Journal of Fundamental and Applied Sciences

ISSN 1112-9867

Available online at http://www.jfas.info

Research Article

Special Issue

THE IMPACT OF EMBEDDED TOTAL PRODUCTIVE MAINTENANCE WITH SIX SIGMA ON SUPPLY CHAIN PERFORMANCE

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Published online: 15 January 2018

ABSTRACT

The purpose of the work presented in this paper is to capture the current state of Six Sigma and Total Productive Maintenance (TPM) as well as to propose the embedded approach of Six Sigma and TPM on improving supply chain performance. The approach to this paper is to answer the questions such as "how does TPM impact the Supply Chain Management Performance?", "how does Six Sigma impact the Supply Chain Management Performance?" and "Can TPM be embedded into Six Sigma to improve Supply Chain Performance?" The relationship proposed in the framework was analyzed using Partial Least Square Structural Equation Modeling (PLS-SEM). The key findings of this paper has shown that supply chain performance can be improved by leveraging on the embed TPM with Six Sigma rather than applying each methodology separately.

Keywords: supply chain performance, Six Sigma, total productive maintenance.

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doi: http://dx.doi.org/10.4314/jfas.v10i1s.48

1. INTRODUCTION

Supply chain performance has become the proxy to measure organization performance since competitions are between the organizations' supply chains and not between the organizations.

Supply chain management is defined as the design, planning, execution, control and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand, and measuring performance globally [1]. Given the societal and economic importance of the industries globally and the burden of the issues faced by practitioners, it is surprising how little attention its supply chain has received to date, at least in comparison with manufacturing. Complexity of supply chain across the globe has impacted supply chain performance such as low service level, high cost, environmental pollution and ineffective utilization of human capital. Six Sigma is a management philosophy and a structured problem solving methodology that was started in Motorola since 1980s. It became popular in various industries after the tremendous results of Six Sigma implementation in General Electric since 2000. It uses the 5 steps problem solving methodology i.e. Define, Measure, Analyze, Improve and Control that aims to improve profitability by reducing variation in all processes. Mathematically, it can be shown that by reducing variation in the processes, the process capability can be improved i.e. Process capability = Customer’s requirement/Process variation. When process variation (measured in standard deviation) is reduced, process capability is improved and hence the process is capable of producing products or services that meet customer’s requirements. Most organization that implement Six Sigma as a program by developing their employees to different level of Six Sigma practitioners i.e. Master Black Belt, Black Belt, Green Belt, Yellow Belt and White Belt. Other organization created its own terminology such as Silver Belt and Gold Belt for its Six Sigma practitioners. The different level of belt indicates the different level of mastery in Six Sigma problem solving approach. A Black Belt is someone who has been trained to use advanced statistical methods such as design of experiment and response surface methodology to solve a complex problem that typically require 6 months and above to complete. A Yellow belt, on the other hand, use simple problem solving methods such as Pareto chart and basic graphical tools to solve a smaller and simpler problem within 1 month. An accumulation of these problem solving that occur at different belt level yield a breakthrough improvement over time in an organization and will enable an organization to be more profitable due to the reduction of the cost of poor quality (COPQ). Total Productive Maintenance (TPM) on the other hand has been used in the manufacturing industries in Japan since 1950s. It aims to improve equipment's reliability and hence improve productivity. The quality and productivity level of any manufacturing organizations that rely heavily on using equipment in their operations are directly determined by their equipment condition. This is especially the case in process industry such as Fast-Moving-Consumer-Goods (FMCG), oil and gas as well as heavy industries. In these organizations, any unplanned stoppage on its bottleneck equipment is directly impacting the production output of that product line. Bottleneck in a manufacturing process is any equipment that dictates the throughput of the entire production line. TPM consists of 8 building blocks which are known as pillars. These pillars are: Leadership Pillar (LDR), Organization Pillar (ORG), Education and Training Pillar (E&T), Autonomous Maintenance Pillar (AM), Planned Maintenance Pillar (PM), Focused Improvement Pillar (FI), Quality Maintenance Pillar (QM) and Safety, Health and Environment Pillar (SHE). Each pillar consists of a cross functional team which serve as the Centre of Excellence (CoE) to build pillar capability within the company. The following are the key objectives of each pillar in TPM.

- Leadership Pillar (LDR): Lead, provide direction and remove barriers of TPM implementation in the company.
- Organization Pillar (ORG): Create the right organization structure and culture to support the TPM implementation.
- Education and Training Pillar (E&T): Create skill matrix and training plan to support the TPM implementation.
- Autonomous Maintenance Pillar (AM): Build capability of front line production workers to be multi-skill and self-directed.
- Planned Maintenance Pillar (PM): Support the building of capability of front line production workers and develop mastery in maintenance practices.
- Focused Improvement Pillar (FI): Identify and manage organization wide loss management system. Build zero loss mindset in employees and provide tools to eliminate losses.
- Quality Maintenance Pillar (QM): Build zero defect system in the company.
- Safety, Health and Environment Pillar (SHE): Build SHE system in the company.

This study conceptualizes and tests the relationships between supply chain performance with Six Sigma and Total Productive Maintenance. Data from this study were collected from 200 Six Sigma and Total Productive Maintenance practitioners. The relationship proposed in the framework was analyzed using Partial Least Square Structural Equation Modeling (PLS-SEM). The result indicates that higher level of embedded Total Productive Maintenance with Six Sigma improve supply chain performance. Also, Six Sigma and Total Productive Maintenance were closely related.

2. METHODOLOGY

2.1. Research Framework

Fig. 1 depicts the research framework developed in this research. The framework proposes that supply chain performance is directly impacted that by each Six Sigma and Total Productive Maintenance as well as the combination of Six Sigma and Total Productive Maintenance with TPM as mediating variable.

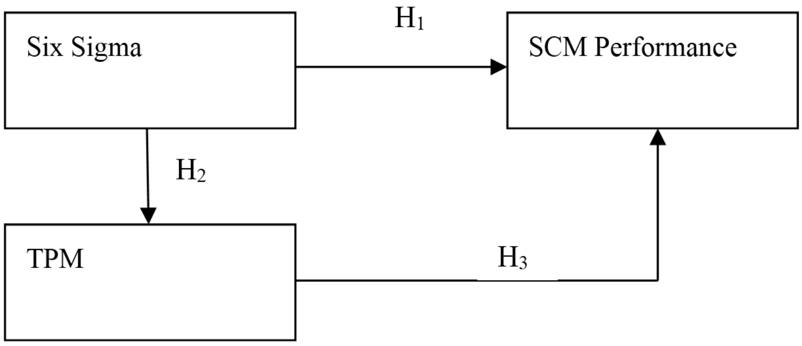

Fig.1. Research framework of Six Sigma, TPM and SCM performance

Supply Chain Performance is the dependent variable in this research. It refers to price/cost, quality, delivery dependability, product innovation and time to market [1, 10-11, 18]. The short-term objectives of SCM are primarily to increase productivity and reduce inventory and cycle time, while long-term objectives are to increase market share and profits for all members of the supply chain [14]. Supply chain performance is closely link to organization performance i.e. how well an organization achieves its market-oriented goals and its financial goals [17] as well as competitive advantage i.e. the extent to which an organization is able to create a defensible position over its competitors [12]. The literature has identified price/cost, quality, delivery and flexibility as key elements in competitive advantages [13]. Furthermore, time has been identified as key driver in competitive advantage [10, 18]. In this research, SCM performance is being used as the dependent variable because there are already many existing literature on the research of organizational performance and competitive advantage. Therefore, the dimensions of the SCM performance constructs used in this research are price/cost, quality, delivery dependability, product innovation and time to market. Metrics must be identified for customers, finance, operations, and other departments that are involved in supporting the supply chain. Six Sigma is one of the independent variables in this research. It consists of 5 dimensions i.e. Define, Measure, Analyze, Improve and Control (DMAIC). In Define phase, the focus is to identify, prioritize and select the improvement project. In Measure phase, the aim is to collect data to determine the baseline performance of the process which leads to deeper understanding of the problem statement of the project. In Analyze phase, the purpose is to conduct root cause analysis to uncover the root cause underlying the problem in the selected project. In Improve phase, the objective is to identify, prioritize and implement relevant solutions to resolve the problem. In Control phase, the aim is to put in place a control mechanism to prevent the similar problem to occur again. Total Productive Maintenance is the other independent variable in this research. It consists of 1 integrated dimension i.e. Total Productive Maintenance (TPM) which is the integration of all the 8 Pillars mentioned above. The aim of TPM is to restore equipment to base conditions i.e. cleaned, lubricated, centered-line and tightened which ultimately ensure equipment reliability. There are 3 research hypotheses in this research i.e.

H1: There is a positive significant relationship between Six Sigma and SCM performance

H2: There is a positive significant relationship between TPM and SCM performance

H3: TPM mediate the relationship between Six Sigma and SCM Performance

2.2. Research Methodology

Qualitative research is used in this research due to the nature of data from the respondent through questionnaires [2]. It is also has the advantages of handling large data set with relatively low cost [15]. Google Form is used in this research and data is analyzed using PLS-SEM software package. In this research, the SmartPLS 3.0 software is used for analyzing the independent and dependent variables of this study. SmartPLS 3.0 is a user-friendly modeling package for partial least squares analysis is supported by a community of scholars centered at the University of Hamburg (Germany), School of Business, under the leadership of Prof. Christian M. Ringle. The variables in partial least squares are known as latent variables.

3. RESULTS AND DISCUSSION

Validity and reliability is important to establish the truthfulness of the constructs the sample intended to measure and that they are representative of the population. To access validity, three types of validity were examined: convergent, discriminant and content validity. Content validity was established based on the content of the corresponding items, it contains expert opinions, literature review and pretesting questionnaires. Convergent validity was established by PLS-SEM in the areas of factor loadings, average variance extracted (AVE) and composite reliability [6, 16]. Addresses convergent validity, which is the extent to which a construct converges in its indicators by explaining the items' variance. Composite reliability is preferred over Cronbach's alpha as a test of convergent validity in a reflective model. Typically, a value of 0.7 is adequate [19]. The composite reliability of Six Sigma, TPM and SCM Performance are 0.71, 0.70 and 0.84 respectively. Average variance extracted (AVE) across all items associated with a particular construct. Typical value of AVE should be greater than 0.5 [5, 7] as well as greater than the cross-loadings, which means factors should explain at least half the variance of their respective indicators. The AVE of Six Sigma, TPM and SCM Performance are 0.52, 0.56 and 0.58 respectively. Discriminant validity was established by PLS-SEM in the areas of square root of AVE and cross loadings [6, 16]. This analysis reveals to which extent a construct is empirically distinct from other constructs both in terms of how much it correlates with other constructs and how distinctly the indicators represent only this single construct. In a good model, the loadings of each indicator with its latent variable should be greater than 0.7 and its cross-loadings (i.e. correlation) with other indicators associated with the same latent variable should be lower than 0.3. In reflective model, the researcher can use either cross-loadings or AVE or both to assess the discriminant validity of the model. In this research, the analysis of using PLS-SEM consists of 2 stages i.e. stage 1: reflective measurement model assessment and stage 2: structural model assessment. The “consistent PLS algorithm”, which is the default PLS modelling approach in SmartPLS 3.0 was used for running the path model in this research. This default setting in SmartPLS use path weighing scheme which maximizes the R^2 of endogenous variables in the model based on regression approach [9] that is the recommended methods by [6, 19]. Since the path coefficients computation in PLS do not assume any known distribution and hence the usual p-value significant levels can be calculated. Hence, it is essential to also run the PLS bootstrapping to compute the bootstrapped significance coefficients. In outer model, SmartPLS 3.0 will compute the standardized loadings value for each of the path connecting the indicators and the latent variable. The loadings value measures the absolute contribution of the indicator to the definition of the associated latent variables. In SmartPLS, loadings value can range from 0 to 1 and the larger the values, the stronger and more reliable the measurement model. The loadings itself can be considered as a form of item reliability coefficients for the reflective models i.e. the closer the loadings to 1.0, the more reliable that latent variable. The indicator reliability can be calculated by taking the squared of each loading [6]. The preferred value of indicator reliability is more than 0.7. If it is an exploratory research, 0.4 or higher is acceptable [8]. For a well-fitted reflective model, the path loadings should be greater than 0.70 [19] which means that more than half of the variance in the indicator can be explained by its latent variable. In empirical practice, if the indicator’s loading is not high (< 0.5) and is non-significant, the data do not support the contention that the indicator is relevant to the measurement of its factor and it may be dropped from the model [4]. A path model is a diagram that displays the hypotheses and variable relationships to be estimated in a PLS-SEM analysis [3]. The path model of this research with independent variable (latent variable or construct) i.e. Six Sigma, mediating variable i.e. TPM and dependent variable (latent variable) i.e. Supply Chain Performance is as shown in the Fig. 2. The model below consists of inner model i.e. the circles and the arrow connecting the circles and outer model i.e. the rectangles and the arrows connecting them. The inner model is also called the structural model, whereas the outer model is known as measurement model. There are two types of latent variables in the following model i.e. exogenous variables or independent variables (Six Sigma) and endogenous variable or dependent variable (SCM Performance). Multicollinearity is not an issue in reflective model since the latent variable is modeled as a single predictor of its associated indicators. However, there is potential multicollinearity at the structural level for reflective model i.e. the latent variables may be multicollinear between each other. After running the model using Smart PLS 3.0, the standardized path coefficients will be placed on the arrows in the inner model and loadings will be placed on the outer model. Note: SP1-5 denotes the indicators of SCM Performance i.e. Price/Cost, Quality, Delivery, Product Innovation and Time to Market.

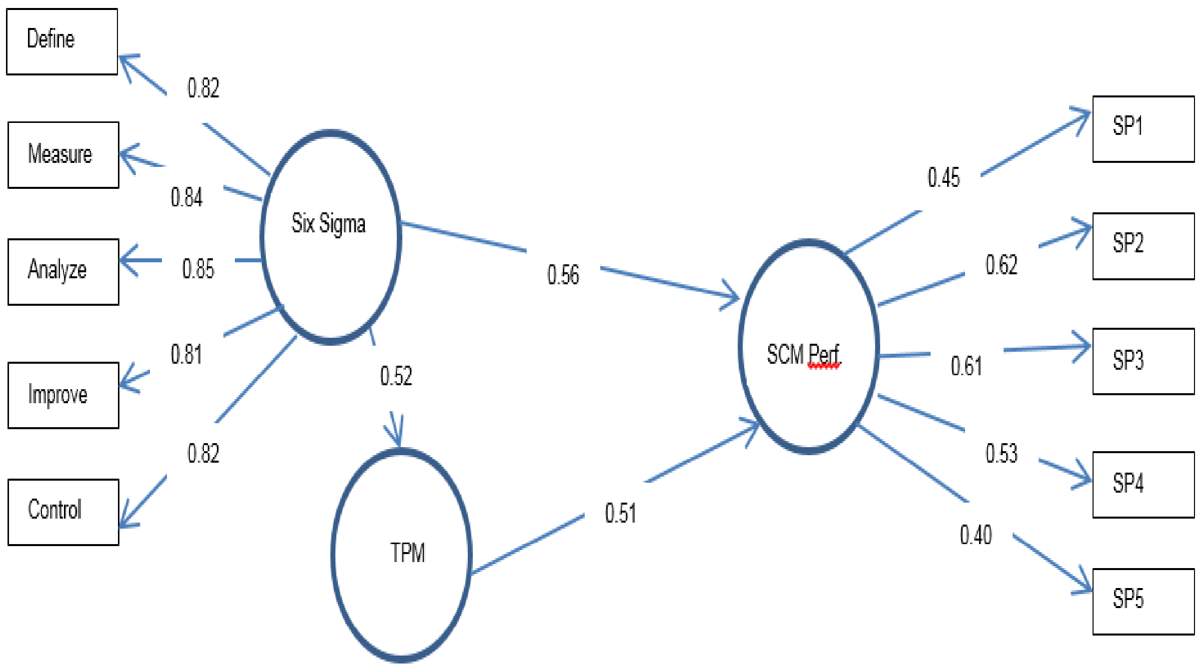

Fig.2. Inner and outer model of Six Sigma, TPM and SCM performance

From the result of analysis, it can be concluded the following hypothesis testing result. All the 3 paths connecting the hypothesis have standardized path coefficients greater than 0.50 and associated p-value lesser than 0.05 indicating that all 3 hypothesis are supported.

Table 1. Summary of PLS-SEM analysis results

Path Estimates/ Loadings	P-Values	Hypothesis
0.56	0.00	H1 supported
0.52	0.00	H2 supported
0.51	0.02	H3 supported

4. CONCLUSION

The present study validates the internal management commitment is one of the key element in SCM practices and impact the lean principles implementation in a company. Although some company are already implemented SCM practices and lean principles, they do not know the exactly how to implement both initiatives in an effective way due to a lack of understanding of the impact of internal management commitment that need to be managed continually. By proposing, developing and demonstrating the internal management commitment as one of the key element in SCM practices which at the same time with direct impact to lean principles implementation, the present study provides Lean practitioners with a useful model for evaluating the comprehensiveness of their current Lean principles and SCM practices implementation. Through the analysis of the relationship of Lean principles with internal management commitment and SCM practices, we have shown that SCM practices can serve as mediating variable that enhance the impact of internal management commitment to lean principles implementation rather trying to implement each of SCM practices and lean principles in isolation. The findings of this research thus point to the importance of embed SCM practices into lean principles implementation to the organization. The findings of this research support the view that embedded SCM practices into internal management commitment can have discernible impact on Lean principle implementation. In terms of research limitations, this research is aiming on company that implementing lean principles using its own internal lean practitioners and does not include those company that use external lean consultant for its lean principles implementation. Hence, the research implications could not be generalized to other company that use external lean consultant for its lean principles deployment.

This paper provides empirical justification for a framework that identifies internal management commitment as one of the key dimensions of SCM practices and describes the internal challenges of internal lean practitioners in implementing lean principles in a company. It examines three research questions: (1) how does internal management commitment impact the Lean principles? (2) how does SCM practices impact the lean principles? (3) can SCM practices be embedded with internal management commitment? For the purpose of investigating these issues a comprehensive, valid and reliable instrument for assessing SCM practices was developed. The instrument was tested using rigorous statistical tests including convergent validity, discriminant validity, reliability and the validation of the structural equation modeling. This study provides empirical evidence to support conceptual statements of company that has higher level of internal management commitment, coupled with leveraging the existing SCM Practices, in lean principles implementation is critical in overcoming the challenges faced by internal lean practitioners. As lean practitioners' major challenge is overcome, the lean principles implementation is more successful as compare to other organizations that has low level of internal management commitment.

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How to cite this article:
Sing SK, Mohd Saudi MH. The impact of embedded total productive maintenance with six sigma on supply chain performance. J. Fundam. Appl. Sci., 2018, *10(1S), 678-688.*