuous improvement programs executed through process improvement projects

	To Tacit Knowledge	To Explicit Knowledge
From Tacit Knowledge	Socialization Tacit→Tacit	Externalization Tacit→Explicit
From Explicit Knowledge	Internalization Explicit→Tacit	Combination Explicit→Explicit

Figure 4.2
Nonaka’s (1994) framework of knowledge creation mechanisms

	To Tacit Knowledge	To Explicit Knowledge
From Tacit Knowledge	**Socialization** • Brainstorming • Nominal group technique • Five why analysis • Discovery phase for surveys	**Externalization** • Work breakdown structure • Fishbone diagram • Value stream map • Failure modes & effect analysis
From Explicit Knowledge	**Internalization** • Error proofing • Control charts in the control phase • Training for frontline operators • Job rotation	**Combination** • Design of Experiments • Multiple regression • Simulation • Quality function deployment (QFD)

Figure 4.3
Six Sigma practices classified by knowledge creation mechanisms

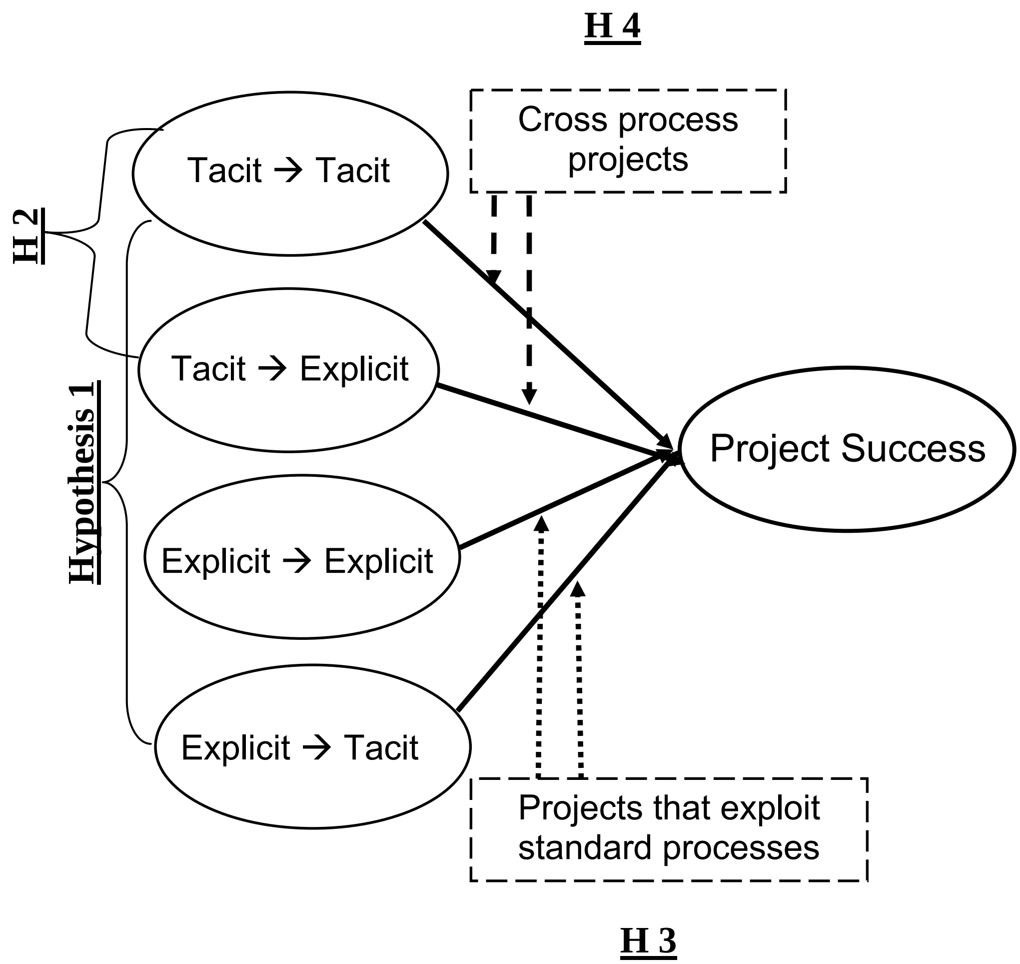

Figure 4.4
Proposed conceptual model and hypotheses

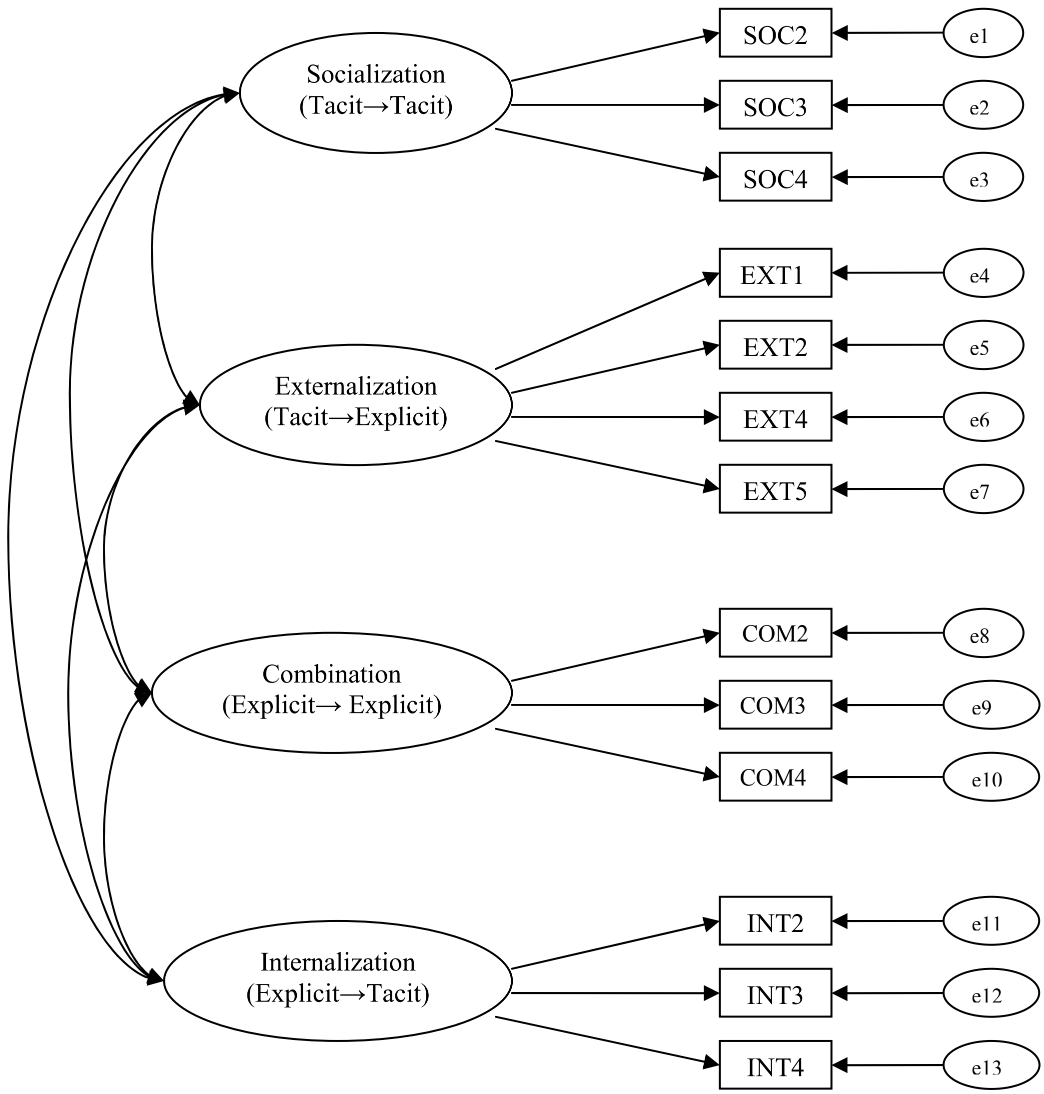

Figure 4.5
Model for Confirmatory Factor Analysis with 13 scale-items and four factors

DEFINE	• Determine requirements of the process customer • Decide the project scope and project goals • Plan project deliverables and schedule for DMAIC stages • Form the project team • Prepare a project charter
MEASURE	• Study the process and determine the relevant metrics • Assess measurement systems for validity and reliability • Design and implement new measurement systems, if needed • Determine the baseline performance on key metrics
ANALYZE	• Determine the amount of variation and waste in the process • Seek out possible underlying causes • Collect and analyze data • Determine reasons for variation
IMPROVE	• Investigate possible changes to the process • Chalk-out action plans to introduce process changes • Pilot test changes • Decide on ways to sustain process changes • Implement changes
CONTROL	• Ensure the standardization of suggested changes • Address any problems with acceptance and implementation • Verify expected results and • Document effects of changes

Table 4.1
Objectives of stages in the DMAIC project execution framework

Argyris	1977	Single and double loop learning
Brown & Duguid	1991	Unified view of working, learning and innovation connecting individual and organizational knowledge
Kim	1993	Operational and conceptual learning
Kogut & Zander	1992	Knowledge based theory of the firm; know-what and know-why
Nahapiet & Ghoshal	1998	Role of social capital in generating intellectual capital for competitive advantage - combination and exchange
Spender	1996	Individual explicit and tacit (automatic) knowledge and organizational explicit (objectified) & tacit (collective) knowledge
Zander & Kogut	1995	Characteristics of knowledge affect transfer -speed and -capability

Table 4.2
Selected research in classifications of organizational learning

Argote et al.	2003	Framework and review of knowledge management literature
Bechky	2003	Different communities of practice share knowledge on the production floor to create new knowledge
Crossan	1996	Knowledge creation perspective can be integrated with organizational learning
Crossan et al.	1999	Exploiting current practices while exploring for new ones; individual, group and organizational levels
Cyert & March	1963	Framework for knowledge management and organizational learning: Behavioral Theory of the Firm
Leonard-Barton	1992	Factory as a learning lab
Leonard-Barton et al	2005	Critical need for companies to balance cross-functional integration and functional expertise
Starbuck	1992	Knowledge has meaning only when it is related to current problems and activities
von Krogh et al.	1994	Organizational knowledge is more than that created by information processing

Table 4.3
Selected research in the process of organizational learning

Cohen & Levinthal	1990	Absorptive capacity: ability to recognize the value of new knowledge and to be able to assimilate it and use it
Gupta & Govindarajan	2000	Factors affecting inter-firm transfer - absorptive capacity, communication quality and strategic value of knowledge
Hansen	1999	In product development projects more complex knowledge warrants closer relationships
Hargadon & Sutton	1997	Intra-firm knowledge integrating mechanisms facilitates innovation
Hatch & Dyer	2004	Inimitability of human capital; acquiring people has negative effect on cost performance
Lee and Choi	2003	Knowledge creation is affected by enablers and in turn knowledge creation affects creativity
Mowery et al.	1996	Integrative mechanisms such as personal meetings help to overcome challenge of tacit knowledge transfer
Szulanski	1996	Factors affecting intra-firm transfer of knowledge - absorptive capacity, causal ambiguity & personal interactions

Table 4.4
Selected research in factors supporting knowledge creation

Alavi & Leidner	2001	Role of information technology for knowledge creation mechanisms
Bloodgood & Morrow	2003	Different levels of tacit and explicit knowledge needed for different types of strategic change
Davenport & Prusak	1998	Working knowledge: How organizations manage what they know
Dhanaraj et al .	2004	Tacit and explicit knowledge transfer differently between international joint venture partners
Dyck et al.	2005	Knowledge creation mechanisms in the redesign and steady production stages of automobile manufacture
Nonaka & Takeuchi	1996	Success of Japanese companies in innovations is based on their inclusion of tacit knowledge

Table 4.5
Selected research on tacit knowledge and knowledge creation mechanisms

Bellows	2004	Six Sigma and Deming's system of profound knowledge
Graham	1995	Total Quality Management Program is a vehicle for organizational learning
Linderman et al.	2004	Integrating knowledge creation processes with principles and practices of Total Quality Management
McAdam & Leonard	2001	Synergies between knowledge management and quality programs
Mukherjee et al.	1998	Conceptual and operational learning predict performance in Total Quality Management projects
Shiba & Walden	2001	Customer focus, continuous improvement and total participation enable creation of organizational capabilities
Sitkin et al.	1994	Control and learning in Total Quality Management
Sterman et al.	1997	Absence of a holistic view leads to failure in creating learning through Total Quality Management

Table 4.6
Selected research relating process improvement and knowledge

To what extent were the stated goals of the project achieved?				
Goal not achieved	**Goal achieved to some extent**	**Goal achieved to a moderate extent**	**Goal achieved to a large extent**	**Goal fully achieved**
In comparison to performance before the execution of the project, how much process improvement was realized due to the execution of the project?				
No improvement	**Slight improvement**	**Moderate improvement**	**A lot of improvement**	**Great deal of improvement**
Did/Will this project provide immediate benefits?				
Definitely no	**Probably no**	**Maybe**	**Probably yes**	**Definitely yes**
Did/Will this project provide long term benefits?				
Definitely no	**Probably no**	**Maybe**	**Probably yes**	**Definitely yes**
How successfully did the project results point to specific cause-effect relationships?				
Not at all	**Somewhat**	**Moderately**	**Largely**	**Completely**

Table 4.7
Project performance scale items

Scales:	Social	External	Combin	Intern	Perform
Number of Items	3	4	3	3	5
Cronbach's alpha coefficient	0.73	0.70	0.71	0.76	0.68
Eigenvalue Single scale PCA)	1.95	2.11	1.89	2.03	2.21
Variance extracted (%)	64.93	52.81	63.11	67.63	44.15
Mean	3.91	3.07	3.71	3.33	4.09
Standard Deviation	0.77	0.89	0.94	1.02	0.58

Table 4.8
Scale diagnostics and descriptive statistics

Measures	Scores	Recommended
Chi-squared (df)	69.29 (59)	
Chi-squared / df	1.17	Between 1 & 2
Root Mean Squared Error of Approximation (RMSEA)	0.04	Less than 0.10
Confidence Interval	(0.00, 0.08)	
Normed Fit Index (NFI)	0.90	≥ 0.90
NNFI	0.97	≥ 0.90
GFI	0.90	≥ 0.90
AGFI	0.84	≥ 0.90
CFI	0.98	≥ 0.90

Table 4.9
Fit statistics for Confirmatory Factor Analysis

	Loadings	Std. error	t statistic
Socialization			
SOC2	0.57	0.09	6.43
SOC3	0.82	0.07	11.41
SOC4	0.68	0.08	8.59
Externalization			
EXT1	0.54	0.09	5.74
EXT2	0.63	0.08	7.52
EXT4	0.47	0.10	4.73
EXT5	0.73	0.08	9.67
Combination			
COM2	0.58	0.09	6.61
COM3	0.71	0.07	9.70
COM4	0.72	0.07	10.14
Internalization			
INT2	0.69	0.07	10.27
INT3	0.54	0.08	6.61
INT4	0.96	0.05	18.54

Table 4.10
Factor loadings of 13 items on four knowledge creation scales

	Social	External	Combin	Intern	Perform
Socialization	1				
Externalization	0.45****	1			
Combination	0.31****	0.43****	1		
Internalization	0.23**	0.27***	0.57****	1	
Project Performance	0.26***	0.09	0.35****	0.38****	1

n=90, ****Significant at p≤0.001***Significant at p≤0.01,
**Significant at p≤0.05, *Significant at p≤0.10

Table 4.11
Inter-scale correlations – knowledge creation and Six Sigma project performance

DV: Six Sigma Project Performance			
Control Variables:	Step 1	Step 2	Step 3
Log (Team Size)	0.06	-0.01	-0.02
Log (BB Six Sigma Experience)	-0.12	-0.17*	-0.19**
Knowledge Creation			
using explicit knowledge:			
Combination (Explicit→Explicit)		0.20	0.21
Internalization (Explicit→Tacit)		0.29**	0.28**
using tacit knowledge:			
Socialization (Tacit→Tacit)			0.23**
Externalization (Tacit→Explicit)			-0.16
F for the step	0.87	9.31****	2.39*
F for the regression	0.87	5.18***	4.40***
R^2	0.02	0.20	0.24
Adjusted R^2	0.00	0.16	0.19

n=90, ****Significant at p≤0.001***Significant at p≤0.01,
**Significant at p≤0.05, *Significant at p≤0.10
Regression coefficients are standardized betas

Table 4.12
Results of regression predicting Six Sigma project performance based on knowledge creation mechanisms

Moderators:	Standardized Process			Related Processes		
	Step 1	Step 2	Step 3	Step 1	Step 2	Step 3
Control Variables:						
Log (Team Size)	0.07	-0.02	-0.02	0.05	-0.02	-0.02
Log (BB Six Sigma Experience)	-0.13	-0.19*	-0.20**	-0.12	-0.20*	-0.16
Potential Moderators:						
Related Processes				0.10	0.02	0.07
Standardized Processes	-0.05	0.02	0.02			
Knowledge Creation:						
Socialization (Tacit→Tacit)		0.23**	0.24**		0.23**	0.18
Externalization (Tacit→Explicit)		-0.16	-0.16		-0.17	-0.15
Combination (Explicit→Explicit)		0.21	0.21*		0.20	0.16
Internalization (Explicit→Tacit)		0.28**	0.27**		0.28**	0.30**
Interactions:						
Socialization * Rel. Proc.						-0.18
Externalization * Rel. Proc.						0.15
Combination * Std. Proc.			0.09			
Internalization * Std. Proc.			-0.04			
F for the step	0.63	5.89****	0.28	0.89	5.66****	0.98
F for the regression	0.63	3.70***	2.89***	0.89	3.70***	3.09***
R^2	0.02	0.24	0.25	0.03	0.24	0.26
Adjusted R^2	-0.01	0.18	0.16	0.00	0.18	0.18

n=90, ****Significant at p≤0.001***Significant at p≤0.01, **Significant at p≤0.05, *Significant at p≤0.10
Regression coefficients are standardized betas

Table 4.13
Regressions for assessing interaction effects of two moderators: (1) related and (2) standardized processes

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APPENDIX A

E MAIL FROM SIX SIGMA / CONTINUOUS IMPROVEMENT EXECUTIVE INVITING BLACK BELTS TO PARTICIPATE IN STUDY

This survey is being administered to collect information on Six Sigma projects. It is part of research being conducted at The Ohio State University to examine the execution of Six Sigma projects. Clicking on the following URL link, or pasting it into your browser, will take you to the survey: ______________________________

The questions in this survey ask information about a project that you have guided, including the objective of the project, the tools and techniques used, and performance metrics. Please answer the survey with reference to one single project that is complete or is currently in the control stage. If you have guided more than one project that is currently complete or in the control stage, please complete one survey for each such project.

Completing one survey will take approximately 15 minutes of your time. Please refer to any project-related documents necessary to help you answer the questions, and answer all questions. You can use the back button on your browser if you would like to go back to earlier responses. Your answers will be recorded only when you click on the "Submit" button at the end of the survey.

Participation in this survey is voluntary. The information you provide will be completely confidential and will only be reported as group data. If you have any questions regarding this survey, please contact Gopesh Anand at (614) XXX-XXXX (Cell) or (614) XXX-XXXX (Office), email anand.3@osu.edu Thank you for your participation in this project.

APPENDIX B

DESCRIPTION OF KNOWLEDGE CREATION CONSTRUCTS AND LIST OF SCALE-ITEMS FOR CATEGORIZING AMONG KNOWLEDGE CREATION CONSTRUCTS

Following are descriptions of four concepts. On the basis of these descriptions, please classify the practices that are listed on the following page into these four concepts. Thank you for your participation.

Background definitions for types of knowledge:

Tacit knowledge: Cannot be documented easily and is therefore transferred only through social interactions.

Explicit knowledge: Can be expressed in words and diagrams easily.

Knowledge conversion concepts:
Collections of practices that convert one type of knowledge to the same type, or to another type of knowledge

Concept	Knowledge conversion	Descriptions and examples:
Socialization **SOC**	**Tacit →** **Tacit**	**Combine** knowledge that **cannot** be written, or represented in pictures and diagrams. Both Inputs and Outputs from these practices cannot be expressed in any documents, so they have to happen through social interaction. **Example:** Informal conversations or discussions among employees.
Externalization **EXT**	**Tacit →** **Explicit**	**Convert** unwritten/un-coded knowledge **into** written descriptions, objective numbers, or pictures and diagrams. The un-expressible knowledge Input is converted to communicable forms of Output. **Example:** Drawing a process map.
Combination **COM**	**Explicit →** **Explicit**	**Combine** explicit knowledge. Codified knowledge Input is used to create new codified knowledge Output, through sorting, combining, and analyzing knowledge. **Example:** Data analysis.
Internalization **INT**	**Explicit →** **Tacit**	**Translate** explicit knowledge like job instructions to actions through observation & practice. Convert explicit knowledge into actions that cannot be described in words & diagrams. **Examples:** Learning-by-doing activities like training on the job, and observing someone.

APPENDIX B (Continued)

Instructions: Listed below are project-related activities. Please classify each activity into one of the four knowledge- concepts by writing the name of that concept in the blank column on the right
If you are uncertain about classifying any activity, please do not try to guess and enter the word "unsure."

Activity	Concept
Recording improvement ideas in a database	
Interaction between team members	
Feedback from implementation of results	
Preparing a business case document for the project objective	
Systematic and formal listing of customer requirements for the process	
Systematic linkage of customer requirements to process characteristics	
Numerical data analysis	
Reliance on objective data for evaluations	
Formal codification of standard operating procedures	
Involvement of the people directly working on the process	
Interaction between team members and customers of the process	
Interactions between team members and suppliers of the process	
Systematic recording of project findings and results	
Visual displays at the process implementation site	
Face-to-face meetings to implement changes suggested by the project findings	
On-the-job training to implement the changes from the project	
Converting subjective customer requirements to objective requirements	
Reliance on previous project reports	

APPENDIX C

RESULTS OF CATEGORIZATION OF KNOWLEDGE CREATION SCALE-ITEMS AMONG CONSTRUCTS

Scale Validity Assessment Results:

Results :Bolded percentages for matched categories

No.	**Knowledge Management Constructs:**	**1 Soc**	**2 Ext**	**3 Com**	**4 Int**	**9 Unsure**
1	Discussions among people working directly on the process	**0.83**	0.04	0.04	0.08	0.00
2	Discussions among members of the project team	**0.96**	0.00	0.04	0.00	0.00
3	Discussions among team members and customers of the process	**0.96**	0.00	0.00	0.04	0.00
4	Discussions among team members and suppliers of the process	**0.92**	0.08	0.00	0.00	0.00
5	Formalizing implied project objectives by preparing business case document	0.00	**0.75**	0.21	0.04	0.00
6	Formally and systematically listing implied customer requirements	0.04	**0.92**	0.04	0.00	0.00
7	Linking tacit customer requirements to specified process characteristics	0.04	**0.71**	0.21	0.04	0.00
8	Recording improvement ideas in a database	0.04	**0.63**	0.25	0.08	0.00
9	Converting subjective customer requirements to objective requirements	0.00	**0.75**	0.25	0.00	0.00
10	Using formal reports from past projects for analyses in current project	0.00	0.00	**0.83**	0.17	0.00
11	Numerical data analysis	0.00	0.00	**0.96**	0.00	0.04
12	***Relying on objective data to evaluate process performance***	***0.00***	***0.17***	***0.46***	***0.33***	***0.04***
13	Formally codifying objective project results into standard operating procedures	0.00	0.17	**0.67**	0.13	0.04
14	Systematically recording objective findings and results for future reference	0.00	0.33	**0.67**	0.00	0.00
15	Using diagrams and models to initiate discussions during the project	0.08	0.21	0.08	**0.63**	0.00
16	Using codified reports to initiate discussions about project performance	0.08	0.00	0.21	**0.71**	0.00
17	Implementing documented changes using on-the-job training	0.00	0.17	0.08	**0.71**	0.04
18	Using codified reports to generate discussions after implementation of results	0.08	0.04	0.08	**0.71**	0.08

(n = 29) Italicized statements are candidates for deletion for the large scale survey.