Implementation of Lean Six Sigma (LSS) in supply chain management (SCM): an integrated management philosophy

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Abstract: Supply chain management (SCM) is essential for any company to survive the increasing pressures of global competition. There have been continuous changes in global manufacturing and service markets, causing supply chain (SC) members to reassess their effectiveness individually and as a whole. A new evolution in quality management (QM) is Lean Six Sigma (LSS), which is a continuous improvement (CI) methodology that aims at customer satisfaction and system waste reduction. SCM can utilise the QM concepts as well as the LSS tools and CI principles to achieve high levels of customer satisfaction regarding cost, quality and delivery. Researchers have considered the integration of Lean and Six Sigma with SCM. This research extends the previous works and proposes the implementation of LSS in SCM. A case study provides an example of how LSS, utilising value stream mapping (VSM), can be used to improve an SC.

Keywords: supply chain management; SCM; quality management; QM; just-in-time; JIT; continuous improvement; CI; Lean Six Sigma; LSS; value stream mapping; VSM.

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1 Introduction

Lean and Six Sigma are developments in continuous improvement (CI) methodology. Lean Six Sigma (LSS) is an approach that combines Lean and Six Sigma tools and philosophies to focus on improving quality, reducing process variation, and eliminating non-value added activities. Its goal is to improve quality by first identifying waste within the organisation; systematically eliminate this waste, and then reduce process variation. A quality programme that the entire organisation can engage in is created, by combining the two methodologies, as each builds upon the other's strengths (Salah et al., 2010a).

In today's supply chain management (SCM) system, because of increasing competition, the supplier is demanded to offer a high quality product with minimum cost to the market.

Despite LSS being around for over 25 years now, a significant number of companies still do not really know what it is. LSS uses the define-measure-analyse-improve-control (DMAIC) process of define, measure, analysis, improve and control to solve problems. The methodology is data centric with excellent tools that are powerful because they offer statistical validity.

However, benefits depend highly upon effective implementation of LSS in SCM, which is often problematic. Hendricks and Singhal (1996) studied the performances of 3,000 firms; many of which use LSS effectively. They compared the LSS firms to similar companies without formal LSS. They found LSS firms were significantly stronger in terms of profitability, return on assets and stock performance. The findings of Hendricks and Singhal (1996) provided an evaluation of the implementation of an integrated approach.

There is a direct relationship between CI and SCM (Salah et al., 2010b). The understanding of supply chain (SC) dynamics or relationships is a key driver of business performance. There is a relationship between total quality management (TQM), SCM and just-in-time (JIT) at the strategic level (Kannan and Tan, 2005). Also, focusing on SC and JIT characteristics can help improve product quality (Tan et al., 2002). The key issue of how SCM is integrated with other operational performance initiatives, such as Lean manufacturing and TQM is still being explored and developed (Ballou et al., 2000; Miller, 2002). This also applies to Six Sigma and LSS.

SCM can utilise the JIT and LSS principles such as focusing on adding value to customers, reducing defectives, streamlining value flow to customers, pulling instead of pushing, choosing few best strategic suppliers, reducing inventory, waste and improving on time delivery, more frequent deliveries of less quantities and delivery to point of use. SCM brings all trade partners together and focuses on an inter-organisational perspective to achieve optimisation and efficiency (Cooper et al., 1997; Lamber and Cooper, 2000). This matches with Taguchi's principle of the minimum loss to the society.

Improving SCM includes the focus on inventory, transportation costs and the SC partners. A trade off needs to exist between the interrelated inventory and transportation costs in order to achieve a higher reduction in total logistics costs (Blumenfeld et al., 1987). A study of the US food industry indicated that an annual waste of $30 billion resulted from the poor coordination among SC partners (Fisher, 1997). One of the observations by Tan et al. (2002) indicated that a realistic approach to SCM is to focus on immediate suppliers and customers. For example, locating next to suppliers has a positive impact on market share. Also, the quality level is more important than product price in the supplier evaluation process. Juran's trilogy consists of quality planning, quality control and quality improvement which all apply to the supplier relations (Baston and McGough, 2007).

The next few sections of this paper aim at introducing SCM and LSS. This is then followed by a discussion of SCM and quality management (QM), and a discussion of LSS and SCM. This research extends the previous works and proposes the implementation of LSS in SCM. Finally, a case study is provided to illustrate how LSS can be utilised to improve an SC.

2 Supply chain management

LSS is a combination of two popular CI methodologies: Lean and Six Sigma. Lean and Six Sigma focus typically on improving the production and transactional processes of an organisation. Although each uses different methodologies and principles to effect the improvement, both have complementary effects (O'Rourke, 2005).

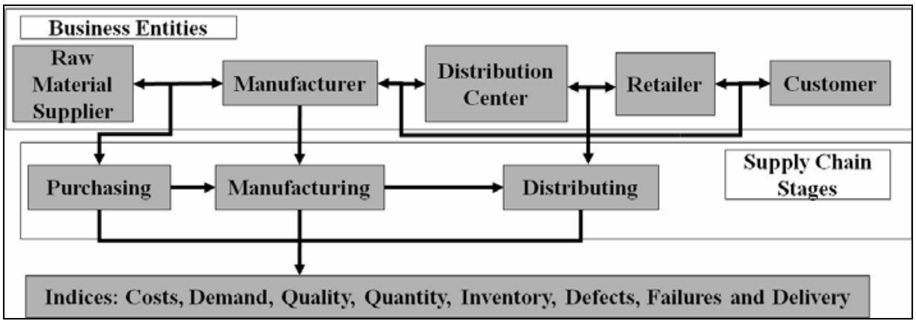
Each of these methodologies has been individually popularised by successful implementations at companies such as Toyota and General Electric. However, these implementations were not without some difficulty. The experiences of the first implementations of Lean and Six Sigma methodologies are unique based on leadership and culture. Subsequent implementations of Lean and Six Sigma have benefited from the literature and experiences produced by these pioneering companies (O'Rourke, 2005).

Nevertheless there is not much research in the literature describing the status of Six Sigma applications in SC including its focus, tools and techniques utilised, benefits and limitation. It is important to describe the status of Six Sigma implementation in the SC to help companies as a benchmarking exercise including tools and techniques, fundamental metrics, potential savings and reasons for potential failures among others (Raj and Attri, 2010).

An SC is the entire network of activities of a firm which link suppliers, warehouses, factories, stores and customers. These activities not only include material flow, but also, services, information and funds (Nahmias, 2009). SCM is about integrating the processes and optimising the efforts of all members of the chain to improve quality, responsiveness, pricing, material flow, add more value to customers, and reduce materials costs (Kannan and Tan, 2005; Chan and Chan, 2006). SCM is a new management philosophy viewed as an initiative focusing on the coordination of the manufacturing, logistics, materials, distribution, and transportation as well as on how companies utilise their suppliers' capabilities to improve competitive advantage. It is the chain that links processes of different organisations from raw materials to the end user, which can be extended to the after-sale services and recycling (Tan et al., 2002). Other examples of researchers who studied SCM include Bowersox and Closs (1996), Lalonde and Pohlen (1996), and Mentzer et al. (2001).

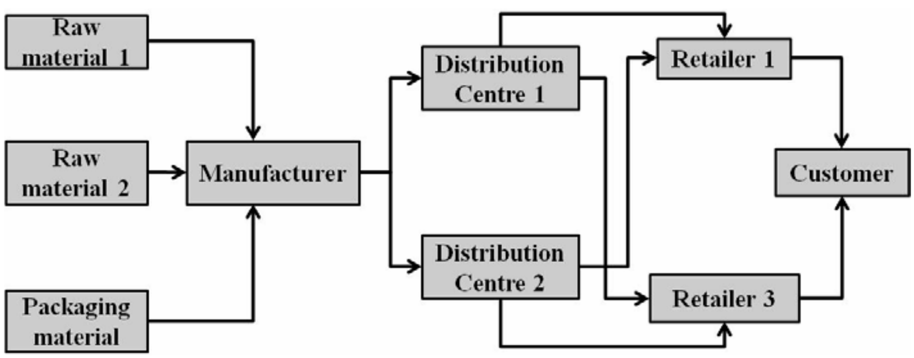
Also, SCM is a set of approaches used to achieve the efficient integration of the SC entities in order to produce and distribute the right quantities, at the right time, to the right place, so that system-wide costs are minimised without sacrificing service requirements (Simchi-Levi et al., 2003). The objectives of the SCM are productivity improvement, inventory reduction and cycle time reduction in the short-term and the improvement of customer satisfaction, profit across the whole SC and market share in the long-term (Tan et al., 1998). The SC business entities as well as its main stages and their indices are shown in Figure 1. The SC is also referred to as the logistics network (see Figure 2).

Figure 1 Integrated SC entities and stages



Source: Adapted from Antony et al. (2006)

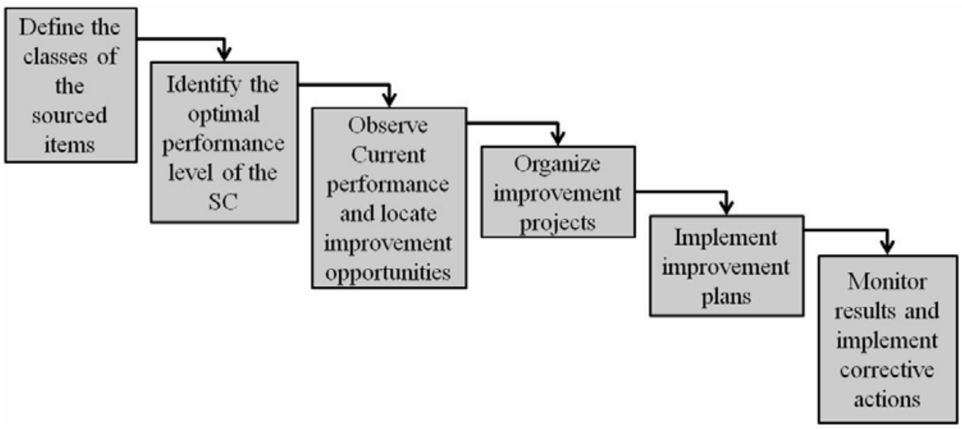
Figure 2 A generic example of an SC



The term SCM emerged from Procter and Gamble in the early 1980's as they tracked the flow of goods in the distribution channel. The focus in organisations has been shifting to the cost opportunities in the SC since the traditional focus of firms, i.e., manufacturing, has become relatively efficient. The primary trade-off in SCM is between cost and time to respond (Nahmias, 2009). In addition to being fast and cost-effective, a superior SC is agile, adaptable and aligning all of its partners' interests to satisfy customers (Lee, 2004).

The concept of SCM has grown from inventory management to overall operations management (Yang et al., 2007). SCM is about the efficient performance of activities such as handling products, partnerships, new product development, promotions, etc. It does not only focus on products flow, but also on life cycle from the process, product and SC design, through promoting and merchandising to fulfilling demand (Kopczak and Johnson, 2003). The literature revealed that SCM either focuses on the transportation and logistics function, the purchasing and supply function, or the integrated material management function which includes the previous two functions (Tan et al., 2002).

Figure 3 SC strategic planning process



Source: Adapted from Foster (2007)

Deliveries to all intermediate points in the SC, which is a dynamic discrete event system, have to be controlled with low variability (synchronised) to make the SC efficient (Antony et al., 2006). This is important to achieve lower levels of inventory through on time delivery of more frequent and smaller batches of products. An effective SCM requires a strategic planning process as in Figure 3. This process greatly resembles Deming's plan-do-check-act (PDCA) cycle. To achieve its full impact, SCM needs to be fully implanted in the business strategy and considered throughout the product life cycle (Kopczak and Johnson, 2003).

The initial step in formulating an effective SC strategy is to understand the demand of supplied products, which can be classified into functional (which requires an efficient SC to supply the predictable demand) or innovative (which requires a responsive SC to supply the unpredictable demand) (Fisher, 1997). To build an effective SC, firms must shift from being functionally based to business process-focused, internally and across the SC. This has lead to the development of frameworks to link strategy, SC processes and proper performance metrics across organisations (Amer et al., 2007). SCM practices include (Tan et al., 2002; Kannan and Tan, 2005):

- integration of activities across the SC and becoming more responsiveness
- establishing a communication system and frequent contacts with all SC members
- communicating future strategic needs to all SC members
- the use of cross-organisational teams
- building trust among SC members and involving them in planning of marketing
- identifying additional markets (the SC can extend beyond immediate members)
- participating in the market efforts of own customers
- participating in the suppliers' sourcing decisions and involving them in the product and process design as well as production planning
- partnering with the few best suppliers to improve their management
- outsourcing non-strategic activities in order to focus on the core ones internally
- determining customer future needs and contacting customers for feedback
- locating close to customer and requiring supplier to locate close to own business
- increasing on time delivery and JIT abilities of own firm and of partners.

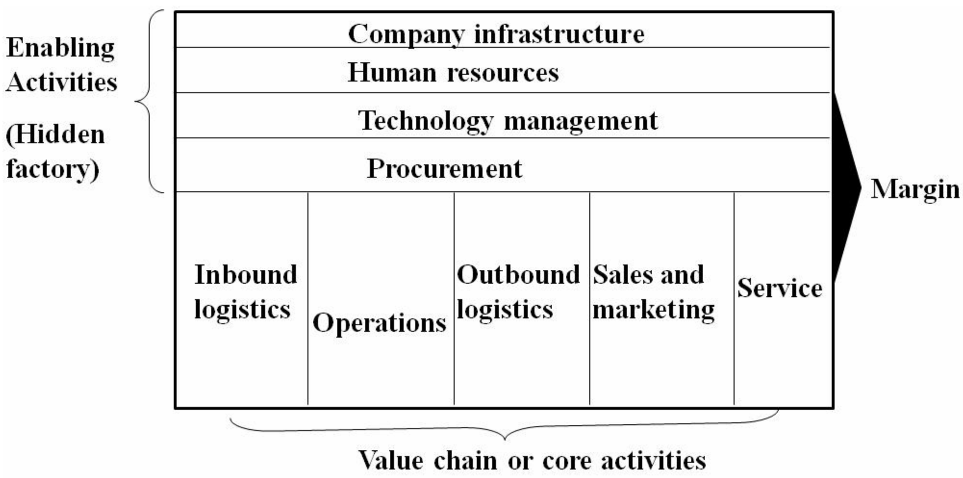
SCM activities encompass the strategic levels (including decisions of long-lasting effects on the system), tactical levels (including decisions updated regularly) and operational levels (including daily decisions). SCM includes decisions related to issues such as distribution network configuration, inventory control, supply contracts, distribution strategies, SC integration and strategic partnering, outsourcing and procurement, product design, information technology and decision-support systems, and customer value (Simchi-Levi et al., 2003; Manzini et al., 2008). Operational SCM key performance indicators (KPIs) include cycle time, utilisation rate, forecasting accuracy and lead-time, whereas financial KPIs include sales, material, transportation and inventory (Yang et al., 2007).

SCM has caused six main shifts in business focus from: cross-functional to cross-enterprise integration, physical efficiency (producing and distributing) to market mediation (matching supply with demand while remaining efficient), improving supply processes to coupling that with getting earlier demand information and affecting demand (using or eliminating promotions, synchronising planning cycles, sharing information, streamlining replenishment using vendor-managed inventory as an example), single-company product design to a collaborative and concurrent design of product, process and SC (i.e., design for SCM), cost reduction to breakthrough business models, and, mass-market supply to tailored offerings by integrating the company's SCM, customer relationship management (CRM) and enterprise resource planning (ERP) systems, to increase the customer's loyalty (Kopczak and Johnson, 2003).

SCM implementation is complex and difficult. Difficulties in SCM are due to the challenge of designing and operating an SC, while minimising the total system-wide costs (global optimisation arising from the complexity of the SC network, the conflicting objectives of the different elements of the SC, the continuous change in the elements of SC, and the variations in demand and costs) as well as maintaining the total system-wide service levels and the uncertainty in customer demand forecast (arising from the challenge of matching supply and demand, the considerable variation in inventory and back-order levels across the SC, inaccuracy of forecasting, and the additional sources of uncertainty to the demand, such as delivery lead times and manufacturing defects) (Simchi-Levi et al., 2003).

The value chain is a tool, which disaggregates a company into its core activities to reduce costs and find sources of competitiveness (see Figure 4). The value system is composed of a group of value chains. One of the significant aspects of the value chain is the connection between a chain of suppliers and consumers. The SCM concept extends the value chain economic concept and provides a more realistic view of it (Foster, 2007).

Figure 4 Michael Porter's value chain



Source: Adapted from Foster (2007)

SC considerations add a third dimension to concurrent engineering (Nahmias, 2009). An example of an SCM model that utilises software is the supply chain operations reference (SCOR) model (Dasgupta, 2003) which is considered as an extension of business process reengineering (BPR). It is based on five levels: plan, source, make, deliver, and return. However, it lacks analytical tools for problem solving and may not provide the flexibility to adapt to SC variability (Amer et al., 2007).

3 Lean Six Sigma management

The integration of Lean and Six Sigma overcomes the shortcomings of both; they compliment each other. Integration can help an organisation achieve results faster and more efficiency. An important goal of production processes and SCs is reducing the order-to-cash cycle. Lean is a CI methodology that has as its goals to improve quality, eliminate waste, reduce lead-time, and reduce total cost of a process. Ohno derived the Lean Methodology from the Toyota Production System. He stated, "The most important objective of the Toyota system has been to increase production efficiency by consistently and thoroughly eliminating waste", which emphasised the link with improved business results (Ohno, 1988). The focus of Lean is on the removal of non-value added steps in an effort to increase process speed and to give the customer what they value. In practice, this typically involves identifying value, defining the value stream, determining flow, defining pull, and improving the process.

Six Sigma is defined as a statistic, a philosophy, and a CI methodology (O'Rourke, 2005). It focuses on reducing variation, with Sigma representing the measurement of standard deviation from the mean of a process. As a quality statistic, Six Sigma allows 3.4 defects per one million opportunities and is related to the cost of quality. The philosophy of Six Sigma is the use of data and statistical analysis tools for systematic processes improvement. O'Rourke (2005) provided a detailed explanation of the Six Sigma methodology as a five-phase, disciplined approach to CI. The five-phases are define, measure, analyse, improve, and control. These phases are referred to as DMAIC.

During the define phase, projects are organised, improvement goals are set, and the overall value of the project is determined. During the measure phase the process is mapped and relevant data are collected. The analyse phase is then used to apply statistical tools to the collected data to determine process capability and sources of variation. The improve phase uses the knowledge gained from the measure and analyse phases to generate possible solutions. The project then moves into the control phase. During that phase the improved process is validated and handed over to the process owner.

Six Sigma focuses on eliminating the variation within the process and assumes that once the variation is minimised the process is improved. To eliminate the variation, Six Sigma uses advanced statistical analysis tools to investigate and isolate the sources of variation.

Lean is concerned with improved process flow, whereas Six Sigma is concerned with reduced process variation. Their approach to waste differs in that in Lean if something does not add-value it is considered to be waste, whereas in Six Sigma variation is waste.

In the practice of 'Lean', the focus is on breaking down processes to the 'bare bone essentials. Six Sigma is a 'problem focused' methodology, and the primary toolsets are Math and Statistics.

Six Sigma and Lean go together hand in hand, although they often are differentiated. Despite any distinctions, the two go very well together and complement one another. As Lean is used to achieve improved process flow, a deeper understanding of the process is developed. If more work is needed, Six Sigma can be used to reduce process variation. They can be effectively deployed together.

Six Sigma is a structured approach used to achieve lower-levels of variability. Lean is a methodology that is used to eliminate waste, variation (any activity that deviates from a target or a standard causing defects), and work imbalance. The integration of the industrial engineering tools of Lean with the statistical tools of Six Sigma (which complement each other) into LSS provides an operational excellence methodology and represents a new wave of the QM evolution (Basu, 2004), which started in the 2000's (Byrne et al., 2007). The integration of key improvement activities in an organisation such as Lean and Six Sigma into the strategic goals is a key foundation to achieve CI (Kaye and Anderson, 1999). The integration of Lean and Six Sigma achieves a full fusion of the Lean philosophy of waste elimination with the Six Sigma mentality of perfection at all times. TQM and LSS are similar in many aspects and compatible with each other. They share numerous values and aims and can benefit from the advantages that each can provide. TQM can be the holistic umbrella that reaches to all stakeholders and LSS can be the extension that provides a strong structure for achieving greater and faster process improvements. George (2002) defines LSS as a methodology that helps companies achieve better cost, quality, speed, customer satisfaction and rates of improvement. LSS can also be described as a methodology that focuses on the elimination of waste and variation. It follows the effective DMAIC structure to achieve customer satisfaction with regards to quality, delivery and cost. After starting a LSS project, it may evolve to use more Six Sigma or Lean tools or a mix of both as suitable to the nature of the project where all tools are LSS tools (Hendricks and Kelbaugh, 1998).

The LSS approach starts with the identification of the need for an improvement initiative. In the define phase, the problem and the goal of the project are chartered and an analysis is performed to quantify its cost-of-poor-quality (COPQ), wasteful activities and the expected financial savings. Value stream mapping (VSM) is a lean manufacturing technique to analyse the flow of materials and information currently required to bring a product or service to the customer. The baseline performance is studied in the measure phase using LSS metrics and VSM of current chain. Also, brainstorming is performed to identify the list of the potential inputs, which are investigated in the analyse phase to verify the critical few negatively affecting the outputs such as product quality and flow. VSM is drawn for the future state. In the improve phase, the critical inputs are studied to determine the solutions, which are implemented through Kaizen events for example. Lastly, in the control phase, the focus is on monitoring the inputs and/or outputs of the improved processes on a day-to-day basis to ensure that the anticipated gains are maintained.

The development of Six Sigma did not eliminate the use of TQM or SPC, but its popularity has established it as an organisational methodology to deliver CI (O'Rourke, 2005). Unlike the development of Six Sigma, LSS consolidates two major CI methodologies into a single holistic approach. Although Lean and Six Sigma focus on different improvement goals, the reduction of waste and process variation, a thorough analysis of each method shows that the methods complement each other. "In a system that combines the two philosophies, Lean creates the standard and Six Sigma investigates and resolves any variation from the standard" (Breyfogle et al., 2001).

Table 1 Differences between Lean and Six Sigma

Issues problems objectives	*Six Sigma*	*Lean*
Focuses on customer value stream	N	Y
Focuses on creating a visual workplace	N	Y
Creates standard work sheets	N	Y
Attacks work-in-progress (WIP) inventory	N	Y
Focuses on good house keeping	N	Y
Process control planning and monitoring	Y	N
Focuses on reducing variation and achieve uniform process outputs	Y	N
Focuses heavily on the application of statistical tools and techniques	Y	N
Employs a structured, rigorous and well planned problem-solving methodology	Y	N
Attacks waste due to waiting, over processing, motion, over production, etc.	N	Y

Source: Adapted from Antony et al. (2003)

Table 2 Comparison of Lean and Six Sigma methodologies

Programme	*Lean*	*Six Sigma*
Theory	Remove waste	Reduce variation
Application guidelines	1 Identify value	1 Define
	2 Identify value stream	2 Measure
	3 Flow	3 Analyse
	4 Pull	4 Improve
	5 Perfection	5 Control
Focus	Flow focused	Problem focused
Assumptions	Waste removal will improve business performance.	A problem exists.
	Many small improvements are better than systems analysis.	Figures and numbers are valued.
		System output improves if variation in all processes is reduced.
Primary effect	Reduced flow time	Uniform process output
Secondary effects	Less variation	Less waste
	Uniform output	Fast throughput
	Less inventory	Less inventory
	New accounting system	Fluctuation-performance measures for managers
	Flow-performance measure for managers	Improved quality
	Improved quality	
Criticisms	Statistical or system analysis not valued	System interaction not considered
		Processes improved independently

Source: Nave (2002)

The theories guiding Lean and Six Sigma methodologies are different but complementary. Both seek to improve the process. Lean assumes that waste removal will speed up the process thereby improving business performance. Six Sigma assumes that process variations cause process problems and that reducing process variation will improve business performance. The key to comparing the two improvement methods is not only the focus of each, but also on the secondary effects (O'Rourke, 2005). As highlighted in Tables 1 and 2, the secondary effects of each methodology mirror the primary focus of the other method. The use of Lean tools within a Six Sigma project approach allows for focus on managing and controlling inventory and work in progress. This allows for a team to begin realising improvements within a process even during the Measure phase of the project. Conversely, is using VSM to identify improvements within a value stream, root cause analysis and brainstorming may identify opportunities better suited for Six Sigma projects. The integrated approach allows organisations to achieve results at all project levels and sizes, from point improvements on the shop floor, to complex projects requiring significant analysis.

4 Supply chain management and quality management

QM involves flows of material, information, funds, etc., through an SC. The SC encourages the expansion of the vision of processes, including upstream and downstream processes. It involves the integration of different functions, processes, and quality dimensions, which can be seen in Table 3. Across the SC process, there are different perceptions of quality, which are important to understand in order to communicate properly and resolve differences. The QM-related activities, which are part of SCM, can be classified into (Foster, 2007):

- upstream activities, which include supplier qualification (using grading approaches, such as International Organisation for Standardisation (ISO) 9000: 2000 and acceptance sampling), supplier development (including the use of electronic data interchange (EDI) to link customer purchasing systems to supplier ERP systems)
- core process activities including CI and VSM activities
- downstream activities, which include logistics, customer support and after-sale.

Kanji (1998) proposed a business excellence model to satisfy the organisations' need for a comprehensive and flexible framework to measure business excellence. Utilising that model, Kanji and Wong (1999) proposed a structured model for SCM that is based on TQM principles. The next section discusses how LSS, which can be considered as a QM and CI methodology, can be integrated with SCM.

Table 3 Product and service quality dimensions

Garvin's product quality dimensions	*Service quality dimension*
Performance	Tangibles
Features	Empathy
Reliability	Service reliability
Conformance	Assurance
Durability	Responsiveness
Serviceability	Availability
Aesthetics	Professionalism
Perceived quality	Timeliness
	Completeness

Source: Adapted from Foster (2007)

5 SCM and LSS management

SCM lacks analytical tools for problem solving and may not provide the flexibility to adapt to SC complexity and variability that lies in the changing market segments and demand (Amer et al., 2007). Some of the key goals for a successful organisation and its suppliers are to digitalise the transactional processes, to enhance the EDI capabilities, and to eliminate wasteful activities and reduce the total SCM costs by using CI methodologies and modern electronic systems (Dasgupta, 2003). In what follows, a discussion is presented of how different researchers considered the integration of Lean and Six Sigma with SCM, respectively.

One of the important concepts of Lean, which is stressed in the enterprise VSM exercises used to improve SC processes (Foster, 2007), is seeing things from the perspective of the whole enterprise SC and not the individual process or entity. For example, rewarding a business entity or process for producing more than what the next business entity in the SC requires (as a customer of the former entity) does not generate any benefit for the SC from the whole SC perspective. On the contrary, this creates more staged inventory and waste. LSS implementation in SCM embraces the principles of JIT. Products need to be delivered on time, with the right quality, the right quantity and at low cost. JIT delivery, which heavily depends on suppliers, is important for the success of JIT production. The Lean approach to SCM can also be described as the Lean logistics approach aiming at reduction of inventories, wastes and lead times (Foster, 2007).

Parveen and Rao (2009) indicated that there is a need for an integrated approach to Lean manufacturing from the perspective of the Lean SC to achieve total leanness across the SC. The nature of the market sector has a direct impact on the Lean approach for any SC. Lean tends to increase demand stability by simplifying, optimising and streamlining the SC. To quickly react to demand variations, it is important to integrate sales and marketing with manufacturing to ensure effective communication, and to design a flexible manufacturing system (Cochran et al., 2000). In order to overcome the conflict between Lean and highly variable demand, Reichhart and Holweg (2007) recommended the use of market-segmentation to benefit from the stability of some customer segments or products. Bicheno et al. (2001) indicated that the inconsistent performance of the SC they studied was caused by demand variations, batching (which should be minimised according to Lean and JIT principles), process instability and delivery performance. It is recommended by Parveen and Rao (2009) for Lean SC to consider the following:

- a collaboration between producers and retailers for setting maximum-profit prices
- an optimal integrated JIT inventory policy which takes into account CI, setup cost reduction and lead time reduction
- an optimal cycle length and an optimal number of inspections using a time-varying lot-size (or batch-size) approach in imperfect production processes and considering CI and setup cost reduction
- an optimal raw material ordering quantity, optimal finished product batch-size and optimal number of Kanbans (for a multistage production system) for production-delivery situations considering process inspection, restoration and rework
- an SC coordination for pricing, order quantity and investment decisions
- the economic production quantity (EPQ) models analysis
- the analysis of rework and the number of shipments in a production system.

The Lean SC makes it economic to produce small amounts and consequently allows producers to reduce inventory costs, reduce production costs and satisfy customer demands (Vonderembse et al., 2006).

Next, a discussion is presented of how different researchers considered the integration of Six Sigma with SCM. Integrating Six Sigma with SCM can bring benefits such as the DMAIC project discipline, sustainability of results, a well-established human resources framework using the belt-system, and a quantitative analysis strength (Yang et al., 2007). Three of the motivating reasons toward the integration of Six Sigma and SCM are: the versatility of the robust Six Sigma metrics in performance measurement, the similarities between Six Sigma and SCM (such as both being process approaches), and the research results indicating that SCM can benefit from the implementation of QM principles (Dasgupta, 2003).

Sanders and Hild (2000) warned against using Six Sigma metrics indiscriminately since there is a disadvantage in transforming the notion of Six Sigma process from a management philosophy to numerical targets for individual processes. This contradicts with Deming's (1993) philosophy of eliminating numerical targets and slogans. Managers need to spread the knowledge of Six Sigma in the right perspective to ensure that metrics are perceived as motivational opportunities for improvement, not hard-core numerical targets (Dasgupta, 2003). Also, metrics should encourage the system perspective emphasised by SCM and VSM, not the process perspective.

Dasgupta (2003) claimed that it is difficult to measure, monitor and improve the performance of an SC and its entities, only with the traditional strategic criteria such as cycle times, lead times, delivery performance, total SCM costs, inventory levels, rolled throughput yield, etc. Thus, Dasgupta presented a structured methodology that uses Six Sigma metrics, which provide a common scale, such as defects per unit or Sigma-level.

After being dissatisfied with its Six Sigma and SCM efforts, Samsung used both Six Sigma and SCM to enhance its operation and improve its efficiency (Samsung, 2007). Six Sigma was used to organise the approach to SCM projects and ensure that enough people were fully trained in SCM and quantitative data analysis. To adapt the approach to support SCM, Samsung have modified define-measure-analyse-design-verify (DMADV) into define-measure-analyse-enable-verify (DMAEV). Samsung (2007) stressed the organisational perspective for improvements as opposed to the local perspective, using KPIs to monitor improvements and using a systematic approach. Training is an essential factor for succeeding in the integration of Six Sigma and SCM as it helps establish an educated and committed workforce that is willing to change and embrace the quality strategy.

Amer et al. (2007) proposed expanding design for Six Sigma (DFSS), which provides means of creating specific target metrics and a methodology for isolating where CI efforts should be spent, to SC design. Their approach focused on using cross-functional teams to understand the voice-of-the-customer (VOC) and the critical customer requirements (CCR) including demand management. Other research proposing and examining Six Sigma as an SCM tool include Christopher and Rutherford (2004), Kelfsjo et al. (2001), and Antony et al. (2003).

In sum, different researchers considered the integration of Lean and Six Sigma with SCM. However, this research extends the previous works and proposes the implementation of LSS in SCM. Within LSS, Six Sigma tools ensure that products are of high quality resulting from capable processes, and Lean tools including VSM ensure the efficient flow through the SCM including inventories, schedules, demand quantities, etc. LSS tools in general aim at reducing costs, wastes, non-value-adding activities and satisfying all customers across the SC. LSS encourages good relationships with customers and suppliers including partnership and problem solving.

6 Similarities and differences between TQM and LSS

LSS is not significantly different than TQM. LSS overlaps TQM significantly and TQM is a major component of most LSS initiatives. The TQM process orientation eventually leads to the same result as LSS. TQM starts with quality, which may not be in the most critical issue of LSS (Andersson et al., 2006).

Traditionally, quality control in manufacturing was mainly the responsibility of a separate department and was conducted at the end of the production process. Rejected products were reworked, sold as seconds or scrapped. After each machine changeover the initial output would be checked, but because WIP cycles tended to be measured in weeks, it was difficult to determine the root cause of quality problems.

As compared to TQM, Six Sigma is a relatively new concept. It was not intended as a replacement, but the two have many similarities and are compatible in both manufacturing and service environments. It is also complementary to statistical process control (SPC), which uses statistical methods for monitoring and controlling business processes. Both TQM and SPC often reach a stage after which no further quality improvements can be reached. Six Sigma though has the potential to deliver better results. Six Sigma takes quality improvement processes to the next level, by focusing on CI in an effort to achieve a defect level of less than 3.4 per million.

Organisational systems for various business processes often use TQM concepts during development, deployment and maintenance. Focusing on maintaining existing quality standards, while making incremental improvements, it is a strategic approach. It also focuses on improving overall quality, by establishing a culture of collaboration among various functional departments.

The basic difference between Six Sigma and TQM is the approach. While TQM views quality as conformance to internal requirements, Six Sigma focuses on improving quality by reducing the number of defects. The end result may be the same in both the concepts (i.e., producing better quality products). Six Sigma helps organisations in reducing operational costs by focusing on defect reduction, cycle time reduction, and cost savings. It is different from conventional cost cutting measures that may reduce value and quality. It focuses on identifying and eliminating costs that provide no value to customers such as costs incurred due to waste.

TQM initiatives focus on improving individual operations within unrelated business processes whereas Six Sigma programmes focus on improving all the operations within a single business process. Six Sigma projects require the skills of professionals that are certified as ‘black belts’ whereas TQM initiatives are usually a part-time activity that can be managed by non-dedicated managers (Andersson et al., 2006).

Six Sigma initiatives are based on a pre-planned project charter that outlines the scale of a project, financial targets, anticipated benefits and milestones. In comparison, organisations that have implemented TQM, work without fully knowing what the financial gains might be. Six Sigma is based on DMAIC that helps in making precise measurement, identifying exact problems, and providing solutions that can be measured (Revere, 2003).

7 Case study: LSS DMAIC applied to SCM

The case study described in this paper is an example of how LSS (including VSM as a key tool) can be used to improve an SC. It is about Company A, which is a retailer of manufactured products. It provides more than 50,000 products and serves mainly the North American market. It employs about 80 people at its main distribution centre (DC). This company started the implementation of Lean, including VSM and JIT, in 2006. Prior to that, the company had a few Six Sigma projects implemented. This study includes the application of VSM to the main DC of this company. This case study is undertaken with the objective of demonstrating the improvements in the function of the DC, due to the implementation of LSS. Factors chosen are: the receiving period, filling rate of orders from retail stores, picking rate, and lead time, which are used to measure the performance of the DC. The data required for the case study was obtained from the company records over a period of about two years. Data was collected from sources that included purchasing, receiving, sales and accounting records. The description of the DMAIC approach below is based on the authors' knowledge and experience in LSS.

7.1 Define

- *project:* improvement of the distribution of products
- *problem:* the logistics operations at the DC are not efficient enough to meet the needs of the business in driving more volumes of products through the SC in less time
- *goal:* to improve the efficiency of the distribution system, increase the volume driven through the SC, reduce costs, reduce the average inventory, increase the inventory turn-over, reduce the lead time, and efficiently supply the stores with their orders (JIT)
- *team members:* champion, manager, buyers' representatives, suppliers' representatives, stores representatives, LSS black belt, process owner, inventory control specialists, DC employees and financial analyst
- *benefits:* a direct impact on the total margin and the cash flow
- *COPQ and baseline performance:*
  a 2006 receiving period (current base-line) = two weeks late
  b 2007 receiving period (target) = one day late
  c 2006 filling rate of orders from retailers (current base-line) = 80 %
  d 2007 filling rate of orders from retailers (target) = 90 %
  e 2006 picking rate (current base-line) = 39 line picks/operator/hour
  f 2007 picking rate (target) = 60 line picks/operator/hour.

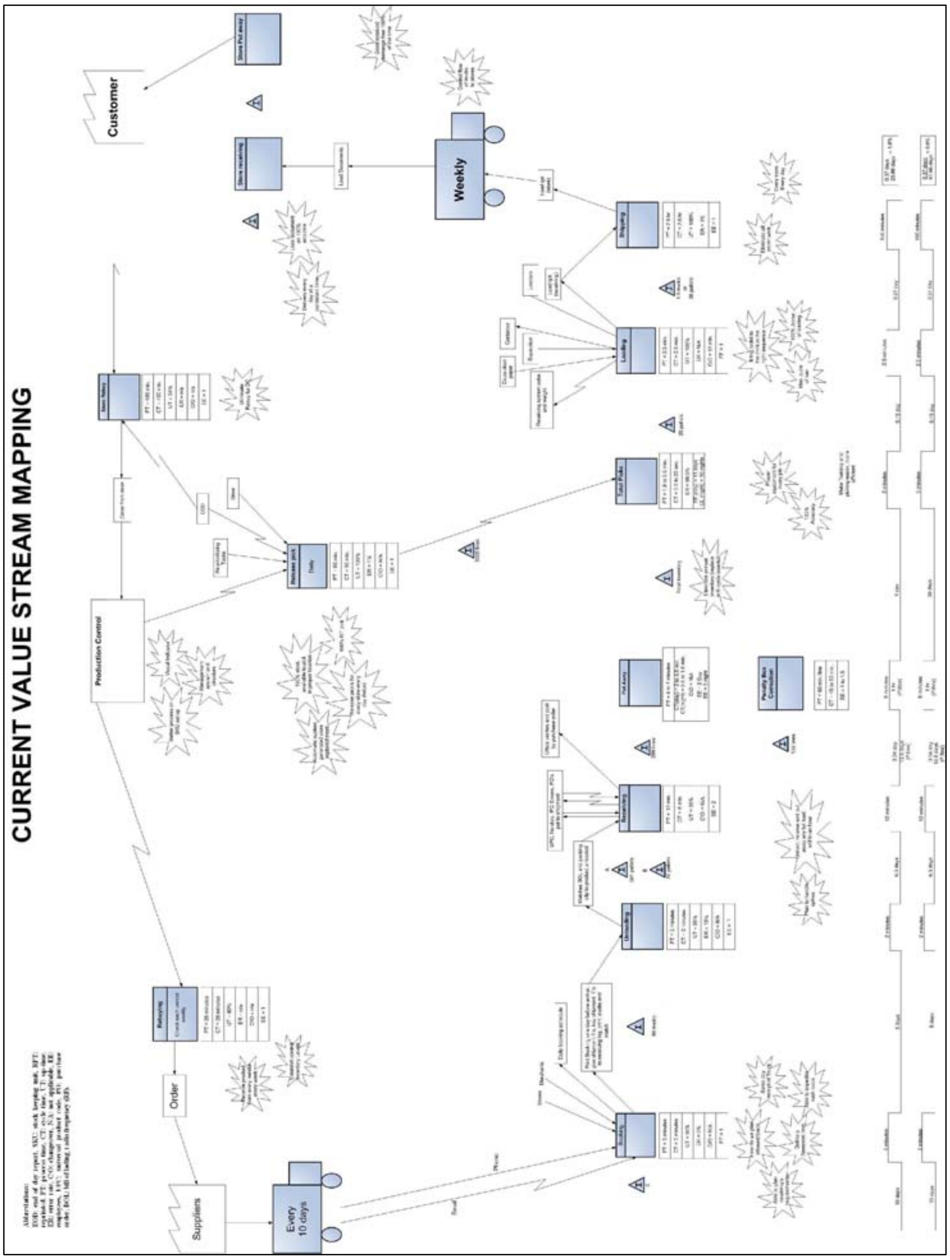
7.2 Measure

To view and to understand the current process, a current state VSM was used to identify waste and improve it. The map assisted the team in identifying improvement opportunities (see Figure 5). Quick hits included several Kaizen events for implementing visual workplace across the DC so that any sign for abnormal condition becomes evident.

7.3 Analyse

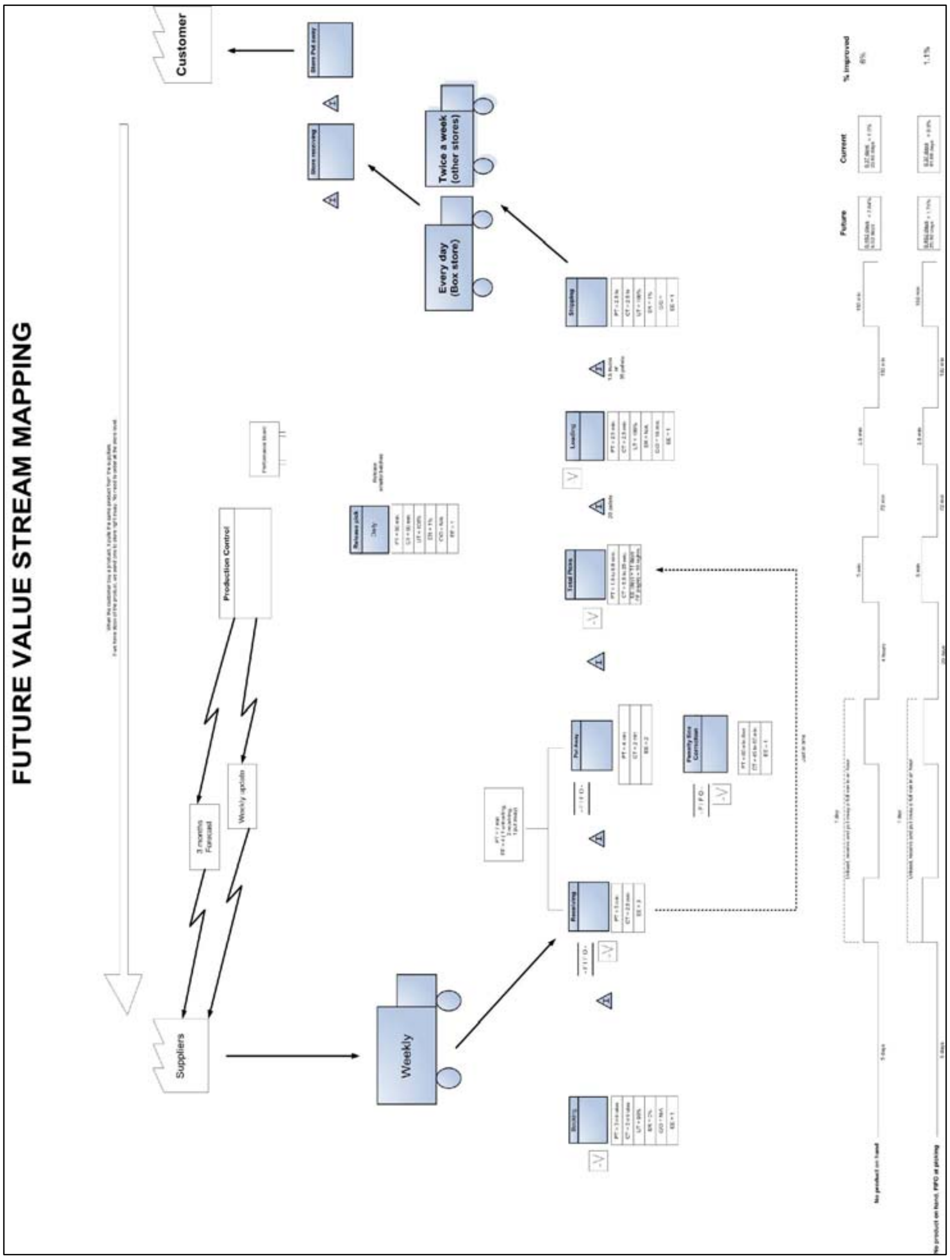
An analysis was performed on the current state VSM. This included an analysis of the unnecessary steps and ways to minimise waste within and between steps, an analysis of the flow of products and information, and an analysis of the lead-time, cycle times, down time, changeover time and rework. Then a future state VSM was created to maximise the value-added content and eliminate waste (see Figure 6).

Figure 5 Current-state VSM exercise (see online version for colours)



Notes: Bill of lading (BOL), cycle time (CT), distribution centre (DC), employees (EE), end of day report (EOD), error rate (ER), inventory (I), not applicable (N/A), process time (PT), purchase order (PO), radio frequency (RF), reprinted (RPT), stock keeping unit (SKU), universal product code (UPC), and up-time (UT).

Figure 6 Future-state VSM exercise (see online version for colours)



Note: First-in-first-out (FIFO) and visual board (V).

Table 4 Implementation action plan

No.	*Process step*	*Kaizen event*	*Type*
1	Receiving	Streamline, visual work place and FIFO set-up	2 days
2	Receiving	Visual work place to identify (and solve) receiving problems	1 days
3	Receiving	Unload, receive and put-away any load within an hr and plan for spikes	1 day
4	Seasonal receiving	Receive and pick products for all stores in a day for small products	30 days
5	Seasonal receiving	Identify seasonal products	1 day
6	Re-buying	Visual work place	1 day
7	Re-buying	Receive products from vendors weekly	30 days
8	Re-buying	Automatic system for replenishment: Set-up EDI between the DC and the different stores where the point-of-sale data at the stores is communicated back to the DC to initiate shipping and to the vendor to initiate replenishment.	90 days
9	Re-buying	Establish control levels for inventory	2 days
10	Booking	Visual work place	1 day
11	Booking	Set up a plan for inbound loads and receiving requirements	1 day
12	Booking	Investigate same day receipt of trucks and ability to expedite rush loads	1 day
13	Put-away (place a received product in its designated location)	Visual work place and first-in-first-out set-up	1 day

Table 4 Implementation action plan (continued)

No.	*Process step*	*Kaizen event*	*Type*
14	Put-away	Investigate the replacement of annual inventory by cycle counts	1 day
15	Inventory control	Visual work place	1 day
16	Loading	Visual work place	1 day
17	Loading	Maximisation of truck load, accuracy of loads and right sequence of pallets	1 day
18	Picking (getting the store's order)	Identify proper tools, plan for training and identify requirements for achieving a 100% accuracy	1 day
19	Shipping	Ship everyday to all big stores and twice a week to the other stores. Control the flow of trucks to the stores and set-up more frequent deliveries of less quantities to reduce inventory and steps (rapid replenishment triggered by the customer). Trucks travel between the stores, suppliers and the DC in cycles. Ship some products directly from supplier to store to reduce total lead time. Consistent delivery times.	2 day
20	Shipping	Eliminate paper work. Achieve damage-free deliveries.	1 day
21	Picking	Visual work place	1 day
22	Invoicing	Visual work place	1 day
23	Production control	Visual indicators, management system, better process on SKU set-up.	2 days
24	Release pick	Implement 100% radio frequency scanning for picking. Release smaller batches (twice a day/store). 100% stock available for picking at right location.	2 days
25	All system	Document procedures (best practices).	90 days

7.4 Improve

An improvement implementation action plan was built to start the implementation of the recognised improvements (see Table 4). Kaizen events were used to implement most improvements. Kaizen events varied in durations from one day to 90 days for a Kaizen project. An example of the actions listed in a Kaizen event is given in Table 5.

Table 5 Re-buying Kaizen list

Priority	*Actions*
3	To have the quantity sold by stores to drop into the reportable quantity daily
3	Only the products sold at retail price should be downloaded into the reportable quantity to avoid excess from bulk-buys (‘end-caps’, clearance items, flyers, seasonal, sale, contractors, etc.)
3	Visual KPI code for downloaded stores sales by SKU in the reported quantity
2	Safety stock should be 1.25 lead time demands (a little bit more for ‘A’ and ‘B’ products) and 1.00 lead time for ‘E’ products
3	Special order codes in the SCM software for orders issued at the store
1	Quarterly ‘end-caps’ and ‘stack-outs’ (seasons) planning meeting for buyers and marketing teams to identify bulk-buys and quantity to be bought in advance
2	Costumer representation at the DC for store inquiries or better communication with stores (a lot time is spent on the phone to answer redundant questions)
2	Report of non-moving products to enable reaction (once a period)
2	To divide the report by class or section and send it to purchasing
1	Variance reports from the SCM and tracking software must be up-to-date
1	Standardisation for use of activity codes
1	Purchasing team to follow-up the purchase orders (POs) initiated centrally
1	Provide a new computer to run reports
1	Provide a scanner for the DC

7.5 Control

The results were validated and a control plan was designed using mistake-proofing approach. At the end of the project, the team succeeded to improve the receiving period to a state of same day receiving using a visual process of a penalty box, the filling rate of orders from retailers to 94%, and the picking rate to about 70 line picks/operator/hour. The additional SKUs of new material added during the project made it very difficult to estimate the improvements in lead time, inventory turns, inventory level and estimated savings, since they varied tremendously. Also, the manager of the DC stressed that one great benefit of the project was the increase in the employees’ engagement level.

Lean and Six Sigma data can be used to identify improvement opportunities, benchmark with peer companies and objectively monitor and assess a company’s performance. The manufacturing organisations need to improve quality, while reducing cost and increasing productivity with limited resources. Successful implementation of the programme needs longer time duration. The results of the case study indicated substantial cost savings due to implementation of LSS.

8 Conclusions

TQM is a philosophy that delivers long-term benefits in terms of profitability, customer satisfaction and quality of products. Different organisations work for TQM implementation and utilise their resources to achieve the anticipated benefits. However, it is generally experienced that TQM implementation is a hard and very painful process. There are certain barriers that inhibit the successful implementation of TQM (Raj and Attri, 2010).

LSS and SCM share common grounds in terms of focusing on processes and solving customer problems to achieve customer satisfaction. They also complete each other and can be integrated together. This work extended the previous works regarding these approaches and proposed the implementation of LSS DMAIC to improve SCM using tools such as VSM and COPQ.

LSS tools which include VSM ensure the efficient flow through the SCM including inventories, schedules, demand quantities, etc. SCM can utilise the LSS principles, such as focusing on adding value to customers, reducing defectives and wastes, streamlining value flow, and improving on time delivery. The suitability of these tools and methods in general depends on understanding the methods and the application environment.

The implementation, management and performance improvement of an SC are not easy tasks. However, SCM can utilise the QM concepts, CI principles and LSS tools in order to achieve high levels of customer satisfaction regarding cost, quality and delivery. The case study provided an example of LSS implementation (including VSM as a key tool) to improve an SC. It validated the implementation and provided a description for all of the DMAIC phases. It showed how SCM could utilise LSS in order to achieve high levels of customer satisfaction regarding cost, quality and delivery.

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Abbreviations

Bill of lading (BOL)
Business process reengineering (BPR)
Continuous improvement (CI)
Cost-of-poor-quality (COPQ)
Critical customer requirements (CCR)
Customer relationship management (CRM)
Cycle time (CT)
Define-measure-analyse-design-verify (DMADV)
Define-measure-analyse-enable-verify (DMAEV)
Define-measure-analyse-improve-control (DMAIC)
Design for Six Sigma (DFSS)
Distribution centre (DC)
Economic production quantity (EPQ)
Electronic data interchange (EDI)
Employees (EE)
End of day report (EOD)
Enterprise resource planning (ERP)
Error rate (ER)
First-in-first-out (FIFO)
Inventory (I)
International Organisation for Standardisation (ISO)
Just-in-time (JIT)
Key performance indicator (KPI)
Lean Six Sigma (LSS)
Not applicable (N/A)
Plan-do-check-act (PDCA)
Process time (PT)
Purchase order (PO)
Quality management (QM)
Radio frequency (RF)

Abbreviations (continued)

Reprinted (RPT)
Stock keeping unit (SKU)
Supply chain (SC)
Supply chain management (SCM)
Supply chain operations reference (SCOR)
Total quality management (TQM)
Universal product code (UPC)
Up-time (UT)
Value stream mapping (VSM)
Voice-of-the-customer (VOC)
Visual board (V)