Six SigmaImplementation in China: Successes and Challenges

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Abstract

Six Sigma has been widely implemented in a variety of industries for many years. Though there are many success stories of Six Sigma implementation in China, there are some failures and also a lot of challenges. Some issues about Six Sigmain China need to be explored, such as what makes the key success/failure factors of Six Sigma implementation, how Six Sigmasupports corporate performance, and how isthe future development of Six Sigmaetc. In this paper, based on the literature study, we conclude seven practices that are commonly identified as critical components for Six Sigma implementation, including top management support and commitment, customer relationship, information & data system, Six Sigma structured improvement procedure, Six Sigma focus on metrics, designfor Six Sigma. The relationships between Six Sigma practices and three types of corporate performance including operational performance, financial performance and innovation performance are explored using Structural Equation Modeling based on 141 six sigma firms' empirical data in China. The results show that Six Sigma management, infrastructure, and core practices have a positive relationship with operational, financial and innovation performance. We also propose the future development of Six Sigma from three perspectives: strategy, integration and innovation.

Keywords: Six Sigma, Corporate performance, Structural equation model

1.Introduction

Six Sigmahas been identified as a systematic process improvement approach that relies on statistical tools and scientific method to enhance process capability, reduce customer-defined defect rates (Brady & Allen, 2006; Dasgupta, 2003; Firka, 2010; Linderman, Schroeder, Zaheer, & Choo, 2003; Pantano, O'Kane, & Smith, 2006; Parast, 2011). There is fairly large and growing body of anecdotal evidence associated with the benefits of implementing Six Sigma, but there is very little systematic and rigorous research investigating these benefits. The academic community lacks theory as a basis for Six Sigmaresearch, which is argued by many scholars, such as Linderman et al. (2003)and Schroeder, Linderman, Liedtke, & Choo (2008). Further studies to determine the effect of Six Sigma on corporate performance is necessary(Hilton, Balla, & Sohal, 2008; Kwak & Anbari, 2006). Furthermore, there is a substantial of empirical research investigating the impact of other quality and process improvement initiatives, such as TQM, on corporate performance. However, empirical research investigating Six Sigma implementation and the impact on corporate performance has been limited (Foster, 2007; Shafer & Moeller, 2012). Thus, this study tends to enrich Six Sigma literature by exploring the following questions: first of all, through a literature review, the critical factors in Six Sigma implementation are identified. A theoretical framework to explore the effect of Six Sigma practices on corporate performance is developed. An empirical study in Chinese Six Sigma firms is conducted to test the proposed model. Finally, the future development of Six Sigmais discussed.

2. Literature review

2.1 Six Sigma practices

In realizing the implementation of Six Sigma, multiple factors should be combined to create a comprehensive Six Sigma system. Measurement factors for Six Sigma practices in related research are not unified. Based on previous research, in our study, top management support and commitment, Six Sigma role structure, customer relationship, information & data system, Six Sigma structured improvement procedure, Six Sigma focus on metrics, design for Six Sigma are regarded as factors to measure the concepts of Six Sigma practices.

Subsequently, these seven factors can be grouped into three categories following the classification ofFlynn, Schroeder, & Sakakibara (1995) and Lakhal, Pasin, & Limam (2006), namely: management practice, infrastructure practices and core practices. Management practice refers to the responsibilities of top managers. Theinfrastructure practices are intended to create an environment supporting the implementation ofSix Sigma core practices.And the core practices focus on applying tools and techniques in continuous improvement(Flynn et al., 1995; Sousa & Voss, 2002; Zu, Fredendall, & Douglas, 2008). Table 1 illustrates these seven constructs of Six Sigma practices and the related descriptions.

2.2 Corporate performance

Corporate performance is also called firm performance or organizational performance. Through a literature review on operations management, including total quality management (TQM), Lean productionand Six Sigma, we can find that the measurement level and operational definition of performance are different due to their research proposal, sample and data. Operational performance and financial performance are the most frequently measurement level used by researchers in the early literature (Choi, Kim, Leem, Lee, & Hong, 2012; Foster, 2007; Gunday, Ulusoy, Kilic, & Alpkan, 2011; Kaynak, 2003).Recently, as innovation capability plays a key role in developing and improving products and services in organization (Kim, Kumar, & Kumar, 2012), Innovationperformance is also considered by scholars, some even explored the relationship between innovation performance to other performance (Choi et al., 2012; Gunday et al., 2011; Prajogo & Sohal, 2006). Thus, operational performance, financial performance and innovation performance are regarded as the three dimensions of corporate performance in this study.

Table 1 Six Sigma practices proposed in the literature

Categories	Practices	Related constructs	Descriptions
Management practices	Top management support and commitment (TMSC)	Top management support (Zu et al., 2008), Leadership (He, 2009), CEO's will (Choi et al., 2012), Leadership management (Schroeder et al., 2008)	Top managers participate in and allocate resources for Six Sigma initiatives. Top management makes objectives, strategies, and vision for Six Sigma implementation and communicates clear to all employees.
Infrastructure practices	Six Sigma role structure (RS)	parallel-meso structure & improvement specialists (Schroeder et al., 2008), Six Sigma role structure (Zu et al., 2008), Infrastructure (He, 2009)	A 'parallel-meso structure' that is parallel to and outside of the typical organizational structure and integrates all ranks of specialists. Six Sigma improvement specialists lead the organization's efforts in quality improvement.
	Customer Relationship (CRS)	customer-oriented metrics (Schroeder et al., 2008), customer relationship (Zu et al., 2008), customer focus (He, 2009)	Customer's needs and expectations are highly considered in Six Sigma management. Customer satisfaction is scientifically measured.
	Information & data system (IDS)	Statistical control and feedback (Flynn et al., 1995), information system (Lee & Choi, 2006), information utilization (Choi et al., 2012)	Systematic management process of information and data resource in order to support the cross functional communication and cooperation, which is essential in executing Six Sigma projects.
Core practices	Six Sigma structured improvement procedure (SIP)	Methodology tool and application (On, 2006), Six Sigma structured improvement procedure (Zu et al., 2008), structure method (Schroeder et al., 2008)	There is an emphasis on using of data-driven, systematic, structured approach in quality improvement, which involves using DMAIC in process improvement and DMADV or the like in product, service and process design (i.e., Design for Six Sigma).
	Six Sigma focus on metrics (FOM)	Result (On, 2006),customer-oriented and financial performance metrics (Schroeder et al., 2008), focus in metrics (Habidin & Yusof, 2012), Six Sigma focus on metrics (Zu et al., 2008)	Quantitative metrics are used to measure improvement performance and establish goals, and help in guiding and assessing continuous improvement projects.
	Design for Six Sigma (DFSS)	Product/service design (Zu et al., 2008)	Design for Six Sigma is a systematic methodology using tools and techniques in design projects to meet customer requirements. DFSS usually focus on new or innovative product/service designs.

2.3 Research model and hypotheses

The relationship between Six Sigma practices and corporate performance have been investigated by some scholars.Zu et al. (2008)investigated the role if Six Sigma in quality management based on 226 US manufacturing plants. They identified three new practices (i.e. Six Sigma role structure, Six Sigma structured improvement procedure, and Six Sigma focus on metrics) associated with Six Sigma in comparing with seven traditional quality practices. And a research model and survey instrument were developed to investigate how these practices affected quality performance and business performance. The research inZu et al. (2008)provides a basis for further research on Six

Sigma. Our research model proposed mainly based onZu et al. (2008). A research model (see Figure 1) is developed to examine the following hypotheses.

H1: Six Sigma management practice is positively related to Six Sigma infrastructure practices.

H2: Six Sigma infrastructure practices have a direct positive effect on Six Sigma core practices.

H3a: Six Sigma core practices have a direct positive effect on operational performance.

H3b: Six Sigma core practices have a direct positive effect on financial performance.

H3c: Six Sigma core practices have a direct positive effect on innovation performance.

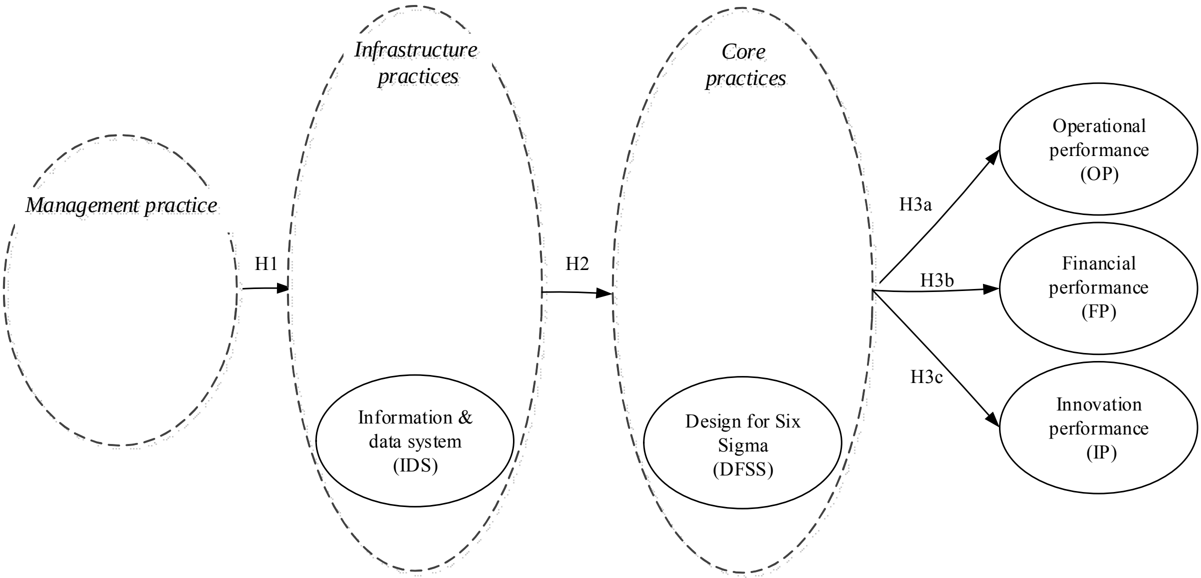


Figure 1 Research model

3.Methodology

3.1 Sample and data collection

The data for this study were collected in the 12th National Six Sigma Conference hosted by Six Sigma Management Promotion Committee in 2015. We delivered 425 questionnaires to the representatives attending the conference and finally received 263 responses. Among these returned questionnaires, 37 contained a large number of missing values or presented almost identical answers for all questions and were thus deem invalid. Finally, a total of 226 questionnaires (53.2% effective response rate) completed by senior leaders, champions, master black belts (MBB), black belts (BB), green belts (GB) or quality managers referring to 141 firms were analyzed.Data were aggregated by calculating the average of the multiple respondents for some of the firms. Thus, our analysis was based on a sample of 141 manufacturing or service firms implementing Six Sigma in China.

3.2 Survey instrument

The questionnaire includes three parts. The first part is to collect basic information about respondent's characteristics including their roles in Six Sigma implementation and whether they have received Six Sigma training or not, to ensure the appropriateness of the respondents. The second parts refer to some basic information about the firms including the industry, Annual revenue, number of employees, ownership and duration of Six Sigma implementation. Sample demographics are presented in Table 2.

Table 2 Sample demographics

	Number of respondents	Percent (%)
Industry		
Manufacturing industry	135	95.7
Service industry	6	4.3
Annual revenue (Y, Million RMB)		
Y≥400	105	74.5
20≤Y < 400	25	17.7
3≤Y < 20	7	5.0
Y < 3	4	2.8
Number of employee (X)		
X≥1000	113	80.1
300≤X < 1000	21	14.9
20≤X < 300	7	5.0
X < 20	0	0
Ownership		
State-owned enterprises	111	78.7
Non state-owned enterprises	30	21.3
Duration of implementation (Z, years)		
Z≤3	57	40.4
Z>3	84	59.6
Total	141	100.0

The third part contains seven-point Likert scales to measure constructs of Six Sigma practices and corporate performance. Measurement items for each construct are obtained from a review of the relevant literature to ensure content validity. Items from extant empirical studies on Six Sigma and quality management are used to evaluate the seven dimensions of Six Sigma practices (e.g. Kim et al., 2012; Lee & Choi, 2006; Zu et al., 2008). The variables of performance are measured by using the measurement items also adapted from the related literature (e.g.Choi et al., 2012; Gunday et al., 2011; Kaynak, 2003; Zu et al., 2008). All the items are measured on a 7-point Likert type scales anchored by “strongly disagree=1” and “strongly agree=7”.

4. Data analysis and results

4.1 Measurement model

Before testing the hypotheses, measurement model should be evaluated for reliability and validity. A comprehensive measurement model is assessed using Amos 20.0 and SPSS 20.0. Measurementreliability is assessed by the calculated Cronbach’s α values and composite reliability (CR). The reliability can be guaranteed if the Cronbach’s α is higher than 0.7 for each factor(Nunnally & Bernstein, 1994).Studies (Fornell & Larcker, 1981; Hair, Black, Babin, & Anderson, 2009) suggest that reliability is acceptable if CR is more than 0.7. As shown in Table 3, the Cronbach's α values and CRs of all measures exceed 0.8, indicating an adequate level of reliability.

Construct validity is assessed in terms of convergent validity and discriminant validity. Convergent validity can be evaluated by the fact that all estimates for the average variance extracted (AVE) are higher than 0.5 (Anderson & Gerbing, 1988; Kim et al., 2012).To examine discriminant validity, we use the approach proposed byFornell & Larcker (1981). As shown in Table 3, the square root of AVE of a construct is greater than the correlation coefficients between the construct and any other constructs (except three of the correlation coefficients a little higher than the square root of AVE), basically satisfying the criteria for discriminant validity. Therefore, the analysis of measurement models confirms that the instrument in this study has satisfactory reliability and validity.

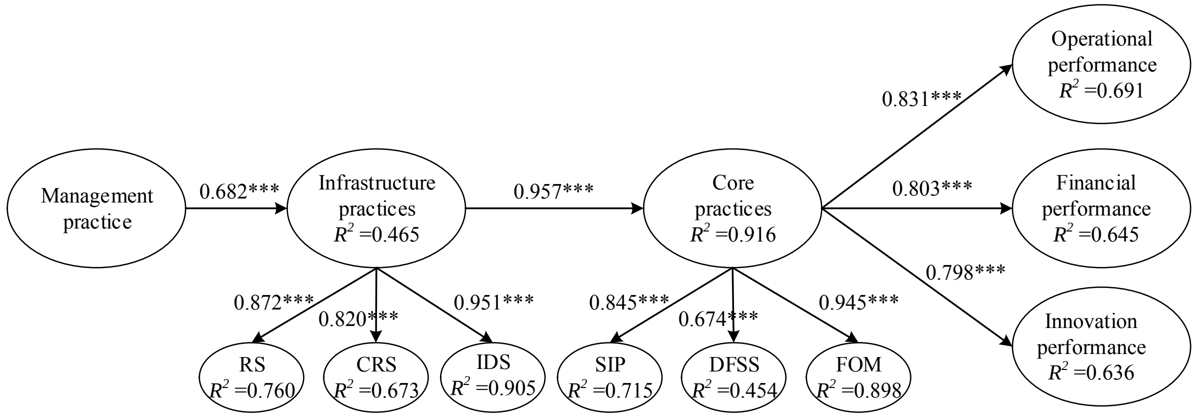
Table 3 Reliability and validity tests

	Items	Cronbach's α	CR	AVE	FP	IP	QP	FOM	DES	IMP	IDS	RS	CRS	LS
FP	4	0.924	0.925	0.756	**0.869**									
IP	4	0.869	0.874	0.635	0.787	**0.797**								
QP	4	0.895	0.897	0.685	0.689	0.646	**0.828**							
FOM	5	0.920	0.921	0.699	0.741	0.746	0.791	**0.836**						
DES	5	0.940	0.941	0.761	0.597	0.719	0.425	0.664	**0.872**					
IMP	5	0.924	0.925	0.712	0.565	0.566	0.756	0.845	0.440	**0.844**				
IDS	3	0.839	0.846	0.648	0.752	0.760	0.740	0.840	0.662	0.799	**0.805**			
RS	3	0.838	0.842	0.641	0.600	0.540	0.704	0.796	0.507	0.792	0.831	**0.801**		
CRS	4	0.878	0.880	0.647	0.711	0.601	0.654	0.716	0.543	0.640	0.781	0.721	**0.804**	
LS	3	0.805	0.863	0.614	0.510	0.540	0.575	0.588	0.472	0.631	0.576	0.635	0.599	**0.784**

Notes: Diagonal bold elements are the square roots of average variance extracted. Off-diagonal elements are the correlations, and all correlations are significant at $p<0.001$.

4.2 Structural model

This study uses structural equation model to test the hypotheses. The fit indices provide evidence of a good model fit compared with their corresponding recommended values (specifically χ^2=1282.822,df=768,χ^2/df=1.670<3; SRMR=0.067<0.08; RMSEA=0.069<0.08, CFI=0.896, TLI=0.889).The standardized path coefficients and variance explained for each equation in the hypothesized model are presented in Figure 2. All the hypotheses are supported. Six Sigma management practice (top management support and commitment) is positively related to Six Sigma infrastructure practices (γ= 0.682, t =6.482) and Six Sigma infrastructure practices have significant relationship with Six Sigma core practices (γ= 0.957, t =6.720). Six Sigma core practices have significant influence on the operational performance, financial performance and innovation performance (γ= 0.831, t =6.594; γ=0.803, t=7.028; γ= 0.798, t =6.552, respectively).The results of the structural model analysis show that the implementation of Six Sigma associates with the corporate performance. This study confirms that Six Sigma management practice is directly related to Six Sigma infrastructure practices, which in turn directly associated with Six Sigma core practices. Moreover, Six Sigma core practices have positive relationship with operational performance, innovation performance and financial performance.



*** Path coefficient is significant at the 0.001 significance level (P<0.001)

Figure 2 Hypotheses testing results

5. Future development of Six Sigma

Though Six Sigma has been widely used in China since year 2001 and its application has been extended from manufacturing to service industry, people often raise questions such as "How is the future of Six Sigma?", " Will Six Sigma be replaced by other initiatives?". As He & Goh (2015) pointed out, perhaps the term Six Sigma may be replaced by some other names in the future, but the concept of continuous improvement in management initiatives will never become out of date. The future of Six Sigma depends mainly on two fronts: one, whether Six Sigma can bring about continuous benefits for an organization; two, whether Six Sigma itself is capable of absorbing and integrating other management thinking and tools to further its prowess.We can conclude that the aforementioned perspectives are three main key words determining the future evolution of Six Sigma: strategy, integration and innovation.

For strategy, Six Sigma deployment should be aligned with business strategy. In this dimension, Six Sigma can be integrated with Balanced Score Card, SWOT analysis and/or other strategy management tools. The key is that big opportunities for improvement can be located using strategic planning tools. And Six Sigma is a powerful tool for achieving business strategic goals through continuous improvement project. Also Six Sigma implementation is a top-down process, only by implementing Six Sigma at the strategic level could organizational buildup and continuous improvement be assured. In China AVIC (Aviation Industry of China) and TISCO (Taiyuan Iron and Steel Company) are very good examples of Six Sigma with strategy management.

For integration, level Six Sigma can be integrated with many management theory and methods such as lean production, quality management systems, performance excellence model, supply chain management, theory of constraints and so on. An increasing number of corporations are now implementing what is labeled as Lean Six Sigma. In China more companies claim their initiative to Lean Six Sigma instead of Six Sigma.

For innovation, as shown in this paper, Six Sigma core practices have positive relationship with operational performance, innovation performance and financial performance.Now Six Sigma methods are widely used for developing new products and services that reach new and broad market; that is, for innovation (Box & Woodall, 2012). The future of Six Sigma depends on that if our understanding of Six Sigma can go beyond its old metric meanings. As Montgomery& Woodall (2008) pointed out, this metric is nonessential aspect of the Six Sigma process improvement and product design frameworks and is now doing more harm than good.

6. Discussion and conclusion

This study investigates the relationship between Six Sigma practices and corporate performance. A proposed model was tested by data from 141 firms implementing Six Sigma in China. The results support the view that Six Sigma practices are positively related to corporate performance. Six Sigma management practice directly affects infrastructure practices, which in turn have a positive effect on core practices. The results are consistent with the finding of Zu et al. (2008). These conclusions also corroborate previous studies on TQM by Flynn et al. (1995), Lakhal et al. (2006),and Zu (2009).

The results highlight that Six Sigma is a systematic and rigorous methodology for problem solving and all the Six Sigma practices are interdependent. Companies should realize the interconnections with a balanced and long-term view on Six Sigma practices. Only by implementing Six Sigma at the strategic level could the firm succeed in pursuing high performance. Top management should have their strategic goals and develop procedure to achieve these goals through Six Sigma.

SixSigma can positively promote corporate performance, perhaps owing to the concept of integration, including the integration of Six Sigmamanagement, infrastructure, and core practices, integration of Six Sigma and other management models, such as lean production and integration of improvement procedure methodology and DFSS approach. The integration of Six Sigmacan be concluded to three levels: strategic, process and methodology.

Development of Six Sigma in organizations is a kind of innovation, our study empirically confirmed that Six Sigma practices associated with innovation performance.

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References:

Anderson, J. C., & Gerbing, D. W. (1988). Structural equation modeling in practice: A review and recommended two-step approach. *Psychological bulletin*, 103(3), 411

Brady, J. E., & Allen, T. T. (2006). Six Sigma literature: a review and agenda for future research. *Quality and reliability engineering International*, 22(3), 335-367

Box,G.E.P.,& Woodall,W.H. (2012). Innovation, quality engineering and Statistics.*Quality Engineering*, 24 (1), 20-29.

Choi, B., Kim, J., Leem, B., Lee, C., & Hong, H. (2012). Empirical analysis of the relationship between Six Sigma management activities and corporate competitiveness: focusing on Samsung group in Korea. *International Journal of Operations & Production Management*, 32(5), 528-550

Dasgupta, T. (2003). Using the six-sigma metric to measure and improve the performance of a supply chain. *Total Quality Management & Business Excellence*, 14(3), 355-366

Firka, D. (2010). Six Sigma: an evolutionary analysis through case studies. *The TQM Journal*, 22(4), 423-434

Flynn, B. B., Schroeder, R. G., & Sakakibara, S. (1995). The impact of quality management practices on performance and competitive advantage. *Decision Sciences*, 26(5), 659-691

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research (JMR)*, 18(1)

Foster, S. T. (2007). Does Six Sigma Improve Performance? *Quality Management Journal*, 14(4), 7

Gunday, G., Ulusoy, G., Kilic, K., & Alpkan, L. (2011). Effects of innovation types on firm performance. *International Journal of Production Economics*, 133(2), 662-676

Habidin, N. F., & Yusof, S. M. (2012). Relationship between Lean Six Sigma, environmental management systems, and organizational performance in the Malaysian automotive industry. *International Journal of Automotive Technology*, 13(7), 1119-1125

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2009). *Multivariate Data Analysis: A Global Perspective (7th Edition)*. Upper Saddle River: Prentice Hall.

He, Z. (2009). Learn something about your Six Sigma program's maturity. *Quality Progress*, 15(August), 23-28

He, Z., & Goh T.N. (2015), Enhancing the Future Impact of Six Sigma Management，*Quality Technology and Quantitative Management*,12(1),83-92

Hilton, R., Balla, M., & Sohal, A. S. (2008). Factors critical to the success of a Six-Sigma quality program in an Australian hospital. *Total Quality Management*, 19(9), 887-902

Kaynak, H. (2003). The relationship between total quality management practices and their effects on firm performance. *Journal of operations management*, 21(4), 405-435

Kim, D., Kumar, V., & Kumar, U. (2012). Relationship between quality management practices and innovation. *Journal of Operations Management*

Kwak, Y. H., & Anbari, F. T. (2006). Benefits, obstacles, and future of Six Sigma approach. *Technovation*, 26(5), 708-715

Lakhal, L., Pasin, F., & Limam, M. (2006). Quality management practices and their impact on performance. *International Journal of Quality & Reliability Management*, 23(6), 625-646

Lee, K., & Choi, B. (2006). Six Sigma management activities and their influence on corporate competitiveness. *Total Quality Management & Business Excellence*, 17(7), 893-911

Linderman, K., Schroeder, R. G., Zaheer, S., & Choo, A. S. (2003). Six Sigma: a goal-theoretic perspective. *Journal of Operations management*, 21(2), 193-203

Montgomery, D.C. &Woodall, W.H. (2008). An overview of Six Sigma, *International Statistical Review*. 76(3), 329-346.

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory*. New York: McGraw-Hill.

On, C. C. (2006). *The development and application of Six Sigma implementation model for HK/China manufacturing companies*., City University of Hong Kong. Retrieved from Available from

Pantano, V., O'Kane, P., & Smith, K. (2006*Cluster-based Six Sigma deployment in small and medium sized enterprises*. Paper presented at the Management of Innovation and Technology, 2006 IEEE International Conference on.

Parast, M. M. (2011). The effect of Six Sigma projects on innovation and firm performance. *International Journal of Project Management*, 29(1), 45-55

Prajogo, D. I., & Sohal, A. S. (2006). The relationship between organization strategy, total quality management (TQM), and organization performance—the mediating role of TQM. *European Journal of Operational Research*, 168(1), 35-50

Schroeder, R. G., Linderman, K., Liedtke, C., & Choo, A. S. (2008). Six Sigma: definition and underlying theory. *Journal of operations Management*, 26(4), 536-554

Shafer, S. M., & Moeller, S. B. (2012). The effects of Six Sigma on corporate performance: An empirical investigation. *Journal of Operations Management*, 7(30), 521-532

Sousa, R., & Voss, C. A. (2002). Quality management re-visited: a reflective review and agenda for future research. *Journal of Operations Management*, 20(1), 91-109

Zu, X., Fredendall, L. D., & Douglas, T. J. (2008). The evolving theory of quality management: the role of Six Sigma. *Journal of operations Management*, 26(5), 630-650