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Structural equation modelling on knowledge creation in Six Sigma DMAIC project and its impact on organizational performance

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ABSTRACT

Six Sigma is a business strategy that helps organizations to improve organizational efficiencies and customer satisfaction; it decreases operating costs and increases profits. Numerous practitioner studies claim that Six Sigma improves organizational performance. However, empirical research in this area is limited. No detailed investigation exists on how Six Sigma leads to improvement of organizational performance. This study suggests that the link between Six Sigma and organizational performance can be explained and developed by integrating organizational knowledge creation processes. A theoretical research model is developed based on the literature. This study investigates the existence of a relationship among organizational knowledge creation processes (socialization, externalization, combination, and internalization) in Six Sigma DMAIC project, knowledge, Six Sigma project success, and organizational performance by using structural equation modeling. The survey study results show general support for the theoretical research model. Findings reveal that organizational knowledge creation processes positively affect knowledge. In turn, knowledge positively affects Six Sigma project success, and Six Sigma project success leads to improved organizational performance.

1. Introduction

The Six Sigma concept was developed by Motorola in the 1980s and boosted by the efforts of General Electric (GE), AlliedSignal, and others in the late 1990s (Braunscheidel et al., 2011). Today, Six Sigma is one of the primary quality initiatives that have been billed as a critical business tool in the 21st century (Pepper and Spedding, 2010; Mader, 2008). Six Sigma not only helps industries improve organizational efficiencies and customer satisfaction, but also reduces operating costs and increases profits (Laureani et al., 2013; Harry et al., 2010; Ho and Chuang, 2006; Gowen and Tallon, 2005; Mahanti and Antony, 2005; McAdam and Lafferty, 2004).

Success stories of large corporations that have adopted Six Sigma, such as Motorola, GE, and AlliedSignal/Honeywell, have been reported in various papers, which claim that Six Sigma implementation results in high financial savings (Gijo et al., 2011; Hendricks and Kelbaugh, 1998). For instance, in the decade between Six Sigma's beginning in 1987 and 1997, the achievements of Motorola included a fivefold growth in sales, with profits climbing nearly 20%, cumulative savings based on Six Sigma pegged at $14 billion, and Motorola stock price gains compounded to an annual rate of 21.3% (Pande et al., 2000). In 1997, GE invested $400 million in Six Sigma, which resulted in reported savings of $700 million (Pande and Holpp, 2002). In 1999, GE spent $700 million and saved over $2 billion (Watson, 2003). AlliedSignal reduced costs by $1.4 billion from 1992 through 1997 (Brue and Howes, 2006). Considering these reports, the academia doubts whether such claim savings are truly attributed to Six Sigma. Sousa and Voss (2002) highlighted the necessity for empirical justification of assertions of all types in quality management literature.

Many Six Sigma publications, such as articles and books, are available. Current concepts in the field of Six Sigma are largely descriptive and based upon the prescription of leading "gurus" who worked in major companies, such as GE, Motorola, and Honeywell, that use Six Sigma (Zu et al., 2008). For example, Pyzdek and Keller's (2009) *The Six Sigma Handbook* was written based on the authors' experiences in companies, such as GE and Motorola, which successfully used Six Sigma. The book provides details about Six Sigma concepts, methodology, tools and techniques, and implementation strategy. Kubiak and Benbow's (2009) *The Certified Six Sigma Black Belt Handbook* and Breyfogle et al.'s (2003) *Implementing Six Sigma* also provide similar Six Sigma

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framework. The practitioner literature primarily provides prescriptive guidelines and procedures that are necessary for Six Sigma implementation. Theory development is seldom discussed. Nonthaleerak and Hendry (2006) commented that, in general, numerous studies have focused on the descriptions of practice rather than on theory development that is useful to managers and scholars. Linderman et al. (2003) remarked that Six Sigma has significantly influenced the industry, but the theory about Six Sigma is lacking. Antony (2004a, 2004b) agreed and noted that despite the significant influence of Six Sigma on the industry, the academic community lags behind in understanding Six Sigma. Schroeder et al. (2008) further argued that systematic and rigorous research is necessary to determine the effect of Six Sigma on organizational performance.

In Malaysia, empirical studies that investigate even the mere existence of Six Sigma initiatives in the country are lacking. With the exception of Jayaraman et al. (2012) study, no other study empirically investigates the extent of the existence of Six Sigma initiatives in the general Southeast Asian region. However, Jayaraman et al. (2012) study only investigated the Lean Six Sigma initiatives based on the perceptions of the practitioners. A few empirical studies also investigated the relationship between Six Sigma and organizational performance, but the results are mixed. The majority of the studies found that Six Sigma has positive effects on organizational performance (Lee, 2002; Flora, 2003; Zu et al., 2008; and Ang et al., 2010). Other studies (Goh et al., 2003; Gutie´rrez et al., 2009) found no significant relationship with organizational performance. Studies that found that Six Sigma has positive effects on organizational performance focused on the direct relationship between Six Sigma and organizational performance. Meanwhile, Arumugam et al. (2013) investigated the effects of two antecedents, namely, resources and team psychological safety, on learning and knowledge creation in Six Sigma project teams that promote knowledge creation and in turn affect project performance.

However, no detailed discussion is available on the phenomenon of how Six Sigma leads to organizational performance. The link between Six Sigma and organizational performance has not been clearly explained and fully developed. A variety of components make up these links, and understanding their interaction is important. A holistic view is useful (Linderman et al., 2004). Linderman et al. (2004) commented that theory about Six Sigma is lacking and that no basis for research exists other than best practice studies. Therefore, the starting point in conducting research on Six Sigma must be the formulation and identification of useful theories that are related to the Six Sigma phenomenon.

Given this situation, the relationship between Six Sigma and organizational performance is an interesting issue. This study proposes that the knowledge-based theory of the firm and Nonaka (1994) organizational knowledge creation theory are useful approaches in explaining the phenomenon that Six Sigma leads to organizational performance. Based on the knowledge-based theory of the firm, knowledge is a strategic resource that the firm uses to develop sustained competitive capability (Davenport and Prusak, 1998; Grant, 1996; Kogut and Zander, 1996; Spender, 1996) and the firm's practices that toward the generation of knowledge can have substantial effects on organizational performance. Based on Nonaka (1994) organizational knowledge creation theory, the conversion between tacit and explicit knowledge allows knowledge to be created through socialization, externalization, combination, and internalization processes. From these two theoretical perspectives, if Six Sigma practices lead to knowledge creation, then the link between Six Sigma and firm performance can be explained. That is, Six Sigma becomes a source of knowledge creation that results in a competitive advantage that leads to improved organizational performance.

This study minimizes the gaps found in the literature by reporting an empirical investigation and understanding of the effect of socialization, externalization, combination, and internalization processes of the knowledge on the success of Six Sigma projects, which in turn leads to organizational performance. Thus, this study empirically supports the earlier research of Linderman et al. (2010) and Lloréns-Montes and Molina (2006) and extends the research conducted by Choo et al. (2007). The rest of the paper is organized as follows: Section 2 introduces Six Sigma, knowledge management, and performance and the development of theoretical models and hypotheses. Section 3 presents the research methods, including data collection and development of measures. Section 4 presents the analysis and results. Section 5 includes a discussion about theoretical and managerial implications, opportunities for future research, and limitations of the research. Section 6 provides the conclusion.

2. Literature review

2.1. Six *S*igma

Brue (2006) provided three meanings of Six Sigma depending on the context: (1) it is a level of quality (Pyzdek and Keller, 2009; Montgomery and Woodall, 2008), (2) it is a problem-solving methodology (Tjahjono et al., 2010; Antony and Banuelas, 2002), and (3) it is a management philosophy (Summers, 2010; Kwak and Anbari, 2006). *Sigma* refers to the Greek letter σ, which is used as a statistical measure of variation in a process (Omachonu and Ross, 2004). A stated sigma level is used to describe how well the process variation meets the customer's requirements (Pyzdek and Keller, 2009). Achieving a Six Sigma level (6σ) of quality means that processes are producing only 3.4 defects per million opportunities with 1.5σ allowable shift under the normal distribution, or practically it corresponds to 99.999770% yield (Raisinghani et al., 2005; Antony (2004a, 2004b))

Six Sigma is a project-driven approach to process- and product-quality improvement (Ray and Das, 2010; Gitlow et al., 2006). Projects are the means by which Six Sigma converts quality improvements into bottom-line financial benefits (Gulcin and Demet, 2010; Kubiak and Benbow, 2009). Six Sigma projects are conducted by a group of improvement specialists, typically referred to as champions, master black belts, black belts, and green belts (Gitlow, 2009; Schroeder et al., 2008; Linderman et al., 2003). They receive intensive differentiated training that is designed to improve their knowledge and skills in statistical methods, project management, process design, problem solving techniques, leadership skills, and other managerial skills (Morgan and Brenig, 2012; Gitlow, 2009; Schroeder et al., 2008; Gowen and Tallon, 2005).

Six Sigma process improvement projects are conducted by using the DMAIC methodology. The DMAIC methodology consists of five phases: Define, Measure, Analyze, Improve, and Control. These phases are designed to take a team through a step-by-step process improvement project, from inception to completion (Wheeler, 2010; Satolo et al., 2009). Kubiak and Benbow (2009) stated that the purpose of the Define phase is to determine the project focus, such as project charter and customer critical to quality. In the Measure phase, project teams collect actual data to estimate the capability of the current process in meeting customer requirement (Gijo et al., 2011; Evans and Lindsay, 2010; Omachonu and Ross, 2004). Arthur (2010) explained that in the Analyze phase, project teams identify, organize, and validate potential root causes. In the Improve phase, project teams identify a solution to the problem that the project aims to address (Keller, 2010; Kubiak and Benbow, 2009). Pyzdek and Keller (2009) stated that in the