

Enhancing Supply Chain Efficiency through Six Sigma: A Comprehensive Review

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ABSTRACT

The application of the Six Sigma approach to manufacturing organizations' supply chains is the subject of this article. The goal of the six sigma methodology is to decrease variances and flaws in goods and services. Since supply chain operations account for 65 to 85% of total costs, applying six sigma can lower costs by cutting waste. Research and development should be conducted to look at implementation challenges and create a model that can be implemented quickly and with fewer resources. This research project is expected to be useful in identifying various models and implementation challenges.

Key Words: Supply Chain Management (SCM), Six Sigma.

1. Introduction

Organizational competitiveness increased as a result of liberalization policies and information technology advancements. Customer joy is just as important to an organization's survival as customer satisfaction. Any business that is unable to adapt its production and quality improvement procedures to satisfy client demands risks going extinct. As a result, businesses create their strategies with their customers in mind. Enhancing the quality of goods and services is essential to ensuring consumer satisfaction. Organizations upgraded plant technology and applied various management strategies, such as Lean manufacturing, Total Quality Management (TQM), Just in Time (JIT), Six Sigma, Supply Chain Management (SCM), etc., in an effort to raise the caliber of their goods and services. Nida Barac et al. (2010) explained type of waste in manufacturing system are overproduction, correction, defects, unnecessary movements of worker, inventory, waiting of materials for processing, extra operation performed, transportation. In recent year large organizations are heavily depends upon their suppliers from small and medium scale for their components and sub-assemblies. Quality culture to be forced in total supply chain to minimize waste, improve consistency and increased efficiency of manufacturing system.

To survive in highly competitive environment it is essential to identify customers' expectations and competitors performance, determine the difference between competitors and own performance and fulfill the difference (Dan Swartwood 2003). Six Sigma is methodology to reduce the defects and variation in processes. The goal of Six Sigma is to squeeze out process variability until the process produces just 3.4 defects per million activities or 'opportunities'.

From the procurement of raw materials to the delivery of completed goods to the client, the supply chain integrates all of these processes. Materials in a supply chain move forward from raw materials to consumers, whereas knowledge moves backward from consumers to manufacturers. Graeme Knowles et al. (2005) estimate that 65 to 85% of overall costs are associated with supply chain operations. Therefore, by concentrating supply chain operations into a single entity and combining them for strategic decision making, cost savings is achievable.

2. Six Sigma

Six Sigma is a quality improvement concept that originated in 1985 at Motorola Inc. in the United States. It aims to achieve near-perfect quality by targeting a defect rate of no more than 3.4 defects per million opportunities (Linderman et al., 2003; Erbiyik & Saru, 2015). Mishra and Sharma (2015) defined Six Sigma as a well-structured management methodology focused on reducing process variations, measuring defects, and enhancing the quality of products and services.

Brun (2011) described Six Sigma as a data-driven approach to eliminating defects, where a defect is defined as anything that results in wasted time, money, lost opportunities, or customer dissatisfaction. According to Schroeder (2008), and Easton and Rosenzweig (2012), Six Sigma utilizes a team of trained experts—Master Black Belts (MBBs) and Black Belts (BBs)—who apply structured problem-solving methods and performance metrics to reduce variation in organizational processes and align improvements with strategic business goals.

The implementation of Six Sigma can significantly benefit organizations by reducing capital expenditures through defect elimination, optimizing the use of existing capacities, increasing employee motivation and morale, and improving the effectiveness of research and development efforts. This leads to shorter engineering development cycles and more consistent product and service quality.

Several key factors contribute to the successful implementation of Six Sigma in an organization. These include top management support and commitment, provision of necessary resources, a proactive and data-driven culture, and the formation of a special organizational structure involving cross-functional specialists (Yun, 2003; Hsien et al., 2007; Moharana, 2012). Additional success factors include a structured project selection and prioritization process, fair and accurate project evaluation, linking Six Sigma to business strategies, and maintaining strong relationships with customers and suppliers. Recognizing and rewarding employees also plays a critical role in sustaining motivation and commitment.

The core methodology used in Six Sigma implementation is the DMAIC framework (Define – Measure – Analyze – Improve – Control), a structured, step-by-step problem-solving process that ensures disciplined execution (Yun, 2003; Chakravarti, 2009; Easton, 2012; Erbiyik & Saru, 2015).

Steps	Explanation	Tools and Techniques
Define	Identification of cause and source of defects, variation and scope of process improvement to satisfy customer requirement. Define the problem clearly and express objectives in terms of numerical as far as possible.	Brain Storming, Five 'why' analysis, Survey, Voice of customer, Statistical data analysis, Cost benefits analysis.
Measure	Quality parameters are selected to measure current performance and sources of variation.	Histogram, Pareto analysis, Scatter diagram, Statistical process control charts, Benchmarking, Quality cost.
Analyze	Critical study and examination of existing processes are carried out to find cause of defects, variation and scope of improvement to achieve objectives of defined projects.	Cause and effect Diagram, Brainstorming. Control charts, Pie charts, ANOVA,

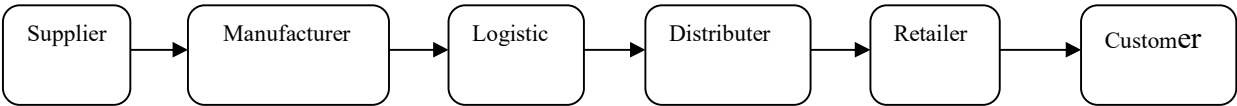
		Flow Diagram, Design of Experiments, Regression analysis, Scatter Diagram.
Improve	Design, redesign, or modify existing process and implement it to eliminate defects.	Brainstorming, Flow Diagram, Design of Experiment, Process capability, Process Sigma, Process maps.
Control	Control parameters for new processes are determined and control plans are implemented to prevent recurrence of defects.	Quality process control charts, Sampling,

Table 1: DMAIC approach with tools and techniques.

3. Supply Chain Management

Supply chain consist chain of supplier (Raw materials, components), manufacturer, transporter, distributor, wholesaler, retailer and customers. Fig 1 shows supply chain network of manufacturing organization.

Flow of Information



Flow of Materials



Fig 1 Supply Chain Network of Manufacturing Organization

According to Swartward (2003), a supply chain is an integrated process involving five key functions: planning, sourcing, making, delivering, and returning. In a typical supply chain, materials flow in a forward direction—from manufacturers to customers—while information flows in the reverse direction, from customers back to manufacturers. The complexity of supply chains arises from the involvement of multiple organizations, often spread across regions or countries.

A significant portion of operational costs in an organization is tied to supply chain activities. As per Knowles et al. (2005), approximately 65% to 85% of total costs are directly related to supply chain operations. In the Indian context, the Centre for Monitoring Indian Economy (CMIE) reported that Indian companies spend about 17% to 18% of their net sales on logistics, with inventory-related costs accounting for approximately 13.1%, compared to the global average of 9% to 12%.

Despite its strategic importance, supply chain management in many organizations faces persistent challenges. These include demand fluctuations, long and complex supply chains, reluctance to share information due to top management attitudes, inadequate communication infrastructure, high transportation and inventory costs stemming from poor logistics infrastructure, extensive documentation, and supplier unreliability (Srivastava, 2006).

To enhance the performance of supply chains, it is essential to view and manage the entire supply chain as a unified system, integrating all members to collaborate effectively. The goal is to eliminate waste, reduce lead times, and increase customer satisfaction by delivering high-quality products and services on time and at a lower cost (Hines, 2004). Sreerag and Regikumar (2013) defined supply chain management as the effective integration of all entities involved in the chain to ensure that the right product is delivered in the right quantity, at the right time, and at the right place.

4. Six Sigma in Supply Chain Management

A supply chain is made up of a lengthy network of manufacturers, distributors, suppliers, logistic managers, and customers. Any supply chain participant's inconsistent performance can cause variations in lead time, stocks, prices, and on-time delivery. Demand fluctuations, order size and composition, pricing, data accuracy, vendor capacity to fulfill quality, delivery time, and quantity are all factors that affect supply chain management (Graeme Knowles et al 2005). Using statistical tools and techniques, six sigma methodology aims to identify the underlying causes of process variation and defects and optimize the process by decreasing process variation, process defects, and process capability. Six sigma in supply chain management (SCM) can lower variability, boost consistency, and increase supply chain efficiency, making it more economical, adaptable, and responsive to client demands.

Six sigma in supply chain management (SCM) can lower variability, boost consistency, and increase supply chain efficiency, making it more economical, adaptable, and responsive to client demands. According to Chang Tseh Hsieh et al. (2007), in order for enterprises to successfully apply six sigma, they must take into account the following criteria in their strategic vision.

- Focus on Customer Requirement: Organization policies are framed by voice of customer.
- Data and fact driven management: Effective measurement system to measure actual output. Actual data compare with planned if deviation occurred corrective action should be taken.
- Continuous Improvement: Processes must be designed, redesigned time to time to meet change in customer and business requirement.
- Proactive Management: Management must anticipate problems and changes in requirements of customer and business and act accordingly.
- Boundary less collaboration: Integrating internal groups, customer, suppliers and other member of supply chain as a single unit.
- A drive for perfection: Motivate and give freedom to people to test new approaches even while managing the risks and learning from the mistake.

4.1 Tools and Techniques:

- Balanced Score card (BSC): It is use to monitor organization performance against strategic goals. It is management system by which organization define their vision and strategy and translate them into action it also provide feedback to continuously improve strategic performance and result.
- Supply Chain Operational Reference (SCOR): SCOR model used to analyze supply chain and identifies improvement opportunities in material flow and information flow. It integrate concept

of business process re-engineering, Benchmarking and process measurement technique to improve overall performance of supply chain.

- Process Mapping Tool: It is graphical representation of process showing the sequence of activities using modified version of standard flow chart. It is use to analyze the define problem.
- Analytical Hierarchy Model (AHP): AHP is decision model which contain list of alterative and hierarchy of criteria. It can use for suppliers evaluation, project selection and prioritization.
- Failure Mode and Effect Analysis (FMEA): FMEA is identify, define and eliminate known or potential failures, problems and error from products, design, system and services before reaches to customer.
- Decision Making Trial and Evaluation Laboratory (DEMATEL): It is comprehensive method for building and analysis a structural model involving relation between complex factors.
- Analytical Network Process Model (ANP): It is network that replaces single direction relationships with dependence and feedback.
- Lean analysis, simulation, benefit sharing and communication and maturity models are some tools which also use in six sigma implementation in SCM.

4.2 Steps of Implementation:

Six sigma implementation in SCM require following steps.

- Step1: Integrate all supply chain members as single entity and improvement action should be started in entire supply chain. It requires boundary less collaboration of internal groups, customer, suppliers and other members of supply chain
- Step 2: Develop business policies on the basis of customer voice. Management should anticipate problems and changes in requirements of customer and business and act accordingly. Needs of customers are evaluated and business policies should be framed accordingly.
- Step3: Develop effective performance measurement system. Performance criteria are identified and current performances are measured. Supply chain performances are evaluated on parameters like reliability, responsiveness, agility, and cost.
- Step 4: Identify and select appropriate project to meet business objective. Project selection is one of the most critical success factors in implementation of six sigma.

Methods of project selection are as follows.

Project Identification: Customer is at the center while formulating business policies. Business organizations determine their policies to achieve organizational goal of customer satisfaction, business excellence, revenue growth and market share. Projects are identified to meet organizational goals.

Project Benefit Analysis: Financial benefits like reduction in cost, return on investment, reduction in rejection and rework, market share, operational excellence and non-financial benefits like customer loyalty and employees moral of each identified projects are evaluated.

Project Risk Analysis: Risk of over budgeting, time delay and probability of project failure are evaluated.

Project Mapping: Projects are mapped on the basis of benefits and risk. Project are categorized into various groups like high benefit – high risk, high benefit – medium risk, high benefit and lower risk etc.

Project Prioritization and Selection: Priority of project decided on the basis of project mapping. Project is selected on the basis of its priorities.

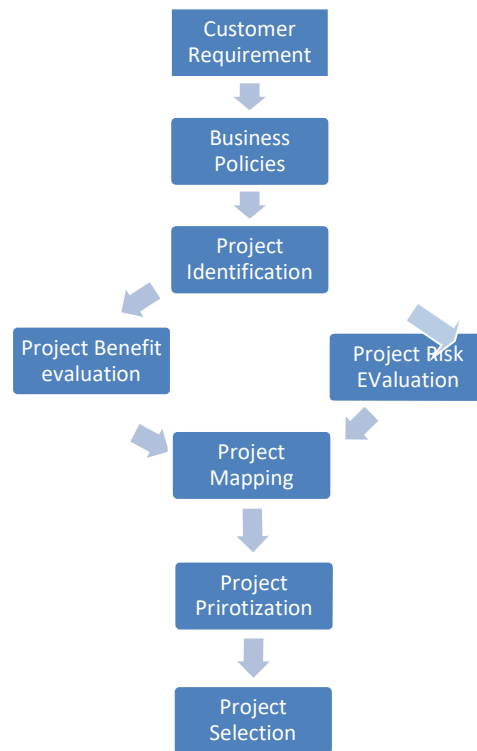


Fig. 2 Project Selection Steps

(Chao-Ton Su and Chia-Jen Chou, 2008; Gulcin Buyukozkan and Demet Ozturkcanto, 2010; Abbas Saghai and Hoesein Didekhani ,2011)

- Step5: Facts of selected projects are measured by developing models to measure base line, setting performance standard and confirming critical to quality issues.
- Step6: Critical study and examination of existing processes are carried out to find cause of defects, variation and scope of improvement to achieve objectives of defined projects.
- Step7: Improve process to attain objectives of project. Various improvement techniques like Design of Experiments (DOE), 5S, process sigma are applied to improve process and achieve objectives of projects.
- Step8: Develop control parameters for new system to prevent recurrences of defects. . Standardization, mistake proofing new process, developing control and response plan are some techniques use to prevent recurrences of defects.

Graeme Knowles et al (2005) suggest conceptual model to implement Six Sigma in SCM by dividing supply chain into strategic cycle and operational improvement cycle. Fig 2 shows implementation model developed by Graeme Knowles et al.

Sr. No.	Steps	Tools and techniques
1	Integration of Supply Chain.	Enterprise Resource Planning (ERP).
2	Develop objectives of business,	Voice of Customer, Strategic Analysis Matrix.
3	Develop performance measurement system.	Business Score Card(BSC), Supply Chain Operational Reference (SCOR) ,
4	Select project for improvement.	Cost and Benefit Analysis, Project Risk Analysis, Process Mapping, Analytical Hierarchy Model (AHP).
5	Measure current performance and variations.	Statistical process control charts, Benchmarking, Quality cost.
6	Analyze cause for variations.	Root Cause Analysis, Decision Making Trial and Evaluation Laboratory (DEMATEL), Analytical Network Process Model (ANP), Analysis of Variances (ANOVA).
7	Improve the process to achieve objectives of project.	Failure Mode and Effect Analysis (FMEA), Design of Experiment (DOE), Simulation Tools
8	Develop control parameters for improved system.	Operational Score Card, Standardization, Process Control Chart.

Table 2: Steps of implementation of Six Sigma in Supply Chain Management.

4.3 Hurdles in implementing Six Sigma in SCM:

Lack of top management commitment, an organization culture that resists change, a lack of funding, a lack of customer support, a lack of knowledge and trust among SC members, inadequate transportation and logistics infrastructure, and a lack of training and competency levels to maintain SC operations and implement new technology to increase its efficiency are the main obstacles to implementing six sigma in SCM (Sanjay Jharkharia and Ravi Shankar 2004, Kiran Bala 2014, Sunil Luthra et al 2015).

5. Conclusion

By lowering costs, quality variance, delivery times, and waste, the six sigma methodology in supply chain management can enhance an organization's performance. It increases the efficiency, flexibility, and reactivity of the supply chain. The attitude of senior management, the availability of resources in small and medium-sized businesses that are supply chain participants, the size of the supplier base, legislative restrictions, and a lack of trust among participants are the main obstacles to implementing six sigma in supply chain management.

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