Applying Six-Sigma to Supplier Development

F. K. Wang[1], Timon C. T. Du[2], Eldon Y. Li[3]

[1] Chang Gung University, Taiwan (fukwun@mail.cgu.edu.tw)
[2] The Chinese University of Hong Kong (timon@baf.msmail.cuhk.edu.hk)
[3] Orfalea College of Business, California Polytechnic State University, U.S.A. (eli@calpoly.edu)

Abstract

Supply chain management (SCM) adopts a systematic and integrative approach to managing the operations and relationships among the different parties in supply chains. Various research studies have investigated how quality management can be employed in SCM to improve the performance of the whole supply network. With the Six-Sigma improvement methodology, a model for the assessment, improvement, and control of quality in SCM is developed. The application guidelines are discussed. Improvements in the quality of all supply chain processes leads to the simultaneous reduction of costs and improved levels of service. One major issue in SCM is supplier development. In our model, supplier evaluation can be conducted by principal component analysis. Future studies will also benefit from the integration of Six-Sigma into SCM.

1. Introduction

Supply chain management (SCM) involves the removal of barriers between trading partners to facilitate the synchronization of information. It involves not only logistic activities (e.g. inventory management, transportation, warehousing, and order processing, etc.), but also other processes (e.g. customer relationship management, demand management, order fulfillment, procurement, and product development and commercialization, etc.). SCM adopts a systemic and integrative approach to managing the operations and relationships among the different parties in supply chains. It is aimed at building trust, exchanging information on market needs, developing new products, and reducing the supplier base to release management resources for developing meaningful, long-term relationships. The high quality of products and services at each level of the supply network is an essential part of successful SCM (Choi & Rungtusanathn, 1999). Improving the quality of all supply chain processes leads to cost reductions, improved resource utilization, and improved process efficiency (Beamon & Ware, 1998). Some research studies have investigated how quality management can be employed in SCM to improve the performance of the whole supply network. Forker et al. (1997) demonstrate that total quality management (TQM) can influence the quality performance in the supply chain by combining nonlinear (Data Envelopment Analysis) and linear regression analyses. Their results suggest that manufacturers should continue to promote TQM practices throughout the supply chain. Wong and Fung (1999) present an in-depth case study of the TQM system of a construction company in Hong Kong. They examine the strategy, structure, and tasks for managing the supplier-subcontractor relationships that form an integral part of total quality pursuits. Matthews et al. (2000) show that the concepts of quality management systems and partnering can be effectively incorporated into the construction supply chain. As working relationships become closer technology transfers increase, which provides organizations with limited resources the opportunity to obtain expert skills from their partners. Houshmand and Rakotobe-Joel (2000) develop the integrated supply chain structural analysis method to identify the priorities for process improvement. Romano and Vinelli (2001) discuss how quality can be managed from a supply chain perspective. Their case study indicates that the whole supply network can improve its ability to meet the expectations of the final customer in terms of quality through the joint definition and co-management of quality practices and procedures. Sohn and Choi (2001) develop a fuzzy quality function deployment (QFD) model to explain the fuzzy relationship between customers needs and design specifications for reliability in the context of supply chain management.

The continuous improvement concepts that were established by Deming, Juran, Feigenbaum and Crosby have provided insight into the measurement of supply chain systems. The Six-Sigma improvement methodology has become extremely popular in the last several years. Six-Sigma is the structured application of the tools and techniques of quality management, applied on a project basis, to achieve strategic business results. Numerous books and articles are available to provide the basic concepts of Six-Sigma, such as those by Harry and Schroeder (2000), Hahn et al. (2000), Breyfogle (1999) and Hoerl (1998). Wyper and Harrison (2000) present a case study of the deployment of Six-Sigma in human resource functions. Six-Sigma can easily be used to develop a model for the assessment, improvement, and control of quality in SCM. Improvements in the quality of all supply chain processes leads to the simultaneous reduction of costs and improvements in levels of service.

This article is divided into the following sections. Section 2 reviews the development and application of Six-Sigma, and Section 3 discusses our application guidelines. Section 4 applies the methodology to supplier development, and Section 5 presents our conclusions.

2. Six-Sigma

Six-Sigma is a logical and systematic approach to achieving continued improvements. This process improvement methodology was developed in the 1980s in Motorola's high volume manufacturing environment (Breyfogle, 1999). A sigma quality level offers an indicator of how often defects are likely to occur, whereby a higher sigma quality level indicates a process that is less likely to create defects. Six-Sigma is named after the process mean with shifted 1.5 standard deviations from the mean that has six standard deviations on each side of the specification limit, and which will produce 3.4 defects per million opportunities (DPMO). Recently, Six-Sigma has been successfully implemented in both manufacturing and service industries. For example, as reported by Harry and Schroeder (2000), Motorola saved US$2.2 billion in the first 5 years of adoption. Honeywell has saved in excess of US$2 billion since it implemented Six-Sigma in 1994. General Electronics initiated Six-Sigma in 1996 and generated more than US$2 billion of revenue in 1999. Black and Decker's savings rose to approximately US$75 million in 2000, which was more than double the savings of the previous year. This took the total savings to over US$110 million after 1997. The implementation of Six-Sigma is not a short-term, quick fix improvement. A committed and charismatic leadership is essential in coaching and guiding the adoption of this holistic, long-term, and continuous improvement methodology. Blakeslee (1999) suggests that seven key principles will ensure that companies can reap benefits from Six-Sigma:

1) A committed leader is needed to ensure successful Six-Sigma implementation.
2) Six-Sigma efforts must be integrated with existing business strategies and key performance measures.
3) Successful Six-Sigma efforts must be supported by the framework of a business process.
4) Six-Sigma requires disciplined customers and market intelligence.
5) Six-Sigma projects must produce real savings or revenue.
6) Six-Sigma projects must be led by thoroughly trained full-time team leaders, who are known as Champions, Master Black Belts, Black Belts, and Green Belts. A Champion is a quality leader in the organization and is responsible for developing and implementing strategy, setting objectives, allocating resources, and monitoring progress. Master Black Belts have a more managerial role, in that they are often responsible for all Six-Sigma work in a particular area or function. Black Belts have a more operational role. In most cases, a Black Belt is a leader of a team that is working on a problem. People who are trained and committed to a Six-Sigma project as part of their regular jobs are referred to as Green Belts (Hoerl, 2001).

   Six-Sigma projects must be supported by the continuous reinforcement and reward of leaders.

3. Application guidelines

The basic framework of the Six-Sigma improvement technology in the supply chain network is given in Figure 1. The framework consists of five integrated modules: Define, Measure, Analyze, improve and Control.

Module 1: Define (prioritize)– This module defines the processes that have the highest priority for improvement, i.e. the key process that will enable maximum leverage and customer satisfaction. Here, Module 1 defines the required activities and the key process output variables that are used to count defects, and calculate the cost of poor quality. Graphical tools such as flowcharts, flow process charts, Gantt charts, and relation diagrams are useful in determining the tasks that are performed in the supply chain (Breyfogle, 1999). After the activities are identified, they are assigned to process improvement. These processes may include inbound and outbound transport, warehousing, production planning / inventory control, order processing, and customer service.

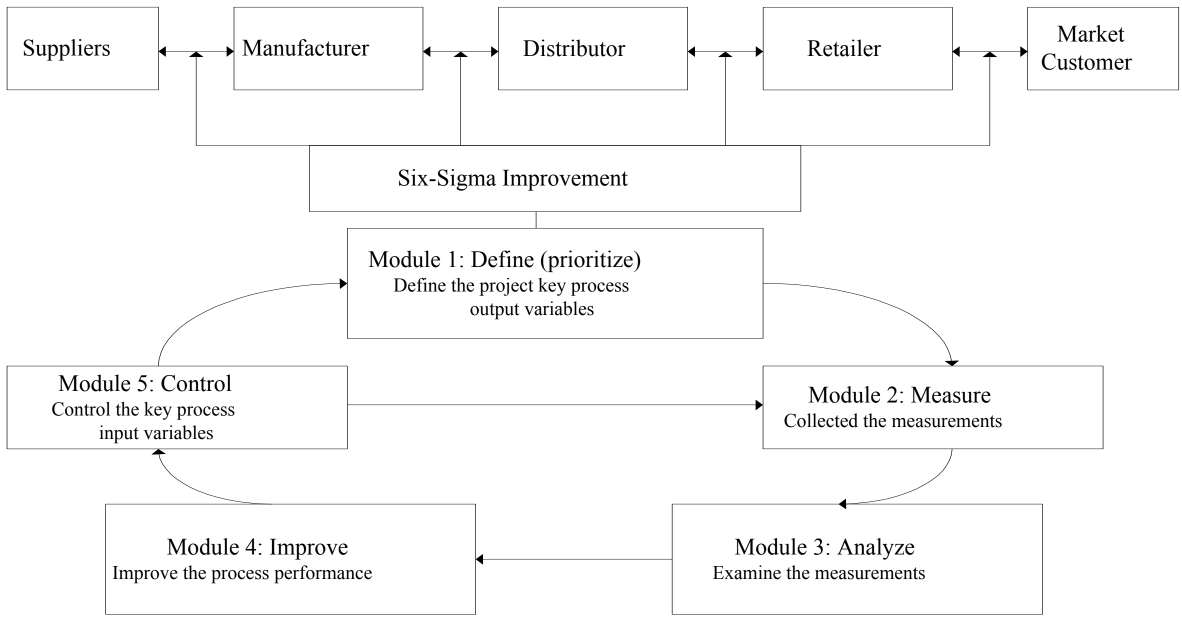

Fig 1. The framework of the Six-Sigma model in the supply chain network

Module 2: Measure– This module measures the capability of the process. The purpose is to identify the performance measures such as cost, productivity, and service levels. Moreover, this measure can also help to identify the deviations of current measurements. The goals of SCM should be consistent with the organizational goals. This module helps to create an understanding of the types of quality measures that are currently employed. First, the deviations that are associated with the various supply chain management and customer requirements are identified. The deviations that are associated with the quality factors for the process are then identified. Numerous quality factors can be measured in SCM. Some of the major metrics are as follows:

- Reliability–concerns about the failure to deliver products;
- Order accuracy–concerns about the probability of the correct orders arriving at or departing from the warehouse on time;
- Worker standards–engineering standards for workers inside the warehouse;
- Customer satisfaction–concerns about whether internal or external customers are satisfied with the service that is provided;
- Worker quality–concerns about such things as safety, damaged goods, etc.; and
- Cost–concerns about the cost that is incurred in a supply chain.

Module 3: Analyze– This module analyzes when and where defects occur. The purpose is to evaluate current performance and re-evaluate the standards for cost, productivity, and service objectives. The best in class standards such as days to supply material (< 5 days) and level of customer satisfaction (> 98%) are used to examine the measurements that are collected in Module 2. A control chart can be employed to detect whether or not the process is in control. Note that a process is considered as in control when there are no occurrences of special causes. For example, a special variation in a supply chain process can be when a truck arrives late due to inclement weather. Once the process is in control, current data can be used to evaluate the process performance. Multivariate chart, regression analysis, analysis of variance and multivariate statistical analysis can also be used in this module.

Module 4: Improve– This module focuses on how Six-Sigma improvement technology can be developed, and identifies the critical factors that arise from the control process. The purpose is to identify and implement changes so that the overall supply chain process performance can be improved. The first step in this module consists of identifying and prioritizing improvement areas. Once these areas have been prioritized, the areas that must receive immediate attention, considering time and cost restrictions, are identified. The purpose of continuous improvement is to reduce the amount of commonly caused variations in the supply chain process. In planning this improvement, hypotheses must be made. Once the causes of variations are identified, a plan is implemented to eliminate them. The plan is then tested to determine whether the solution is able to reduce variations. After this testing, the improvement should be implemented throughout the process. The process should be tested again to determine whether it is in control. If the process is in control, the standards of cost, productivity, and service objectives are set to those of the improved process. The process variability reduction can be improved by the experimental design and Taguchi methods.

Module 5: Control– This module identifies the controls that must be in place to sustain the benefit of the new process. The purpose is to control and monitor productivity and service performance to ensure that the process meets the identified standards. There are numerous quality tools that can be used in this step. Some tools are given as follows:

- Control charts, such as exponentially weighted moving average (EWMA) charts or engineering process control (EPC) charts, for variability analysis;
- Cause and effect diagram for troubleshooting analysis;
- Failure model effects analysis (FMEA) for failure analysis;
- Histogram for variable frequency analysis;
- Scatter diagram for variable relationship analysis; or
- Run chart for trend analysis.

Six-Sigma improvement projects can be considered as the driving force for cost reduction and service improvement in SCM. Consider the flow chart in Figure 2, which can be used to highlight the project benefits. First, the potential value of the project must be acknowledged by the Six-Sigma Black Belt (team leader), the project sponsor (champion), and the relative people from different departments in the organization. Once the definition of the defect in the SCM is agreed upon and data of the existing process are acquired, a preliminary analysis of possible benefits such as improvements in the level of service and cost reduction etc. can be developed. Throughout the Improve and Control phases of Six-Sigma project, the results are compared with those of industry benchmarks such as the average and the best in class. This identifies the company's advantages as well as opportunities to improve its supply chain performance.

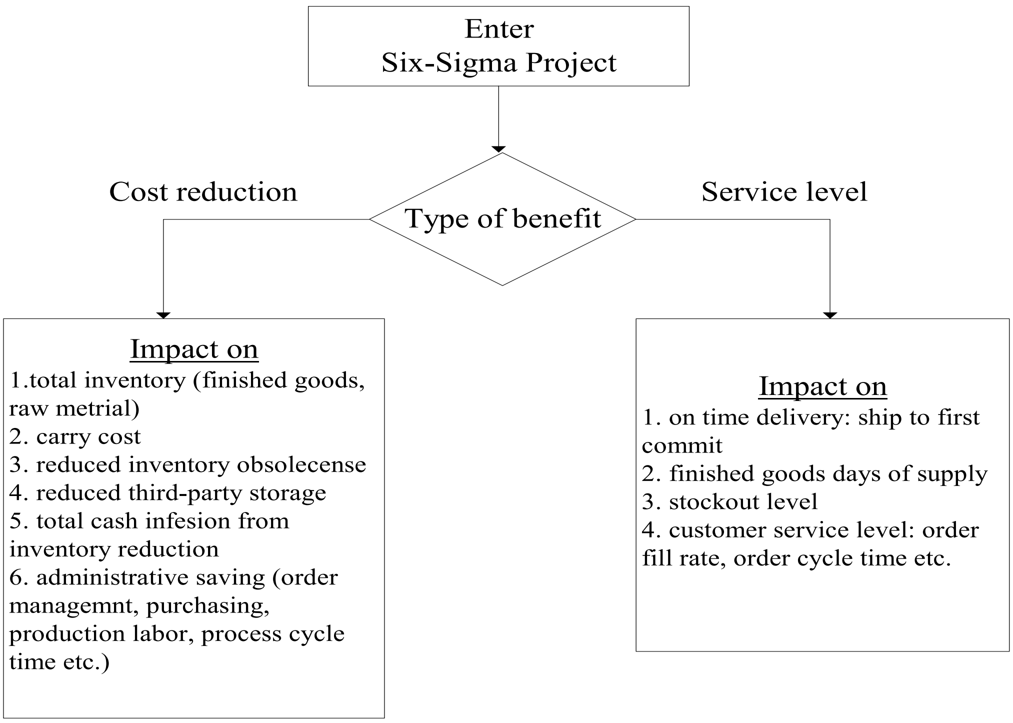

Fig. 2. The flow chart of the project benefits

4. Applying to the supplier development

One major issue in SCM is the supplier development (Avery, 2001). Supplier development involves a long-term cooperative effort between a buying firm (a manufacturer for instance) and its suppliers (i.e. its material providers), and is aimed at creating and maintaining a network of competent suppliers. The development activities include supplier selection and monitoring, supplier assistance and training, the provision of incentives for continuous improvements, and supplier organizational integration. The ultimate objectives of supplier development are supplier base reduction, concurrent engineering, reductions in cycle time, reductions in inventories, and increases in customer satisfaction (Hahn et al., 1990). Grieco (1989) suggests that there should be five steps in the supplier certification process: preliminary evaluation, product design and quality certification, a review of the supply process, performance monitoring, and certification. Raytheon has applied Six-Sigma to improving its supplier development activities. The Raytheon process for supplier development has six steps: the identification of supplier candidates for projects, the definition of objectives and resources, the identification of baseline opportunities (which do not have to focus on cost-cutting) and rank, the analysis of selected opportunities, the implementation of projects, and the documentation and realization of improvements (Avery, 2001). Raytheon's Night Vision camera, which is available on certain Cadillac automobiles, shows how Six-Sigma was used to transform a piece of defense technology into a small, cost-effective, and durable commercial product.

In the Six-Sigma improvement process for the supplier development, the main objective is to constantly and carefully evaluate the supplier's performance. For example, an accurate rating system can maintain competitive pressure on suppliers by monitoring and comparing their improvement over time. In addition, an accurate rating process with multi-dimensional criteria can reduce the risk of encountering "contractual hazard" in buyer-specific investments. To demonstrate how statistical tools can evaluate the supplier's performance, principal component analysis (PCA) is used here. PCA is a statistical method for multivariate data analysis that can be used to reduce the amount of data. It transforms original and related measurement variables into a set of uncorrelated linear functions. The first principal component variable displayed the largest variation among the principal component variables and combines all of original variables in a linear fashion. Similarly, the second, third and the remaining principal component variables have properties that are similar to that of the first principal component variable. That is, the second principal component represents the next largest variation, and so forth. In most practical problems, the analysis of only a portion of component variables is enough to depict most of the variation information of the multivariate data. Moreover, these principal component variables define a lower dimensional subspace in the simple problem. Normally, the information of the multivariate data in this lower dimensional subspace is sufficient to effectively determine the performance. The detailed PCA process is presented in the Appendix. Readers can refer to Johnson and Wichern (1998) for more information. The following is an example that illustrates the procedure.

The measurement data from 25 suppliers of a PC manufacturer in Taiwan includes two major input variables (quality management practice $= x_1$, and employee training $= x_2$) and three major output variables (product quality $= y_1$, price $= y_2$, and delivery $= y_3$). These five variables were measured in a composite score between 0 and 1. However, to maintain confidentiality, the data are normalized. The PCA ranking procedure is based on the ratios of individual inputs and outputs and one more variable takes into account the overall performance of each supplier defined as follows:

$$d_1 = \frac{y_1}{x_1},\ d_2 = \frac{y_1}{x_2},\ d_3 = \frac{y_2}{x_1},\ d_4 = \frac{y_2}{x_2},\ d_5 = \frac{y_3}{x_1},\ d_6 = \frac{y_3}{x_2},\ d_7 = \sum_{i=1}^{6} d_i$$

We have two principal components PC1 and PC2, which account for 99.94%, (62.98% and 36.96% respectively) of the total sample variance. Thus, the performance score of each supplier can be obtained by:

$$\text{Performance Score} = 0.6298 \times \text{PC1} + 0.3696 \times \text{PC2}$$

Table 1 lists the performance scores for all 25 suppliers. The performance evaluation of suppliers can be used to make critical managerial decisions on how to optimize the supplier network, how to effectively allocate resources for supplier development programs, and how to initiate benchmarking and reengineering programs, etc. Here, the performance score from the PCA method provides useful information for the ranking all suppliers. Those suppliers with the leading scores should be classified as the first tier group for long-term relationship. Those with lower performance scores should be encouraged to upgrade their capabilities. Finally, those suppliers that do not eventually achieve the minimum performance score must be eliminated from the supplier base.

Table 1 Performance score for 25 suppliers by PCA

Supplier	Performance Score	Rank
S-18	3.0669	1
S-3	2.9944	2
S-10	2.8738	3
S-17	2.7558	4
S-15	2.7460	5
S-14	2.6875	6
S-6	2.6689	7
S-19	2.5788	8
S-8	2.5522	9
S-4	2.4893	10
S-25	2.3850	11
S-20	2.2795	12
S-24	2.2713	13
S-22	2.2584	14
S-2	2.2519	15
S-5	2.2025	16
S-23	2.1722	17
S-7	2.0802	18
S-21	2.0495	19
S-1	2.0151	20
S-11	1.9723	21
S-16	1.9444	22
S-12	1.8102	23
S-13	1.6695	24
S-9	1.5929	25

5. Conclusions

When a company attempts to improve the performance of its SCM, it is crucial for it to understand the quality of the supply chain network. Hence, the five steps of the Six-Sigma model are designed to facilitate continuous improvement and process control. Six-Sigma is a systematic, data-driven approach to analyzing the root causes of business problems, and is a method for using such measures to analyze, improve, and control the overall quality of the supply chain network. The successful implementation of Six-Sigma depends on committed and effective leadership.

When applying Six-Sigma to supplier development, the concept of continuous improvement can solve the dynamic of the supply chain network. When multiple dimensions are simultaneously considered in evaluating the overall competence of a supplier, the performance score of each supplier can be obtained by the PCA method. Suppliers with high performance scores are likely to sustain a high level of capabilities, and are better candidates for inclusion in an optimized supply base.

Thus, improvement in the quality of all supply chain processes reduces costs and improves the level of customer service. Six-Sigma emerges as a new strategy to enhance the performance of SCM. It is believed that the integration of Six-Sigma into SCM will become a standard practice for any e-business application that seeks an advantage in this highly competitive era of globalization.

References

[1] AVERY, S. (2001) Linking supply chains saves Raytheon $400 million, *Purchasing*, August, pp. 27, 30, 32-34.

[2] BEAMON, B.M. & WARE, T.M. (1998) A process quality model for the analysis, improvement and control of supply chain systems, *International Journal of Physical Distribution & Logistics Management*, 28, pp. 704-715.

[3] BLAKESLEE, J.A. (1999) Implementing the six sigma solution, *Quality Progress*, July, pp. 77-85.

[4] BREYFOGLE, F.W. (1999) *Implementing Six Sigma: Smarter Solutions Using Statistical Methods* (New York, Wiley).

[5] CHOI, T.Y. & RUNGTUSANATHAM, M. (1999) Comparison of quality management practices: across the supply chain and industries, *The Journal of Supply Chain Managemen*t, 1999, 35, pp. 20-27.

[6] FORKER, L.B., MENDEZ, D. & HERSHAUER, J.C. (1997) Total quality management in the supply chain: what is its impact on performance, *International Journal of Production Research*, 35, pp. 1681-1701.

[7] GRIECO, J.P.L. (1989) Why supplier certification and will it work, *Production and Inventory Management Review and APICS News*, 9(5), pp. 38-42.

[8] HAHN, C.K., WATTS, C.A. & KIM, K.Y. (1990) The supplier development program: a conceptual model, *International Journal of Purchasing & Materials Management*, Spring, pp. 2-7.

[9] HAHN, G.J., DOGANAKSOY, N. & HOERL, R.W. (2000) The evolution of six sigma, *Quality Engineering*, 12, pp. 317-326.

[10] HARRY, M. & SCHROEDER, R. (2000) *Six Sigma: The Breakthrough Strategy Revolutionizing the World's Top Corporations* (New York, Doubleday).

[11] HOERL, R.W. (1998) Six sigma and the future of the quality profession, *Quality Progress*, June, pp. 35-42.

[12] HOERL, R.W. (2001) Six sigma black belts: what do they need to know?, *Journal of Quality Technology*, 33, pp. 391-406.

[13] HOUSHMAND, A.A. & RAKOTOBE-JOEL, T. (2000-01) Integrating the supply chain management and continuous quality improvement approaches by use of the integrated supply chain structural analysis method, *Quality Engineering*, 13, pp. 91-106.

[14] JACKSON, J.E. (1980) Principal components and factor analysis: part I - principal components, *Journal of Quality Technology*, 12, pp. 201-213.

[15] JOHNSON, R. A. & WICHERN, D.W. (1998) *Applied Multivariate Statistical Analysis* (Singapore, Prentice-Hall).

[16] MATTHEWS, J., PELLEW, L., PHUA, F. & ROWLINSON, S. (2000) Quality relationships: partnering in the construction supply chain, *International Journal of Quality & Reliability Management*, 17, pp. 493-510.

[17] ROMANO, P. & VINELLI, A. (2001) Quality management in a supply chain perspective: strategic and operative choices in a textile-apparel network, *International Journal of Operations and Production Management*, 21, pp. 446-460.

[18] SOHN, S.Y. & CHOI, I.S. (2001) Fuzzy QFD for supply chain management with reliability consideration, *Reliability Engineering and System Safety*, 72, pp. 327-334.

[19] WONG, A. & FUNG, P. (1999) Total quality management in the construction industry in Hong Kong: A supply chain management perspective, *Total Quality Management*, 10, pp. 199-208.

[20] WYPER, B. & HARRISON, A. (2000) Deployment of six sigma methodology in human resource function: a case study, *Total Quality Management*, 11, pp. 720-727.