Proceedings of the International Conference on Industrial Engineering and Operations Management

Publisher: IEOM Society International, USA DOI: 10.46254/AP06.20250062
Published: August 5, 2025

Combined Lean-Six Sigma for Process Improvement at Different Facilities: A Review

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Abstract

Lean is the concept of boosting an organization's speed and efficiency by removing waste. On the other hand, Six Sigma is a continuous improvement approach recommended to eliminate variability. This article presents a comprehensive review of integration of Lean Six Sigma (LSS) for process and service improvements across various facilities and industries. By synthesizing literature, this review study explores the potential benefits and effectiveness of combined Lean-Six sigma. It highlights their complementary strengths Lean's emphasis on waste reduction and flow efficiency, and Six Sigma's focus on reducing process variability and improving quality. The review demonstrates that LSS has evolved into a strategic framework applicable not only to manufacturing but also to healthcare, education, and public services. Key findings reveal that when implemented effectively, LSS leads to enhanced operational efficiency, customer satisfaction, cost savings, and quality outcomes. The study concludes that Lean Six Sigma, supported by leadership commitment and cultural adaptation, offers a powerful toolkit for continuous improvement in diverse operational contexts.

Keywords
Lean, Six sigma, Service, Product, DMAIC, Waste

1. Introduction
The service process is not fundamentally different from a production process; both meet unnecessary delays, flaws, deviations, and expenses. During the operation of delivering products and services. Lean-Six Sigma (LSS) hybrid methodology can significantly simplify, optimize, and streamline those operations and remains influential in industry management practices (Daniyan et al., 2022; Singh and Rathi, 2019). LSS has recently become a part of many industrial companies' extensive and cutting-edge applications. It is now used in public organizations' continuous improvement initiatives, including higher education, hospitals, municipalities, and government agencies (Antony et al., 2019). Lean engineering and Six Sigma have dissimilar performance initiatives but are favoured in supporting

organizations that aspire for operational superiority to participate in global competition. They are confirmed techniques with a mutual goal of continuous improvement, but they meet these objectives differently (Sreedharan and Raju, 2016). Their hybridization is an appropriate technique that blends efficiency and sustainability. The goal of Lean Six Sigma is to reduce cycle time by combining the "Lean" a manufacturing system that aims to remove seven kinds of waste: transportation, inventory, motion, waiting, overproduction, over-processing, and defects with the "Six Sigma" technique, which reduces output inconsistency in the process.

Lean in the service industry emerged in the early 1970s, gaining significant momentum only in the late 1980s. Lean processing in the service industry focuses on adding value by eliminating waste and improving various aspects, such as quality, speed, customer satisfaction, and total costs (Davim, 2018). In other words, it can be said that the adoption of Lean concepts, practices, principles, tools, and techniques has been identified to enhance quality and streamline processes within the service industry. Lean principles have been implemented in various service industries, including banks, hospitals, and airlines. The necessary knowledge and understanding of Lean engineering is a key for its successful implementation and organizational culture and employee's mindsets should also be adaptive. Lean methodology, which originated from Toyota's manufacturing processes, emphasizes the elimination of waste to streamline operations and maximize value delivery to customers. Lean methodology emphasizes optimizing processes to ensure that every activity adds value to the end product or service. The Lean methodology's notion of waste corresponds with action deemed waste since it uses resources (labor, materials, time, etc.) without enhancing the fit, form, or functionality of the good or service provided to the customer. Organizations can improve overall customer satisfaction, save costs, streamline processes, and shorten lead times by eliminating these non-value-added operations (Mishra and Terker, 2023).

Six Sigma is a theory and approach in quality management that focuses on minimizing variance, quantifying flaws, and enhancing the calibre of goods, services, and processes (Mohd Asri et al., 2024). Motorola introduced the Six Sigma concept in the 1980s, and General Electric popularized it in the 1990s. Six Sigma is a collection of techniques and methodologies that use statistical analysis to assess and develop an organization's procedures, processes, and performance to identify and eliminate variations to improve quality (Kolbusz and Antosz, 2023).

Combining two methods for process improvement identified and proven effective is called Lean Six Sigma (LSS). Toyota developed Lean manufacturing for its factories in the 1970s to reduce expenses, implement Just in Time, and enhance timeliness. The foundation of Six Sigma is a methodology that relies on quantifiable, reliable data and customer feedback. It improves overall product quality and service and reduces manufacturing process inconsistencies (Makwana and Patange, 2019; Tampubolon and Purba, 2021). Since both strategies are customer-focused when properly combined, they result in quicker procedures at a lower cost and higher quality. LSS uses Lean concepts to streamline corporate processes and decrease waste, resulting in more satisfied consumers and addressing variations in organizational processes by applying Six Sigma systems and tools Their combination or hybridization gives an opportunity to simultaneously utilize their benefits and yield more robust results.

Lean Six Sigma is a combination of approaches and tools that helps firms gain a competitive advantage by becoming more agile and cost-effective than competitors. Lean enables firms to reduce the time required to meet consumer needs. However, Six Sigma helps find and correct errors and defects in meeting customer requirements. Combining these two methodologies provides a powerful toolkit for maximizing productivity, profitability, and growth (Gupta et al., 2025).

Extra value can be defined as products, services, procedures, and activities that offer a particular value to the company by combining the concepts of Lean and Six Sigma. The Lean Six Sigma approach has the benefits of removing waste, reducing lead time, and reducing cycle time (Bicer, 2022). Adopting Lean Six Sigma has significantly improved process efficiency, profitability, and customer satisfaction. The challenges in their implementation include resistance to change, difficulty measuring service quality, addressing variability in customer demand, and ensuring employee engagement and empowerment. Figure 1 illustrates some of the significant benefits of hybrid Lean-Six sigma.

This study has reviewed the implementation of Lean Six Sigma for process and service improvement at different facilities. Various important past studies have been considered to establish the connection between Lean Six Sigma implementation and increased efficiency and productivity in various sectors (Figure 1).

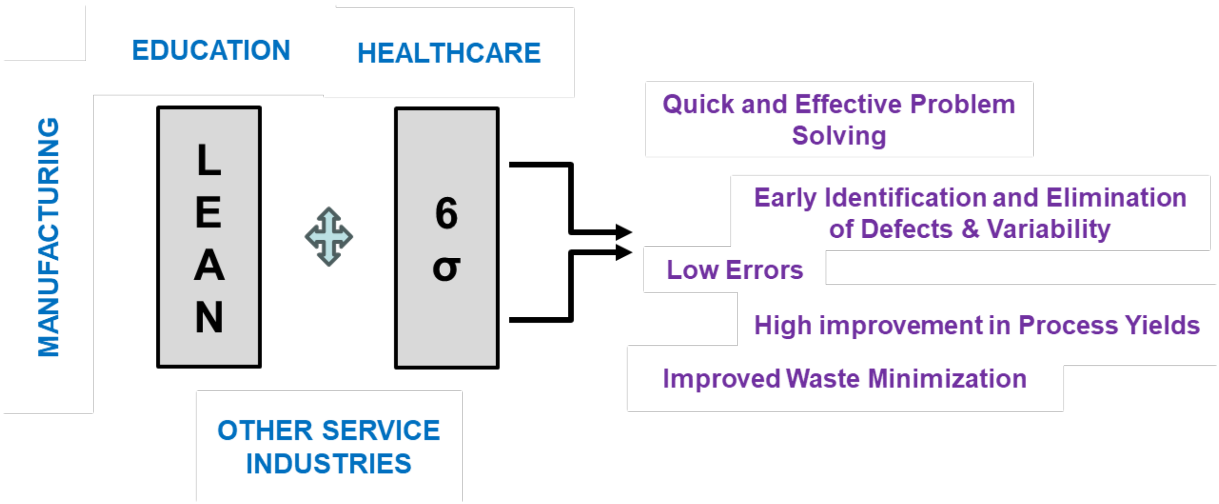

Figure 1. Benefits of Lean-Six sigma.

2. Review and Analysis of Combined Lean Six Sigma Past Work

Lean Six Sigma is readily applicable in the manufacturing industry, but there are evidences to prove the positive impact of this hybrid technique for service sectors as well. The important past studies conducted under the influence of hybrid Lean-Six Sigma, are summarized in Table 1 and discussed here as under.

To enhance production efficiency and minimize waste in a glass transformation company, Maazoun et al. (2024) examined the impact of Lean through the DMAIC approach, commonly associated with Six Sigma,. Lean Manufacturing was highlighted as a key strategy to minimize costs, maximise efficiency, and improve production quality by eliminating waste throughout the business process. The reorganisation of the workshop layout led to a reduction in unnecessary movement and enhanced overall efficiency. The implementation of pull systems helped align production with demand, reduce waste, and optimize flow within the workshop. 5S Methodology improved stock management and work organization, resulting in a cleaner, more organized, and more efficient workplace. DMAIC approach provided a structured method for problem-solving and continuous improvement, resulting in better production planning, enhanced flow efficiency, and substantial financial gains for the company. The improvements positively impacted the working environment, increasing employee motivation and engagement. This Lean manufacturing approach using DMAIC has proven effective in enhancing production efficiency, improving flow, and achieving significant financial gains for the glass transformation company. By optimising physical flows, implementing 5S, and adopting a structured improvement framework, the company achieved improvements in operational efficiency, product quality, and employee satisfaction.

Ferreira et al. (2019) introduced the development and validation of a combined methodology, iLeanDMAIC, which integrated Lean tools with the Six Sigma DMAIC approach to solve organisational problems and enhance production efficiency. The results demonstrate that this combined methodology can help organisations continuously improve their processes by reducing waste and variability while optimizing production flow. Lean thinking enables organizations to identify and eliminate waste, thus improving productivity and profitability. DMAIC is a structured problem-solving methodology that focuses on process improvement, defect reduction, and variability minimization. By combining Lean tools with the DMAIC approach, the new methodology called iLeanDMAIC aims to provide a simple, efficient, and cost-effective solution for continuous improvement. The iLeanDMAIC methodology was implemented as a case study in an organisation operating in the wood products sector. The methodology successfully validated its effectiveness in enhancing production by reducing the changeover time in the assembly machine from 39 minutes to 17 minutes, representing a 44% improvement in the manufacturing time. The implementation showed significant efficiency gains by reducing the time spent on non-value-added activities. The integrated approach helped organizations become more cost-effective by reducing waste and optimizing processes. The outcomes of this study indicate that the combined methodology, iLeanDMAIC, effectively leverages Lean tools and DMAIC principles to optimize production processes and reduce waste. A successful case study in the wood products sector shows that the methodology can deliver significant time savings and efficiency improvements.

A three-phase Lean implementation framework was proposed by Khan et al. (2022) to minimize defects and waste in the metal casting industry. The framework integrated the Six Sigma DMAIC methodology with Lean tools and used solid cast software for computer-assisted casting simulation to analyze defects. A real-time case study used the sand-casting process to validate the framework, demonstrating more than 30% improvement in metal weights, 40% improvement in mold weight, and an approximately 25% improvement in casting yield. That led to significant reduction in casting rejection and cost. These results suggested that the proposed framework provides a standard roadmap for practitioners, motivating the casting industry to implement Lean practices for performance enhancement through organizational change.

Matshidiso (2021) conducted a case study approach in a plastic film packaging industry, demonstrating how integrating Lean Six Sigma techniques can significantly enhance the implementation of Kaizen, leading to substantial organizational improvements. The primary focus was on utilizing Lean Six Sigma to construct a semi-automated model to streamline the non-conformance closure process (also known as the defect troubleshooting system), which was identified as inadequate during an external ISO audit. The first objective involved defining the necessary ISO standards to develop a model that adhered to those requirements. This step was crucial to ensure the model aligned with compliance standards. The next step was to assess the current non-conformance closure methods to uncover their weaknesses. By employing Lean tools like the 5 Whys and the Ishikawa diagram, the root causes of the ineffective procedure were identified. Lean techniques were integrated to build a semi-automated model that complied with ISO standards. This model acted as a catalyst for continuous improvement by accelerating non-conformance closure. The semi-automated model was applied to each non-conformance raised. The results were closely monitored, showing improved efficiency in the closure process. Auditors accepted this new method upon evaluation. The study recommended deploying fully automated non-conformance software and analyzing seven types of waste to drive further enhancements. Integrating Lean Six Sigma principles, particularly through tools like Ishikawa and 5 Whys, successfully developed a semi-automated model that improved the non-conformance closure process. The DMAIC approach facilitated each evaluation phase, demonstrating that Lean tools significantly support faster Kaizen implementation. This model can also be a foundation for a fully automated future system, aligning with continuous improvement principles.

The study conducted by Gijo et al. (2019) included a case where LSS methodology was applied to transform the process and the mindset of staff and management in an IT firm. The project focused on three main attributes: management commitment and leadership participation, customer centricity, and bottom-line impact with cultural change. Implementing LSS led to 4 hours reduction in resolution time and a 30% decrease in standard deviation. The indirect financial savings estimated at 30000 USD. LSS-based systematic problem-solving methodology enhanced decision-making through effective data collection and analysis. This work reinforced the value of LSS as a management strategy that drives continuous improvement and competitive advantage across various functions.

Araman and Saleh (2022) investigated the sources of variation in the aluminium profiles hot extrusion process at a company in Palestine to improve process capability. The study used the DMAIC Lean Six Sigma methodology to identify and address these variations, focusing on a critical-to-quality (CTQ) characteristic i.e. the D3 dimension of bottom sash aluminium profiles. The DMAIC approach was utilized to analyze historical data and employ tools like Pareto charts, a cause-and-effect diagram, and a decision matrix to identify the root causes of defects. As a result of implementing the suggested improvements the following were achieved: defects per million opportunities (DPMO) reduction with 73990, >0.5 sigma level improvement, and approximately 10% increment in process yield.

Singh and Rathi (2023) focused on implementing an environmental Lean Six Sigma (ELSS) framework in a medical equipment manufacturing industry to achieve operational sustainability. The framework integrated the DMAIC methodology with sustainability and Lean tools, providing a structured approach to minimize environmental impact while enhancing production efficiency. Significant improvements were observed where capacity utilization (CU) increased from 59.25% to 74.3%. Defects per million opportunities (DPMO) decreased from 309,523 to 48,951.44, reflecting an 84.18% reduction. More than 30% reduction was achieved in cycle and lead times. Indoor air quality level improved and chemical emission was also reduced. Social benefits were also realized, including better workplace safety, improved employee behaviors, and enhanced customer satisfaction.

Shamsuzzaman et al. (2018) used LSS methodology in a telecom service company. The study used a comprehensive framework under the DMAIC methodology, integrating both qualitative and quantitative research methods. The study applied LSS tools and achieved ~5 days reduction in sales order lead time, 1 day reduction in value-added service order lead time to achieve more than 3 times increment in sigma level and 50% improvement in order fulfillment process.

Persis et al. (2020) explored in a case study approach the application of Lean Six Sigma (LSS) in a multi-specialty hospital to enhance patient care and achieve operational excellence. The research focused on improving the performance of the cardiology department by utilizing a novel approach, Select-Define-Measure-Map-Analyse-Improve-Control-Sustain (SDMMAICS), which is an extension of the traditional DMAIC framework. Implementing LSS methodologies helped to identify and eliminate bottlenecks and significantly improved patient turnaround time, workforce utilization, and organizational profitability. The study demonstrated an annual cost-saving of approximately 44,000 USD by reducing staff idle time and optimizing resource allocation (Table 1).

Table 1. Summary of some important previous attempts utilizing combined Lean-Six sigma for various purposes

Researcher	Type of Industry	Key Findings
Araman and Saleh (2022)	Extrusion company	-Sigma level improved with more than 0.5 -Approximately 10% process yield improvement -The annual cost saving more than 50k USD
Daniyan et al (2022)	Rail car industry	-In a railcar boggy assembly process, waste generation was identified as the reason of low process efficiency -LSS approach resulted in: More than 45% improvement in process cycle efficiency More than 25% reduction in lead time More than 70% reduction in nonvalue added time.
Khan et al. (2022)	Casting industry	Significant improvements in mold and casting weights and reduction in rejection rate and final cost.
Shamsuzzaman et al. (2018)	Telecom service	Significant reduction in lead times and 50% improvement in order fulfillment process with improved customer satisfaction.
Singh and Rathi (2024)	Medical equipment manufacturing	Environment Lean Six sigma helped to achieve 10% enhancement in capacity utilization and more than 75% reduction in defects per million opportunities.
Magodi et al (2022)	Small manufacturing enterprise	Improvement in operational efficiency of bookkeeping and tax consultation process by 60% reduction in non-value added time and 47% in downtime
Hsiao et al (2023)	Plastic manufacturing	Daily defect rate was found below the set target of 3% and product quality improvement was achieved. Further, reduction in customer complaints was also reported.
Krishnan et al (2022)	Tool manufacturing	-The developed LSS model was complemented with Kaizen. -30% improvement in Sigma level and 12% improvement in cycle time of tool production
Thakur et al (2023)	Healthcare (Diagnostic lab)	40% reduction in the usage of calibrators for clinical diagnostics that led to the annual saving of thirteen thousand Canadian Dollars.
Nedra et al (2022)	Garment manufacturing	5% reduction in process flow time for trousers sewing.

Imanov et al (2022)	Aircraft maintenance	Reduction in turnaround time by 7h
Noskievičová and Moravec (2022)	Bottling plant	-Reduction in stoppage frequency by 20%. -Annual cost saving 8k Euro
Bloja et al (2020)	Energy service sector	7 times improvement in customer data actualization rate
See and Tay (2021)	Food storage	36% reduction in food packaging time and reduction in manpower requirement.

3. Conclusion

The article concludes that combined Lean-Six Sigma is a robust and adaptable strategy for continuous improvement of quality of products, services, and processes. Despite the complexities of implementing LSS in service settings, the methodology provides measurable benefits when applied thoughtfully. When implemented correctly, Lean Six Sigma can produce operational efficiency, profitability, and process quality benefits. The combined effect of Lean tools and Sig sigma techniques have been found beneficial for process yield improvement, product quality enhancement, reducing errors and costs, and minimizing waste. The hybrid LSS helps to identify and eliminate sources of variability. High level management support, motivated employee and their effective participation, leadership are some essential factors behind successful implementation of LSS. Service sector needs sincere LSS future interventions to gain much better understanding of its implementation effect, specially in education, hospitality, and banking sectors. LSS integration with sustainable and green and artificial intelligent technologies is yet another promising future research avenue.

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Biographies

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