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Research Article

Boosting Supply Chain Effectiveness with Lean Six Sigma

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Abstract

This article explores the integration of supply chain management (SCM) and Lean Six Sigma (LSS), which can create a powerful systematic methodology for achieving manufacturing excellence and improving customer satisfaction. SCM in industry refers to the systematic coordination and integration of all activities involved in the procurement, production, and delivery of goods and services, from the sources of raw materials to the end customer. It ensures the right products are delivered in the right quantities, at the right time, and at the lowest possible cost. In this context, enhancing SCM has become a fundamental necessity for organizations aiming to improve operational efficiency, effectiveness, market share, and customer satisfaction. In this effort, LSS is a systematic methodology for improving process efficiency and effectiveness through continuous improvement by eliminating waste, minimizing defects, reducing lead time, and improving customer satisfaction. This research presented a comprehensive literature review focusing on applying the LSS methodology in SCM, as no comprehensive review is available. This study highlights the integration of LSS practices into SCM and provides a roadmap for future studies that focus on exploring the applications of LSS and its impacts on SCM. In conclusion, by aligning LSS principles with SCM strategies, organizations can achieve operational excellence, reduce costs, and improve overall supply chain efficiency while effectively meeting customer demands. Furthermore, this study aims to propose a framework that can be used to explain how the LSS methodology can be applied in different SCM fields. This comprehensive analysis aims to guide academics and professionals in improving supply chain performance using LSS tools.

Keywords

SCM, TQM, Six Sigma, Lean, LSS, Continuous Improvement

1. Introduction

Manufacturing excellence is based on improving efficiency, effectiveness, and customer satisfaction across the supply chain processes. The integration of Supply Chain Management (SCM) and Lean Six Sigma (LSS) presents a powerful approach to driving operational excellence in manufacturing. By combining these two methodologies, manufacturers can optimize processes, reduce waste, improve quality, and ensure smoother coordination between different stages of the supply chain. SCM is the organization and coordination of the entire flow of materials in a company, from sourcing raw materials to delivering finished products and services. Effective SCM ensures that materials and products are delivered on time, within budget, and to the required quality standards. Figure 1 illustrates the supply chain workflow diagram. The Supply Chain Operations Reference (SCOR) model is a well-known framework that divides supply chain operations into five phases: planning, sourcing, manufacturing, delivery, returns, and enabling. As shown in Figure 2, The planning phase involves

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analyzing market trends, customer preferences, and historical data to forecast and determine future demand for products or services. Through this phase, companies calculate the quantity of goods to be purchased from suppliers. The sourcing process is an important step in SCM for identifying suppliers, negotiating contracts, managing relationships, and ensuring quality control. Companies find reliable suppliers to provide the required raw materials. Favorable terms and conditions help secure cost-effective deals to meet quality standards. The manufacturing stage aims to convert raw materials into finished products through the production process. The activities consist of assembly lines, quality control checks, inventory management, and packaging. The manufacturing process ensures that goods are produced on time with minimum waste and consumption of resources. Delivery involves the transportation and delivery of products or services to customers. Delivery activities include order fulfillment, inventory management, and logistics. Companies have taken into account various factors such as transportation costs, speed of delivery, and customer preferences. Returns is the process of dealing with the return of products from customers. Returns occur for various reasons such as product defects, customer disappointment, or differences in customer requirements. The stage consists of activities such as product inspection, product disposition, return authorizations, and processing of refunds or exchanges. Handling returns is an effective process for businesses to reduce costs and maintain customer loyalty, [1, 4, 22, 23, 29, 39].

Organizations constantly seek ways to enhance operations efficiency, reduce costs, and improve competitiveness. In this effort, Lean Six Sigma (LSS) tools provide structured approaches to streamline operations and improve efficiency and effectiveness. As shown in Figure 3, the main objectives of LSS are to improve process quality, improve production rate, reduce delivery time, reduce production cost, and improve customer satisfaction. DMAIC is a specific framework for process continuous improvement within LSS that includes, (D) defining the problems and objectives, (M) measuring the current situation, (A) analyzing the problems root causes, (I) implementing a workable solution (I), and (C) controlling the process to ensure and maintain the continuous improvement. Figure 4 shows the most popular LSS tools. By using these tools and techniques, the organization can improve business processes, [24-27].

In conclusion, the manufacturing sector is under increasing pressure to improve efficiency, effectiveness, and customer responsiveness. Supply chain management focuses on improving the supply chain from start to finish, while Lean Six Sigma eliminates waste, defects, and variation. A literature review indicates that studies on integrating SCM with LSS are few and there is no common framework and methodology. Therefore, the present work aims to highlight the current state of SCM-LSS applications and integration and propose a common LSS framework to continuously improve SCM processes. After this introduction, this study is organized into five sections: In the second section, a literature review is conducted. In the third section, the review methodology is described. The results of the descriptive analysis can be seen in the fourth section. Finally, in the fifth section, conclusions and future work are presented.

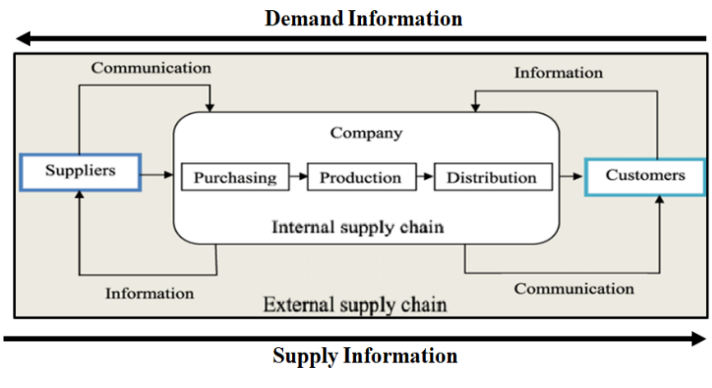

Figure 1. Supply chain flow diagram.

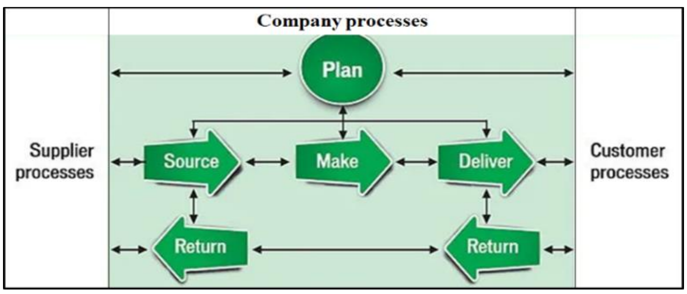

Figure 2. Different phases of SCM.

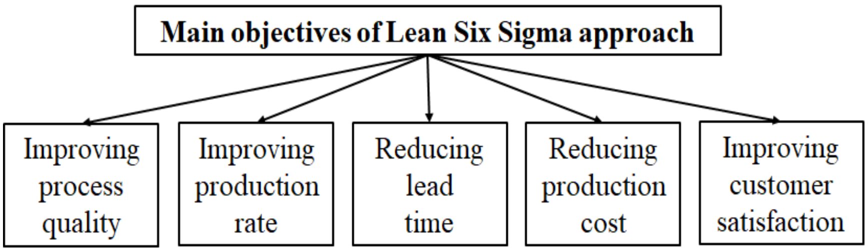

Figure 3. *Main objectives of the Lean Six Sigma approach.*

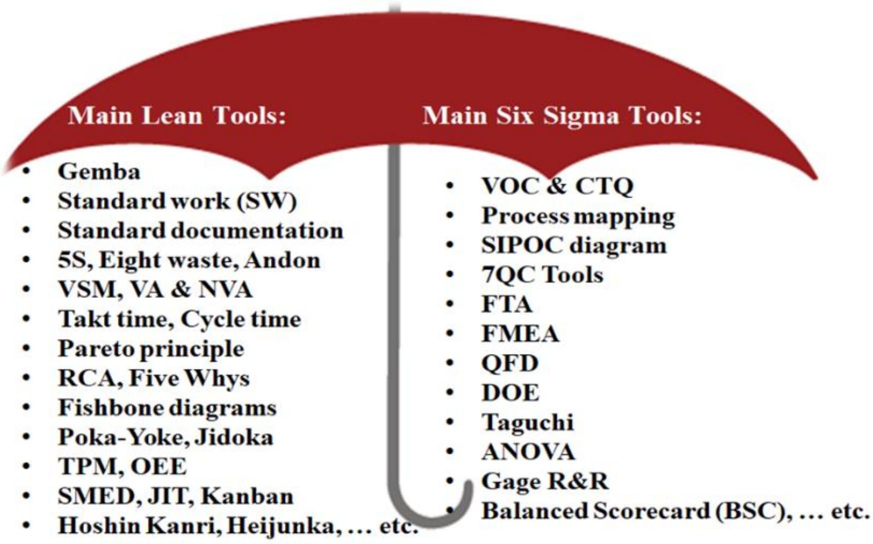

Figure 4. *Main LSS tools.*

2. Literature Review

In general, many companies are facing pressure to improve resource productivity and product quality while reducing production costs, which has led many companies to implement the LSS approach in their supply chain operations. As shown in Table 1, a large number of research papers were found that discussed the LSS-SCM methodology during the period (from 2012 to August 2024). This table shows that the LSS-SCM methodology has gained more interest in recent years. Several research related to LSS in SCM has been carried out in many papers, such as Jauhar et al, [36] discussed the integration of LSS and SCM that focused on product and process improvements that lead to controlled, sustainable, and proven improvements in the bottom line. According to Mitchell and Kovach, [46], it is believed that SCM is vulnerable to disruptions due to several variables such as demand fluctuations, product quality, and number of shipments. Tortorella et al., [72] discussed the relationship between LSCM practices and supply chain performance. This study discovered that not all practices could be merged into one bundle some have synergies with one another, while others might conflict and hinder their benefits. Jakhar et al., [35] studied the impact of lean tools on a sustainable SCM by considering the green aspects. Duarte and Cruz-Machado, [20] developed a framework to implement the Green Lean SCM. Gultom and Wibisono, [29] discussed the impact of LSS on SCM performance. Garcia-Buendia et al., [21] analyzed how research in LSCM has developed over the period (1996-2018) and identified the main issues explored and future directions. Gomaa, [23] discussed the most important LSS tools for improving SCM and proposed a framework for LSS-SCM in manufacturing. Gomaa, [25] developed an LSS-SCM framework in manufacturing for a case study in the spare parts industry.

In conclusion, several studies have focused on applying and integrating LSS tools at the different phases of SCM. Table 2 provides a comprehensive survey of LSS-SCM studies, classified based on contribution, application, objectives, and tools of LSS.

Table 1. Annual distribution of the LSS-SCM publications (from 2012 to August 2024).

Period	#	References
2012	1	[36]
2013	1	[57]
2014	2	[11, 45]
2015	3	[30, 40, 63]
2016	7	[2, 17, 37, 46, 59, 64, 75]
2017	2	[72, 76]
2018	5	[15, 35, 56, 70]
2019	9	[12, 19, 20, 29, 32, 33, 48, 60, 71]
2020	10	[5, 7, 9, 34, 43, 44, 50, 69, 74, 80]
2021	14	[10, 14, 18, 21, 31, 41, 42, 49, 51, 54, 55, 67, 78, 79]
2022	8	[22, 23, 38, 52, 53, 61, 68, 77]
2023	11	[3, 6, 13, 16, 24, 25, 23, 58, 62, 65, 73]
August 2024	7	[1, 4, 8, 26, 27, 28, 39]

Table 2. Applications of LSS tools in the various stages of SCM (from 2020 to 2024).

#	Reference	Contribution	Application	Main objectives	Main LSS Tools
1	Gomaa, 2024, [27]	Proposed LSS framework for manufacturing	Spare parts production	Improving sigma level, process capability, OEE	DMAIC, Mapping, VSM, 8Waste, Pareto, δL, Charts, 5S, OEE, DOE, TAG, RCA, C&E.
2	Gomaa, 2023, [25]	Studied LSS framework for SCM	Spare parts production	Improving quality, lead time, and value-added.	DMAIC, KPIs, VOC, Mapping, VSM, 8Waste, Pareto, Charts, 5S, OEE, RCA, C&E.
3	Adeodu, 2023, [3]	Considered LSS framework for warehouse processes	Logistics	Improving warehouse cycle and lead time	DMAIC, VSM, PCE, Cpk, 8Waste, Charts, 5S, RCA, C&E, KPIs, Actions.
4	Reyes, 2023, [58]	Developed a model for lean supply chain planning	Footwear industry	Improving quality, lead time, and value-added.	DMAIC, TPM, Kanban, Poka-yoke, 5S, Kaizen, JIT, Jidoka, Heijunka, Andon, VSM.
5	Sisman, 2023, [62]	Proposed LSS framework in supply chain logistics	Plastics industry	Reducing logistics cost	DMAIC, Charter, Mapping, Brainstorming, SIPOC, CTQ, 7QC, FMEA, δL, RCA.
6	Sundram, 2023, [65]	Developed LSS framework for supply chain logistics	Logistics	Reducing logistics Cost and lead time	DMAIC, Charter, CTQ, brainstorming, Tree diagrams, Mapping, Cpk, RCA, C&E.
7	Trubetskaya, 2023, [73]	Studied LSS framework for manufacturing	Animal feed production	Reducing inventory stock and lead time	DMAIC, Mapping, VSM, Pareto, SW, PCC.
8	Mittal, 2023, [47]	Developed six-sigma framework for manufacturing	Rubber weather strips industry	Reducing production defect and cost	DMAIC, CTQ, Mapping, Pareto, C&E, 5S, CBA.
9	Sharma, 2022, [61]	Discussed LSS framework for manufacturing	Automobile manufacturing	Reducing defect and idle time	DMAIC, Mapping, Charter, VSM, 8Waste, Pareto, C&E, δL.

#	Reference	Contribution	Application	Main objectives	Main LSS Tools
10	O'Mahony, 2021, [51]	Proposed LSS tools in SCM of an operating room	Health services	Reducing stock holding and out-of-date stock	DMAIC, Charter, SMART, Mapping, SIPOC, RACI, CTQ, VOC, 5S.
11	Praharsi, 2021, [55]	Studied LSS framework in SCM	Maritime industry	Achieving supply chain resilience	DMAIC, 7Waste, CTQ, C&E, FMEA, δL.
12	Tay, 2021, [68]	Developed LSS tools for SCM	Logistics	Enhancing value-added	DMAIC, Mapping, VOC, VSM, C&E, Poka-Yoke, KPIs.
13	Tay, 2021, [67]	Presented LSS tools for logistics supplier selection	Logistics	Improving the supplier selection process	DMAIC, Mapping, VOC, C&E, 5S, SW, KPIs Dashboard.
14	Kumar, 2021, [41]	Developed LSS framework for manufacturing	Engine cylinder production	Reducing defect %	DMAIC, Charter, Mapping, ABC, Pareto, Charts, C&E.
15	Hardy, 2021, [31]	Proposed LSS framework for manufacturing	Laminated panel production	Improving OEE	DMAIC, Charter, Mapping, CTQ, Takt, VSM, OEE, Charts, C&E, PDCA, FMEA.
16	Murmura, 2021, [49]	Studied LSS framework for manufacturing	Iron production	Reducing defect and lead time	DMAIC, Charter, Gantt, Mapping, VSM, δL, Charts, 5Why, C&E.
17	Patyal, 2021, [54]	Considered six-sigma framework for manufacturing	Chemical industry	Reducing customer complaints	DMAIC, Charter, Mapping, Cpk, 5Why, C&E.
18	Almutairi, 2020, [7]	Discussed LSCM framework for healthcare organizations	Hospital SCM	Reducing non-value-added activities	TQM, VOC, Mapping, VSM, TPM, ANOVA.
19	Andersson, 2020, [9]	Presented six-sigma framework for supply chain risk	Manufacturing companies	Improving awareness	DMAIC, TQM.
20	Madhani, 2020, [44]	Proposed LSS framework in SCM	Theoretical analysis	Enhancing efficiency and effectiveness	DMAIC, 8Waste, VSM.
21	Liu, 2020, [43]	Studied VSM framework for manufacturing	Footwear production	Reducing defect, WIP, and lead time	DMAIC, VSM, Takt, DOE, Taguchi.
22	Nandakumar, 2020, [50]	Considered LSS framework for manufacturing	Food industry	Improving OEE	DMAIC, Mapping, VSM, OEE, ANOVA, 5S, C&E.
23	Tiwari, 2020, [69]	Developed sustainable lean production framework	Cookware production	Improving sustainability and safety	DMAIC, Charter, KPIs, VSM, Pareto, 8Waste, C&E.

3. Research Gap Analysis

Supply chain management (SCM) involves coordinating procurement, production, inventory, distribution, and logistics. SCM focuses on streamlining supply chain operations, reducing costs, and improving efficiency, responsiveness, and customer satisfaction. In this context, the Lean Six Sigma methodology combines the principles of Lean (eliminating waste) and Six Sigma (reducing defects and variations) to improve process efficiency and effectiveness. Studies of LSS integration into supply chain management highlight how LSS enhances supply chain performance by reducing lead times, cost efficiency, and improving quality and customer satisfaction, [25, 27, 44, 51, 55, 58]. Despite the vast amount of research activity on supply chain practices under the LSS approach, much of this research has focused on a specific area of the SCM activities such as sourcing, logistics, inventory, manufacturing, or finance. Moreover, few case studies have discussed the impact of LSS applications on SCM performance. Furthermore, the concept of LSS in SCM remains underdeveloped due to the lack of a common LSS framework for SCM and shortcomings in SCM performance evaluation methods, [3, 7, 9, 31, 41, 43, 47, 49, 61, 62, 65, 67, 69, 73].

In conclusion, the research gaps highlight opportunities to advance knowledge on the transformative potential of LSS in SCM. Addressing the identified gaps could lead to innovative strategies to improve supply chain efficiency, sustainability, and resilience. Future research should adopt multidisciplinary approaches, integrating traditional LSS with digital innovations, sustainability goals, and global dynamics. Finally, the present work aims to propose a common SCM-LSS framework that can explain how LSS tools are implemented in different SCM stages.

4. Research Methodology

In a globalized and competitive manufacturing environment, achieving operational excellence is no longer optional. Supply Chain Management (SCM) and Lean Six Sigma (LSS) are critical frameworks that improve efficiency, reduce costs, and enhance quality. Good internal supply chain planning (SCP) helps to meet market demand most efficiently, aiming to improve customer satisfaction, increase profitability, and prevent excess demand or inventory shortage. This requires developing a reliable and integrated supply chain plan from market demand forecasting, master production schedule, raw material orders, raw material inventory, manufacturing operations, marketing, and distribution to delivering the right product to the right customer at the right time and cost. Figure 5 depicts a proposed internal supply chain planning flowchart. The task of demand planning is to forecast future demand from customers over some time for various products and services, taking into account the constraints, problems, goals, and objectives of the various departments involved in the supply chain. Improving forecast accuracy increases the level of customer service and reduces inventory. The task of the master planning process is to create a plan for the entire supply chain, including production, inventory, purchasing, and financial flow decisions. Thus, master planning generates a plan for future supply from internal and external sources. The results of master planning are objectives/targets/instructions for the action plans of each discipline in the supply chain such as material requirements planning, product inventory planning, production planning and scheduling, material inventory planning, purchasing planning, logistics planning, and budget planning. The master planning interacts with all phases of action planning by sending instructions and receiving feedback. Synchronizing the action planning based on the master planning improves on-time delivery. Moreover, master planning provides valuable inputs for product cost analysis and financial planning. Table 3 shows an integrated internal supply chain planning proposal.

Risk analysis in supply chain planning involves identifying, assessing, and mitigating risks that could disrupt the smooth operation of the supply chain. A comprehensive risk analysis ensures that businesses are prepared for uncertainties and can adapt efficiently to unexpected events. Effective risk analysis is essential for minimizing disruptions, maintaining customer trust, and ensuring operational continuity. Table 4 shows a proposal for the most important risk elements for internal supply chain planning.

Based on the literature review, the main Expected objectives and methodology of LSS application in SCM can be summarized as shown in Table 5. This methodology and set of objectives provide a solid foundation for leveraging Lean Six Sigma principles to create more efficient, cost-effective, and customer-focused supply chains.

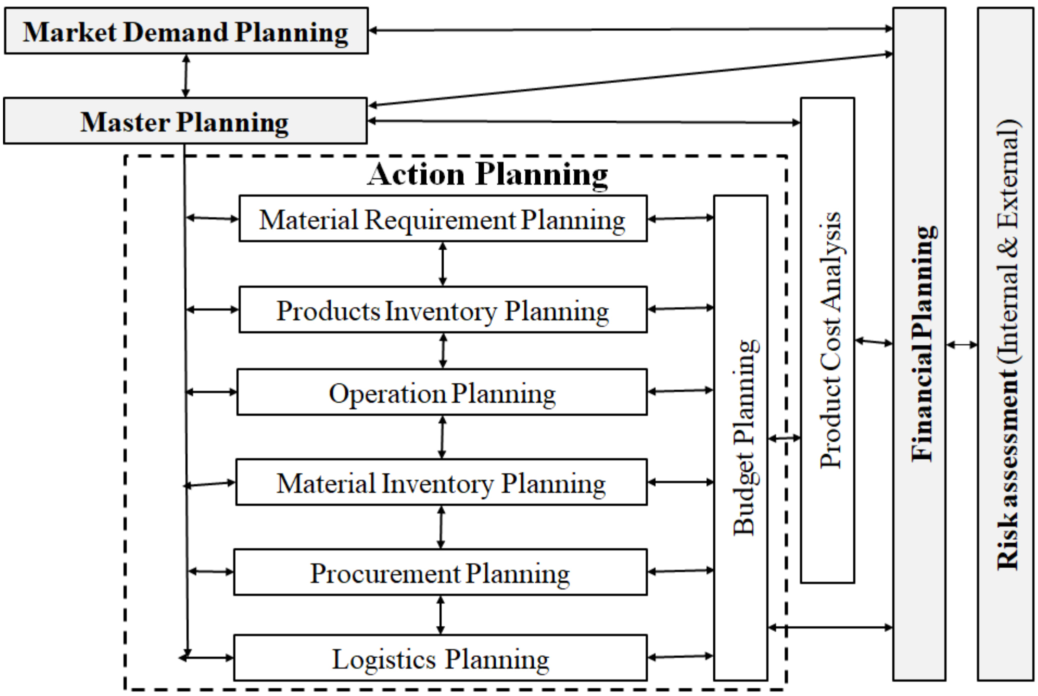

Figure 5. Proposed internal supply chain planning flowchart.

Table 3. Proposed internal supply chain planning methodology.

Planning Phase	#	SCP Steps
Product File	1	Product Information
	2	Supply Chain Description
	3	Value Chain Description
	4	Process Mapping,… etc.
Current Situations Analysis	5	SWOT Analysis
	6	Current KPIs Analysis
	7	SCM Problems, Objectives, and Targets
Demand Planning	8	Market Demand Forecasting
	9	Market Demand Planning
	10	Distribution Planning
Supply Planning	11	Master Planning
	12	Material Requirement Planning (MRP)
	13	Finished Products Inventory Planning
	14	Operation Planning
	15	Material Inventory Planning
	16	Procurement Planning
	17	Logistics Planning
Financial Planning	18	Product Cost Analysis
	19	Budget Planning
	20	Financial Planning
Risk assessment	21	Internal risk assessment
	22	External risk assessment

Table 4 Proposed risk analysis for internal supply chain planning methodology.

Risk Type	#	Risk Elements	Internal	External
Demand Planning Risk	1	Forecasting risk	x	x
	2	Demand risk		x
	3	Market risk		x
	4	Competition risk		x
	5	Distribution risk		x
Supply Planning Risk	6	Material risk		x
	7	Inventory risk	x	
	8	Operation risk	x	
	9	Process quality risk	x	
	10	Process safety risk	x	
	11	Procurement risk	x	

Risk Type	#	Risk Elements	Internal	External
	12	Human resource risk	x	
	13	Logistics risk		x
	14	Supplier risk		x
	15	Product cost risk	x	
Financial Planning Risk	16	Product price risk		x
	17	Budget risk	x	
	18	Customer satisfaction risk		x
	19	Delivery risk	x	
Customer Risk	20	Product quality & safety risk	x	
	21	Customer service risk	x	

Table 5. *Main objectives and methodology of LSS application in SCM*

#	Main Objectives	Methodology
1	Improving process efficiency	• Minimize non-value-adding activities (e.g., delays, inspections, rework).) in procurement, manufacturing, and logistics. • Identify and remove the 8 Wastes. Map out the current supply chain process from supplier to customer. • Construct Value Stream Mapping (to visualize current processes and flows). • Reduce lead times by streamlining processes.
2	Enhancing quality and reducing defects	• Achieve near-zero defects in product delivery and inventory management through Six Sigma principles. • Achieve Six Sigma-level defect rates, enhancing product/service reliability. • Apply Statistical Process Control (SPC) charts to monitor variability
3	Optimizing inventory management	• Balance inventory levels to reduce holding costs while ensuring demand fulfillment. • Focus on ABC Analysis to prioritize critical items and optimize safety stock. • Use demand forecasting tools to reduce stockouts and overstocking. • Implement Economic Order Quantity and safety stock models. • Implement Kanban Systems for inventory management to ensure just-in-time replenishment • Use feedback loops to align inventory management with operational needs.
4	Reducing lead times	• Streamline operations to achieve faster order fulfillment and delivery. • Create a Value Stream Map (VSM) to document the flow of materials and information in the MRO inventory process. • Conduct brainstorming sessions to identify specific pain points (e.g., high lead times, excessive inventory, poor supplier performance). • Identify bottlenecks, redundancies, or areas prone to errors.
5	Enhancing customer satisfaction	• Improve product quality, delivery accuracy, and responsiveness to customer needs. • Implement systems for quality checks to prevent errors in order fulfillment (wrong products, quantities, or damaged goods). • Deliver products on time and as per customer requirements. This can be achieved through efficient scheduling, route optimization, and real-time tracking systems. • Use data analytics to personalize offers, promotions, and communication to create a more tailored experience for customers.
6	Achieving cost reductions	• Identify and eliminate cost drivers across the supply chain. • Minimize inventory carrying costs, reduce rework, and optimize transportation.

#	Main Objectives	Methodology
7	Supporting decision-making process	• Optimize your supply chain to reduce costs and pass savings on to the customer. • Use data-driven approaches for process optimization and resource allocation. • Use data-driven insights for strategic decisions. • Collect historical data on key supply chain metrics such as cycle time, inventory turnover, defect rates, order accuracy, and delivery time. • Apply KPIs dashboard and performance gap analysis.
8	Improving supply chain flexibility	• Improving supply chain flexibility helps businesses adapt to disruptions, meet changing customer demands, and enhance competitiveness. • Enable adaptability to changing market demands and disruptions. • Diversify suppliers by sourcing materials from multiple suppliers, preferably in different regions, to reduce dependence on a single source and build relationships with backup suppliers of key components. • Improve communication with suppliers, manufacturers, and logistics partners to ensure a coordinated response to disruptions.
9	Enhancing standardization	• Document improved processes and create Standard Operating Procedures (SOPs). • Train employees across the supply chain on new workflows and tools • Regularly conduct Kaizen events to refine and standardize the processes.
10	Sustainability of changes	• Develop a control plan to monitor key metrics (e.g., lead time, defect rates) post-implementation. • Use Control Charts to identify any deviations and ensure process stability. • Use Kaizen for continuous improvement initiatives in critical supply chain areas.

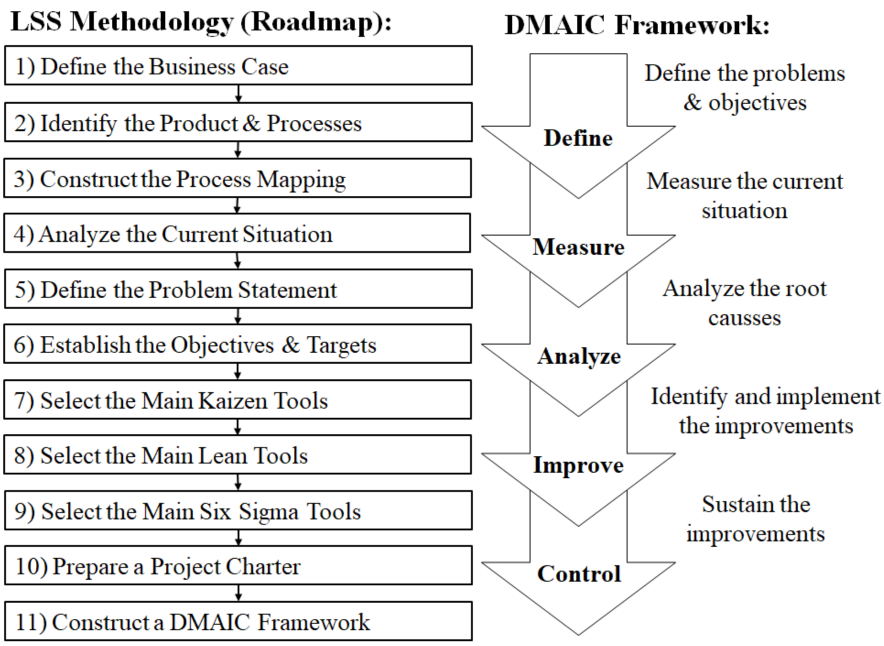

Figure 6. Proposed LSS Methodology.

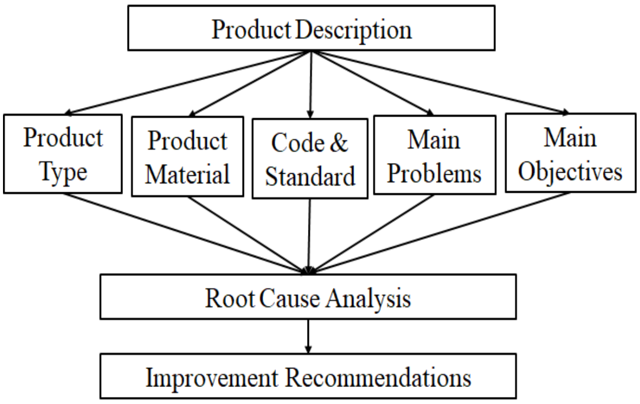

Figure 7. Product description flow chart.

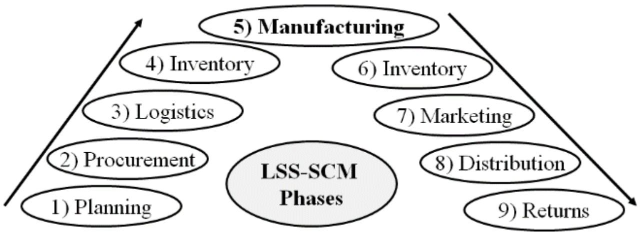

Figure 8. Different phases of LSS-SCM.

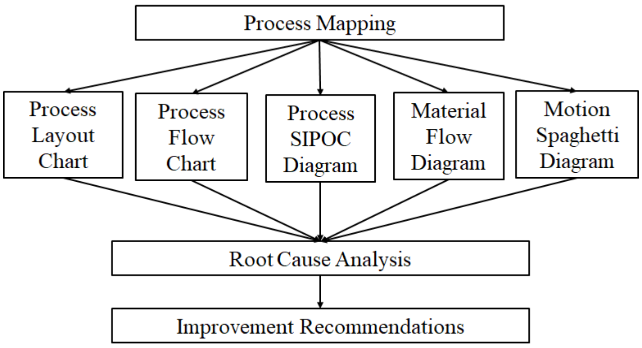

Figure 9. Process mapping flow chart.

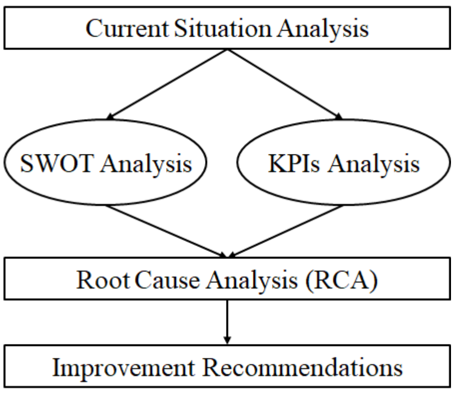

Figure 10. Current situation analysis flow chart.

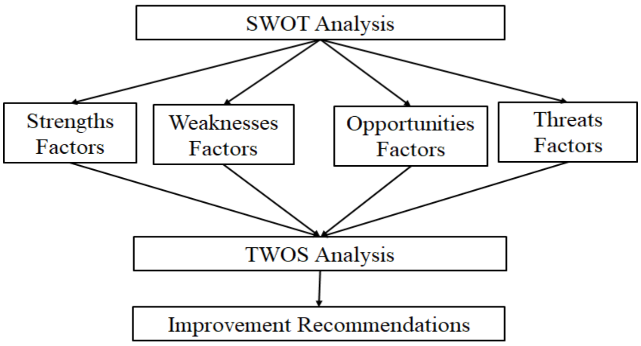

Figure 11. SWOT analysis flow chart.

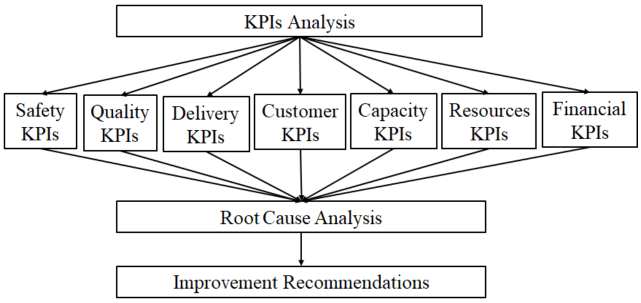

Figure 12. KPIs analysis flow chart.

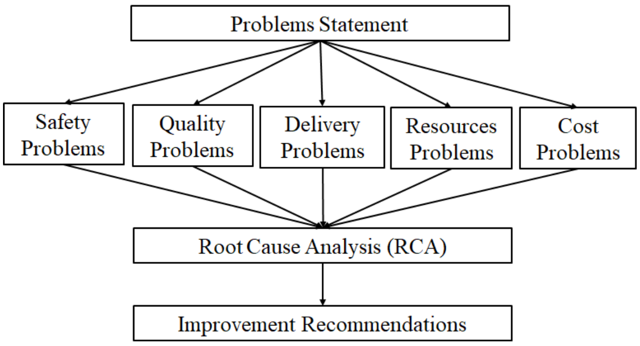

Figure 13. Problem statement flow chart.

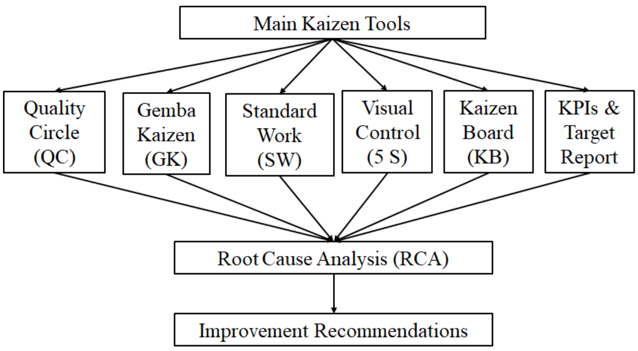

Figure 14. Main Kaizen tools flow chart.

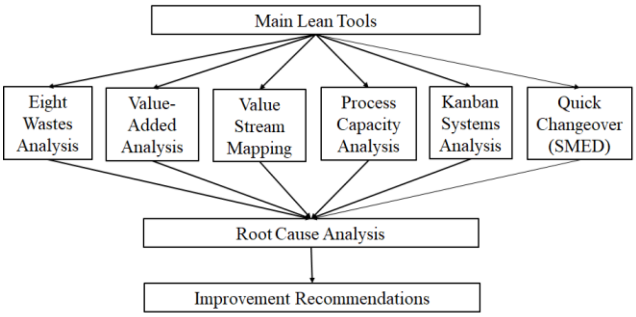

Figure 15*. Main Lean tools flow chart.*

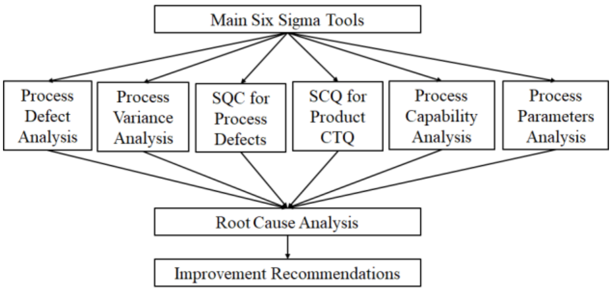

Figure 16*. Main Six Sigma tools flow chart.*

The LSS methodology is proposed in 11 steps as shown in Figure 6. Each step is detailed as shown in Figures 7-16. The LSS-DMAIC (Define, Measure, Analyze, Improve, and Control) framework is proposed as shown in Table 6, as follows:

1. Define Phase - The purpose of this stage is to clarify the scope of work and identify key problems and objectives. After building the SCM study team, a current situation analysis is prepared through brainstorming sessions. Based on the company's history of current process performance, a list of problems, objectives, and KPIs is determined. Based on the brainstorming sessions, the main LSS tools for different areas of SCM are proposed and process mapping for the main SCM processes is constructed.
2. Measure Phase - This phase aims to understand and measure the current status of the supply chain system and identify the important metrics related to product quality, delivery time, process performance, customer satisfaction, etc. Standardized forms and questionnaires are conducted to collect the required information during the planned period. A list of major defects, faults, and problems in the various supply chain processes and their level of severity are identified and measured.
3. Analyze Phase - The purpose of this stage is to analyze defects, errors, and problems and identify the root causes. Quality control charts and lead time control charts are created for different processes. Pareto charts are created for different defects, errors and problems. Therefore, brainstorming sessions are conducted to identify the root causes and fishbone diagrams are created. The resulting cause and effect diagrams are used to identify the major factors caused by elements such as material factors, method factors, machine factors, manpower factors, measurement factors and environmental factors. Process capability charts for different processes are analyzed. Value Chain Model (VSM) diagrams are created to document information flow, material flow, and lead time flow. Finally, process efficiency is calculated and analyzed and a detailed study of non-value-added activities and waste is identified and analyzed.
4. Improve Phase- This phase begins with the inclusion of recommendations and solutions obtained during the analysis phase, and the project team works together to develop, test, and implement an improvement plan that achieves continuous process improvements. The 7S (5S + Safety + Sustainability) principle, standardization of work, and other Kaizen tools are followed to organize and improve work efficiency and reduce safety risks.
5. Control Phase- In this phase, the team in each process develops a control plan to monitor and maintain the improvement plan. This plan outlines how the processes will be standardized as well as how the procedures will be documented. In addition, the actions taken to improve the process and best practices should also be well documented. The final activity in this phase is the Project Closure and Lessons Learned Report.

Table 6*. Proposed DMAIC framework for SCM.*

DMAIC	Main Activity	Main Tools
Define	1) Team building	Focus group in each field
	2) Define the business vision, mission, values, goals and strategic objectives.	Strategic thinking and Brainstorming sessions
	3) Develop business benchmarking and targets.	External and internal benchmarking
	4) Business SWOT analysis and PESTLE analysis.	Brainstorming sessions
	5) Prioritize the processes.	Pareto chart and rule 80/20
	6) Define the selected process.	Project charter and Gantt chart

DMAIC	Main Activity	Main Tools
Measure	7) Capture AS IS the process information.	Process mapping, SIPOC, Spaghetti diagram, and current situation analysis
	8) Prepare a data collection plan	Data collection plan
	9) Design standard information templates	Standardization
	10) Collect the required information	Brainstorming sessions
	11) Measure the current performance.	KPIs, Sigma level, and gap analysis
Analyze	12) Process value-added analysis	Lean 8 wastes analysis and Value stream mapping (VSM)
	13) Process defect analysis	Pareto chart
	14) Process capability analysis	Control charts and capability Cp, Cpk
	15) Root cause analysis and C&E diagrams.	5Whys and fishbone diagrams
Improve	16) Identify performance criteria for improvement.	Brainstorming sessions
	17) Determine process benchmarking, KPIs, and targets.	KPIs, benchmarking
	18) Model and validate the new TO-BE process model.	Targets, prototyping
	19) Standardize the process information.	Work standardization, visual control (5S), Kaizen, etc.
	20) Identify IT requirements.	Digital transformation
	21) Create and apply the improvement plan.	Improvement plan and Kaizen tools
Control	122) Proposed and performed the change management plan.	Change management plan
	23) Develop and implement a control plan.	Control plan and process control charts
	24) Control and evaluate results (before & after).	Process performance evaluation, Sigma level, ANOVA, and learned lessons

5. Conclusion and Further Work

This paper examines the integration of Supply Chain Management (SCM) and Lean Six Sigma (LSS) as a strategic approach to achieving manufacturing excellence. By combining SCM's focus on operational efficiency with LSS's focus on quality and waste reduction, companies can achieve significant improvements in performance and customer satisfaction. By focusing on reducing waste, improving quality, and enhancing collaboration throughout the supply chain, manufacturers can achieve more agile, efficient, productive, and cost-effective operations. This integration not only drives immediate operational improvements but also contributes to long-term sustainability and competitiveness in a rapidly changing market.

The main objective of this work is to review and discuss the literature related to the application and integration of the SCM approach with LSS tools, as no comprehensive review is available. Most existing studies examine supply chain management and LSS separately but rarely provide practical frameworks for integration. This article addresses this gap by proposing a step-by-step integration framework supported by empirical evidence. Furthermore, this study aims to develop a SCM-LSS framework that can be used to explain how the LSS methodology can be applied in different SCM fields.

This comprehensive analysis is intended to guide academics and industry professionals in the areas of SCM using LSS tools. For future research, conducting real case studies by sampling manufacturing companies to validate the proposed framework is suggested. Also, future research should explore advanced technologies, such as AI-driven analytics, to deepen this integration and address existing challenges.

Abbreviations

5S	Visual Control and a Workplace Organization Method
7QC	Seven Quality Control Tools
C&E	Cause and Effect Diagram
CBA	Cost Benefits Analysis
Cpk	Process Capability
CTQ	Critical to Quality
DMAIC	Define, Measure, Analyze, Improve, and Control
DOE	Design of Experiments
FMEA	Failure Mode Effect Analysis
JIT	Just in Time
KPIs	Key Performance Indicators

LSS	Lean Six Sigma
OEE	Overall Equipment Effectiveness
RACI	Responsibility Matrix
RCA	Root Cause Analysis
SCM	Supply Chain Management
SCP	Supply Chain Planning
SIPOC	Supplier-Inputs-Process-Outputs-Customer
SQC	Statistical Quality Control
SW	Standard Work (Standardization)
TPM	Total Productive Maintenance
VOC	Voice of Customer
VSM	Value Stream Mapping
δL	Sigma Level

Author Contributions

Attia Hussien Gomaa is the sole author. The author read and approved the final manuscript.

Conflicts of Interest

The author declares no conflicts of interest.

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