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Exploring lean six sigma: A comprehensive review of methodology and its role in business improvement

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Abstract
In a highly competitive industrial landscape, organizations are increasingly adopting strategies to enhance product quality, with Lean Six Sigma emerging as a notable approach. This paper presents a comprehensive review of Lean Six Sigma, a synergistic approach combining the waste-reduction principles of Lean with the process optimization strategies of Six Sigma. The study underscores the importance of the Lean Six Sigma approach as a valuable tool for businesses, seeking process improvement and increased competitiveness and acknowledging that its applicability depends on an organization's specific circumstances and needs. Furthermore, the paper critically assesses the benefits and potential criticisms of Lean Six Sigma, providing balanced insights into challenges to its implementation. By offering a comprehensive understanding of Lean Six Sigma, this review paper serves as a valuable resource for organizations aiming to enhance their operational efficiency, reduce cost, and improve customer satisfaction.

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Introduction

In examining the pivotal methodologies that have shaped process improvement in various industries, Lean Manufacturing and Six Sigma emerge as fundamental concepts. This paper aims to succinctly review their evolution, principles, and joint adoption in enhancing industry processes. Lean Manufacturing, rooted in the post-World War II era, evolved from Toyota's Production System, a paradigm focused on waste minimization and process efficiency. This approach was subsequently conceptualized as 'Lean' by MIT researchers and elaborated in seminal works like 'The Machine That Changed the World' and 'Lean Thinking'. Parallel to this development was the evolution of manufacturing practices, notably marked by the first and second Industrial Revolutions. These eras were characterized by significant advancements, including Henry Ford's assembly line model, which laid the groundwork for mass production. The ensuing period saw the rise of Six Sigma, a methodology emphasizing process variability reduction and quality enhancement. The convergence of Lean Manufacturing and Six Sigma into Lean Six Sigma represents a synergistic approach to operational excellence. This paper aims to critically analyze the historical development, current status, and global implications of Lean Six Sigma from published research articles, while also exploring its potential future applications in an ever-evolving business landscape.

Lean Manufacturing emphasizes two fundamental pillars: Just-in-Time (JIT) and Jidoka [1]. JIT advocates for a demand-driven production strategy, minimizing inventory and waste through Takt Time, Overall Equipment Efficiency (OEE), and Continuous Flow. These elements collectively enhance operational efficiency by aligning production with customer demand and ensuring a smooth, uninterrupted workflow [2-4]. Jidoka, or automation with a human touch, focuses on integrating quality into the production process. It involves automated systems for defect detection, thus preventing the advancement of defective products[1].

and promoting a culture of continuous improvement and employee empowerment in quality assurance [5].

Lean Manufacturing is structured around overcoming three fundamental challenges: Muda (waste), Muri (overburden), and Mura (inconsistency) [7]. This framework is designed to enhance process efficiency by systematically identifying and eliminating seven primary forms of waste, represented by the acronym DOWNTIME: Defects, Overproduction, Waiting, Non-utilized skills, Transportation, Inventory, Motion, and Excess Processing [7-10]. Underpinning this methodology are several key tools and techniques that facilitate the practical application of Lean principles. These include Kaizen, a philosophy of continuous improvement [11-13]; 5S, a system for optimizing workplace organization [14, 15, 16, 17, 18]; Kanban, a visual tool for workflow management [19, 20]; Standardized Work, ensuring consistency in operations [21]; the 5 Whys technique for root cause analysis [22]; Single Minute Exchange of Die (SMED), aimed at reducing setup times [23]; and Total Productive Maintenance (TPM), which focuses on maximizing equipment efficiency [14, 24, 25]. Furthermore, Value Stream Mapping (VSM) is employed to visually identify and eliminate waste in process flows [26], while Heijunka, or production leveling, is used to stabilize production fluctuations and further enhance efficiency [27].

The applicability of Lean Manufacturing is evident in its widespread application across diverse sectors. In the manufacturing industry, Lean principles have been pivotal in optimizing production processes [28]. The healthcare sector has successfully integrated Lean methodologies to enhance surgical pathways, medication dispensing processes, and overall patient experience. Despite the proven effectiveness of Lean Manufacturing principles in various sectors, research into their application and sustainability, particularly in healthcare, remains limited [29]. The Information Technology (IT) industry has embraced Lean principles through Agile methodologies, utilizing frameworks such as Kanban and Scrum to achieve iterative and efficient software development [30]. This cross-sectoral adoption underscores the adaptability and effectiveness of Lean Manufacturing principles in driving operational excellence and continuous improvement in various professional landscapes. However, despite the proven effectiveness of Lean Manufacturing principles in various sectors, research into their application and sustainability, particularly in healthcare, remains limited [29].

Six Sigma, a data-driven methodology, aims at defect elimination in processes and products by minimizing variation. Its core is the concept of achieving near-perfection, quantified as 99.9997% efficiency, or just 3.4 defects per million products made [31]. The methodology is structured around the DMAIC process: Define, Measure, Analyze, Improve, and Control. In the Define phase, project goals are set, and Critical to Quality characteristics (CTQs) are identified, aligning efforts with customer expectations. The Voice of Customer (VOC) is crucial here, prioritizing customer needs through various methodologies [32]. The Measure phase involves data collection to baseline the current process state. It emphasizes precision and accuracy in measurement, ensuring credibility in data collection [33].

In the Analyze phase, the focus is on identifying and validating root causes of problems, using tools like Brainstorming, Cause-and-Effect Diagrams, and Statistical Process Control. This phase bridges the gap between current performance and desired outcomes [34]. The Improve phase is dedicated to identifying and implementing solutions to the identified problems, backed by data from previous phases. Tools like brainstorming and decision matrices are commonly employed here [35]. Finally, the Control phase ensures the sustainability of improvements. It involves standardizing new processes, documenting changes, and establishing monitoring mechanisms [36].

The rest of the paper reviews the integration of LM and Six Sigma and their emerging technologies. Section 5 discusses the implementation issues of Lean Six Sigma initiatives. Finally, the conclusion, prospects, and promising directions as possible inspirations for future research were suggested.

Methodology

This study aims to conduct a comprehensive literature review to analyze the applications and impacts of Lean and Six Sigma methodologies for business improvement. This will be achieved through a systematic review of peer-reviewed literature, synthesizing findings to understand how these methodologies have been adapted and their effectiveness in this field. The methodology for this literature review follows the three-stage process outlined by Tranfield, Denyer, & Smart (2003), which consists of planning the review, conducting the review, and reporting and disseminating. This structured approach ensures transparency and repeatability and minimizes research bias [37].

Planning the review

The review will focus on literature published since 2000 to ensure contemporary relevance and applicability. Databases such as Google Scholar, IEEE Explore, Web of Science, and Science Direct will be utilized to gather relevant research papers. The criteria for inclusion will be based on the application of Lean and Six Sigma methodologies for business improvement with a focus on identifying benefits, challenges, and outcomes. A search strategy will be developed involving key terms related to Lean and Six Sigma, combined with terms specific to business improvement. A preliminary flowchart outlining the review steps will be created to guide the research process.

Conducting the review

The terms ‘Lean,’ ‘Six Sigma,’ ‘Lean Six Sigma,’ ‘Challenges,’ and ‘Business improvement’ were used to search for articles. The initial screening will be based on titles and abstracts, focusing on papers that specifically address Lean and Six Sigma applications for business improvement. Papers not directly related to these methodologies or outside the scope of this review will be excluded. Relevant papers will undergo a detailed examination, including full-text review, to evaluate methodologies, findings, and relevance. Data extraction will include the author(s), publication year, study focus (e.g., process improvement, efficiency enhancement), tools and techniques used, and key findings.

Reporting and Dissemination

Findings will be synthesized to highlight key themes, trends, and insights related to the implementation of Lean and Six Sigma. The review will discuss the implications of these findings for practitioners and suggest directions for future research. A comprehensive report, including a breakdown of articles published in each country by year, is provided in Fig. 2.

Integration of lm with six-sigma philosophy

In today's competitive business landscape, organizations are constantly seeking ways to enhance their operational efficiency, improve quality, and deliver value to customers. Two methodologies that have emerged as powerful tools in achieving these goals are Lean Manufacturing (LM) and Six Sigma. Both approaches have been widely adopted and proven effective in driving process improvement and organizational excellence.

Integrating lean and six-sigma.

Lean and Six Sigma are two distinct but complementary methodologies for continuous improvement in any organization. Lean emphasizes speed, eliminating waste, and creating value for customers by maximizing efficiency and productivity, while Six Sigma focuses on reducing process variation and eliminating defects to improve product and service quality, reduce costs, and increase customer satisfaction [38]. When combined, Lean and Six Sigma form a powerful approach called Lean Six Sigma (LSS), which integrates the principles and tools of both methodologies to achieve significant improvements in process performance, customer satisfaction, and financial outcomes. LSS uses a structured and data-driven problem-solving approach, typically through the DMAIC (Define, Measure, Analyze, Improve, Control) framework, to identify and address root causes of problems and achieve sustained improvements [39] [40]. The benefits of LSS are numerous, including increased productivity, reduced costs, improved quality and customer satisfaction, and enhanced employee engagement and empowerment. By embracing Lean Six Sigma, organizations can achieve operational excellence, drive innovation, and gain a competitive edge in their respective industries. The combination of Lean and Six Sigma methodologies offers a comprehensive and systematic approach to continuous improvement, making LSS a valuable framework for organizations committed to achieving excellence in their processes, products, and services. Table 2 presents areas of application of lean and six sigma – the challenges and their outcomes.

Green Lean Six Sigma is an improvement strategy which contributes more significant performances to a process, product, or service than the individual approaches. Each approach in GLSS complements each other to provide value by identifying and removing waste resulting in environmental sustainability. For Lean Six Sigma to meet green requirement, all the problem-solving stages of lean and six sigma must be targeted at reducing green waste with cleaner production. The core objective of GLSS is to reduce wastes thereby increasing the process or system efficiency with negligible environmental pollution [41] to increase the profitability and producing environmentally sustainable products [42] and effective usage of materials to minimize wastes, defects and emissions [43], as shown in Fig. 8. The implementation of Green Lean Six Sigma is quite difficult despite its benefit of improving profitability, productivity, and environmental sustainability. Sreedharan *et al.* [44] conducted another study to identify the barriers to a successful Green Lean Six Sigma implementation which can be summarized as follows:

- Poor knowledge on environmental sustainability by employees and suppliers.
- Unfavorable green manufacturing policies
- Lack of trust.
- Lack of supervision for executing green supply practices because of inappropriate policies
- Reluctance of employees to adopt environmental practices.
- Uncertainties associated with the cost of manufacturing green products which may cause the product to be expensive and customers might not be able to afford it.

Another study conducted by Hussain *et al.* [45] reveals the role of government and political environment in the success of green manufacturing. They concluded that unfavorable government policies are the most critical factor that hampers Green Lean Six Sigma implementation. A favorable political environment and government policies such as subsidies, rewards, tax concessions would aid the successful implementation of Green Lean Six Sigma.

Green Lean Six Sigma (GLSS)

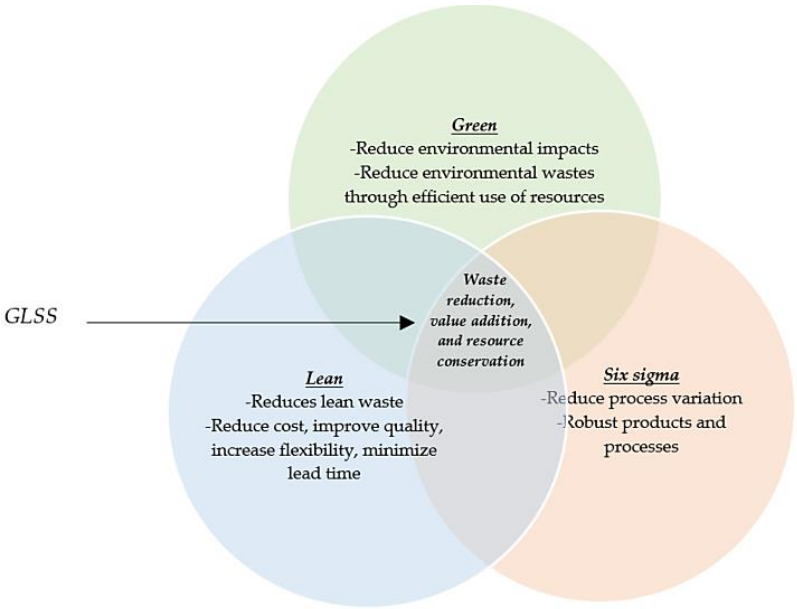

Fig 3: Green Lean Six Sigma [46]

To overcome these challenges and successfully implement GLSS, companies may need to invest in training and education to raise awareness about environmental sustainability. They may also need to lobby for favorable government policies or seek ways to make green manufacturing more cost-effective. In the long run, the benefits of implementing GLSS, both in terms of profitability and environmental impact, can far outweigh these initial challenges.

Table 2: Areas of applications of lean six sigma

S/No	Industry/Company	Process Challenge	Tools applied	Outcome	Reference
1	Manufacturing –fan production	▪ Inefficient material transport leading to 11% non-value adding time.	VSM	Decrease in total lead time for fan production from 647.94 minutes to 340.9 minutes	[47]
2	Window screen production process	▪ Poor plant layout ▪ Ineffective usage of shelf space ▪ Incorrect labeling of boxes ▪ Placement of parts into the wrong boxes	5S	Cost saving of $45,000 annually.	[48]
3	Manufacturer and distributor of pharmaceutical products.	▪ Inefficient floor space utilization ▪ Long lead time ▪ Poor inventory management	5 Whys, VSM	38% reduction in storage area and 50% reduction in production staff.	[49]
4	Electronics industry	▪ Poor inventory management ▪ Waste and bottlenecks ▪ Unorganized workplace	ABC analysis, 5S, DMAIC, Cause and Effect, PDCA and VSM	31.4% reduction in lead time and thus increasing the production rate by 23%.	[50]
5	Healthcare - Hospitals in Ireland	▪ Non availability of medical records at the required time and place ▪ Increased cases of patients falling in the hospital ▪ Lengthy process of administering Clozapine for psychiatric patients	5S, Root Cause analysis, Process Mapping, Control Chart, Load levelling, Checklist, seven wastes	▪ Improvement in defect rate for medical records from 28 defects in 90 records to 5 defects in 220 records ▪ Introduction of mistake proofing practices to prevent fall occurrences. ▪ Reduction in the lead time of administering clozapine from 15 days to 3 days	[51]
6	Printing Company	▪ Failure in meeting demand caused by poor setup of the machines	Root cause analysis, Value stream mapping, time study	▪ Productivity improvement from 2,709 impression/hour to 3,303 impression/hour (21.93% increase) in the printing machine	[52]
7	Paper printing Industry	▪ Predominance of wastage which includes downtime, non-conforming product and undue motion ▪ Elongated Takt time and cycle efficiency	Value stream mapping, Pareto analysis, 5S	▪ Reduction in downtime from 32.6% to 11% ▪ Increase in cycle efficiency from 23% to 40% ▪ Increased takt time of 4.11 seconds/piece to 4.71 seconds/piece ▪ Defects level reduced to 6 sigma	[53]
8	Biopharmaceutical	▪ Improvement of current process and reduction of current cycle time	Value stream mapping (current and future state), SIPOC Diagram, CTQ, Root Cause analysis	▪ Reduction in process cycle time from 1310 min to 592.5 min ▪ Removal of Nonvalue added activities from the process, accounting to 54% of total process cycle time	[54]
9	Airline	▪ Mishandled baggage at baggage handling system due to low system reliability	SIPOC Diagram, House of Quality, Fishbone, FMECA, Process flow chart	▪ Introduction of RFID to address low system reliability. ▪ Reduction of baggage screening level from 5 to 3, leading to reduction in bag wait time by 68.6%	[55]
10	Agriculture – Farm Equipment Sector	▪ Field failure of tractor assembly	SIPOC, Fishbone, New SOPs	▪ 95% reduction in field failure rate ▪ Cost savings of 4.36 million Indian Rupees per annum	[56]
11	Food processing	▪ Process Improvement drive to reduce variation in weightage of	Why Analysis, Control charts, Root cause	▪ 50% reduction in rejection rate of milk powder pouch	[57]

		products	analysis	▪ Projected annual savings of 8,000,000 Indian Rupees	
12	Information Technology	▪ Adoption of Lean Six Sigma to the Information Technology Infrastructure Library (ITIL) framework for process improvement	PDCA, DMAIC, ITIL, UAT	▪ Improvement in sigma level of defective tickets from 1.93 to 2.8 Sigma ▪ Elimination of waste by reducing team size from 33 to 27 ▪ Annual cost savings of $288,000 USD	[58]
13	Agriculture – Animal feed	▪ Increasing rising costs of production and complexity of customer demands	Value stream mapping, standardized work charts, Pareto chart, Control charts	▪ 25% reduction in finished goods inventory ▪ 66% reduction in lead time ▪ 16% increase in Takt time	[39]
14	Aerospace	▪ Challenges with production capacity and capability	Value stream mapping, QFD chart, Single Minute Exchange of Die (SMED)	▪ 20.5% reduction in build time (lead time) from 58 -46 days ▪ 5% reduction in the time it takes for value added activities. ▪ 44.5% reduction in time it takes for non-value-added activities	[59]
15	Higher Education	▪ Increasing customer satisfaction in the University computer center	5 why, value stream mapping, Control chart	▪ Satisfaction level of customers improved from 2.89 to 4.4 on a scale of 1-7 ▪ Annual cost savings of 360,000 Indian rupees ▪ Positive feedback from end users	[60]
16	Banking and finance	▪ High cost per employee ▪ Low service quality	VSM	▪ lower wait time for customers and ▪ lower stress levels for employees, ▪ increased customer satisfaction ▪ More profit and business	[61]

Challenges to implementing lean six sigma initiatives

Just like other endeavors, implementing improvement changes emanating from the Lean Six Sigma method has its own challenges, which vary from organizations to individuals. Some of these challenges are discussed below:

1. Culture: This is perhaps the most significant hurdle to implementing improvement initiatives. The culture of an organization would dictate how opportunities for improvement are easily identified, the philosophy around change, as well as how this mindset is cascaded down the organization. An organization that does not prioritize improvement and innovation would struggle with implementing the Lean Six Sigma methodology, or consequently reaping the benefits if these changes are implemented [62]. Overcoming cultural barriers requires strong leadership, effective communication, and a commitment to fostering a culture of improvement throughout the organization. Additionally, providing training and education on Lean Six Sigma principles can help shift the culture towards embracing improvement initiatives.
2. Leadership: The disposition of management towards improvement changes is very important in the implementation of Lean Six Sigma. Leadership support and involvement are crucial for the successful implementation of Lean Six Sigma. Without the commitment and dedication of top management, it can be difficult to allocate the necessary resources, drive change, and sustain improvement efforts [63]. Leaders need to champion the Lean Six Sigma initiatives, provide the required resources, and actively participate in improvement projects to demonstrate their commitment to the process.
3. Unions: The goal of the Improvement project is operational efficiency, which mostly has a resulting effect of reduction in redundancies and workforce. As such, this threatens the existing workforce and triggers a counter reaction from workers and the union. This can potentially affect improvement drive and implementation within an organization [64]. Overcoming union resistance requires effective communication, involvement of union representatives in the improvement process, and emphasizing the benefits of Lean Six Sigma in terms of job enrichment, skill development, and overall organizational success.
4. Noise & Blockers: Resistance to change is a common challenge in implementing Lean Six Sigma initiatives. Some individuals may resist or obstruct the changes due to fear, lack of understanding, or personal interests. It is important to address these barriers through effective communication, stakeholder engagement, and addressing concerns or misconceptions about the changes. Additionally, providing training and support to help individuals adapt to the changes can minimize resistance and overcome blockers.
5. Knowledge Gap: Shortage of personnel skilled in the knowledge of lean Six Sigma and improvement projects will impact the adoption and implementation of the improvement drive within an organization [36]. Implementing Lean Six Sigma requires personnel who

are skilled and knowledgeable in the methodologies and tools. However, organizations may face challenges in finding qualified individuals or providing sufficient training to build the required expertise. Investing in training programs, hiring experienced Lean Six Sigma professionals, or partnering with external experts can help bridge the knowledge gap and ensure the successful implementation of improvement initiatives.

6. Instant Gratification: Lean Six Sigma is a long-term approach to continuous improvement, and the benefits may not be immediately evident. Some organizations may be focused on short-term results and struggle to sustain their commitment to the improvement initiatives. Educating stakeholders about the long-term benefits, setting realistic expectations, and celebrating small wins along the way can help overcome the desire for instant gratification and maintain momentum for continuous improvement.
7. Involvement of Process Owners: Process owners, who are responsible for managing and overseeing specific processes, play a critical role in the success of Lean Six Sigma initiatives. Their involvement and commitment are essential for understanding the current state of the process, identifying improvement opportunities, and implementing sustainable changes. Engaging process owners from the beginning, providing them with the necessary training and support, and empowering them to drive the improvement initiatives can enhance the effectiveness and efficiency of Lean Six Sigma implementation.

Conclusion and Prospects

The rapid advancements in information and communication technologies have brought about significant changes in society, affecting both individual lifestyles and business practices. To survive and remain competitive in this evolving landscape, businesses need to deliver the right products, at the right location, with low costs, while meeting customer demands and expectations. As Lean Six Sigma continues to evolve and adapt to the changing landscape of industries, emerging technologies such as artificial intelligence (AI), software applications, and Industry-4.0 would play a significant role in enhancing its effectiveness and efficiency. Lean Six Sigma can leverage data-driven insights and automation to drive continuous improvement and meet the challenges of an increasingly digital and interconnected world. AI and machine learning algorithms can be leveraged to analyze large volumes of data and identify patterns and insights that may not be easily observable through traditional analysis methods. These technologies enable organizations to gain deeper and faster insights into process performance, identify root causes of problems, and make data-driven decisions. AI-powered tools can also automate certain tasks and streamline process monitoring, allowing for real-time feedback and continuous improvement.

Dedicated softwares such as Industry 4.0 provide valuable support in managing projects, tracking progress, and analyzing data. These applications offer features such as data visualization, statistical analysis, project management, and collaboration tools, making it easier for project teams to implement Lean Six Sigma methodologies and monitor their progress. These software solutions facilitate efficient data collection, analysis, and reporting, reducing the administrative burden and enabling teams to focus more on problem-solving and improvement efforts. The use of sensors, Internet of Things (IoT) devices, and real-time data collection enables organizations to have a comprehensive view of their operations and identify process variations and inefficiencies more effectively. With the availability of real-time data, Lean Six Sigma practitioners can make timely decisions, implement corrective and preventive actions (CAPA) promptly, and continuously monitor process performance. Furthermore, Industry 4.0 technologies enable the concept of "Smart Manufacturing", where machines and systems communicate with each other and self-adjust to optimize performance. This integration of Lean Six Sigma principles with advanced technologies allows for proactive identification of issues, predictive maintenance, and dynamic process control, leading to improved quality, reduced waste, and increased productivity.

It is important to note that while emerging technologies offer significant potential, they should be implemented thoughtfully and strategically. Organizations must ensure that the technology aligns with their Lean Six Sigma goals and complements the human expertise and problem-solving capabilities. Additionally, the integration of emerging technologies should be accompanied by the necessary training and skill development to enable employees to effectively utilize and interpret the data generated.

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Declaration of interest statement

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. Womack JP, Jones DT, Roos D. The Machine That Changed the World: The Story of Lean Production--Toyota's Secret Weapon in the Global Car Wars That Is Now Revolutionizing World Industry (167 Pages). [Internet]. 1990 [cited 2023 Jan 15]. Available from: http://www.pdfdrive.com/the-machine-that-changed-the-world-the-story-of-lean-production-toyotas-secret-weapon-in-the-global-car-wars-that-is-now-revolutionizing-world-industry-e187900819.html
2. Liker J. The Toyota Way. New York, NY: Mc-Graw Hill; 2004. [Internet]. 2004 [cited 2023 Jan 29]. Available from: https://www.mudamasters.com/en/lean-production/toyota-way-j-liker-summary
3. Ohno T. Toyota Production System: Beyond Large-Scale Production. New York: Productivity Press; 1988. doi: 10.4324/9780429273018.
4. Dillon AP, editor. A Study of the Toyota Production System: From an Industrial Engineering Viewpoint. Boca Raton: Routledge; 2019. doi: 10.4324/9781315136509.
5. Tekin M, Arslandere M, Etlioglu M, Koyuncuoğlu Ö, Tekin E. An Application of SMED and Jidoka in Lean Production. 2019, 530-545. doi: 10.1007/978-3-319-92267-6_45.
6. Simboli A, Taddeo R, Morgante A. Value and Wastes in Manufacturing. An Overview and a New Perspective Based on Eco-Efficiency. Adm. Sci. 2014, 4(3). doi:

10.3390/admsci4030173.
7. Panneman T. Lean Transformations - when and how to climb the four steps of Lean maturity. Maarssen (NL): panview, 2017.
8. Bhamu J, Singh Sangwan K. Lean manufacturing: literature review and research issues. Int. J. Oper. Prod. Manag. 2014; 34(7):876-940. doi: 10.1108/IJOPM-08-2012-0315.
9. Sinha N, Matharu M. A comprehensive insight into Lean management: Literature review and trends. J. Ind. Eng. Manag. 2019; 12(2). doi: 10.3926/jiem.2885.
10. Belekoukias I, Garza-Reyes JA, Kumar V. The impact of lean methods and tools on the operational performance of manufacturing organisations. Int. J. Prod. Res. 2014; 52(18):5346-5366. doi: 10.1080/00207543.2014.903348.
11. Durodola O, Oladipupo O, Falana O. Kaizen (Continuous Improvement) in Agriculture. 2022. doi: 10.13140/RG.2.2.12152.11526/1.
12. Falana O, Durodola O, Oladipupo O. Implementing Kaizen/Continuous Improvement in Manufacturing Industry. 2022. doi: 10.13140/RG.2.2.21692.92807.
13. Oladipupo O, Durodola O, Falana O. Kaizen/Continuous Improvement and its Relevance to Improving Operations. 2022. doi: 10.13140/RG.2.2.15702.93766.
14. Arai M, Sekine K. TPM for the Lean Factory: Innovative Methods and Worksheets for Equipment Management. [Internet]. Routledge & CRC Press; 1996 [cited 2023 Jan 29]. Available from: https://www.routledge.com/TPM-for-the-Lean-Factory-Innovative-Methods-and-Worksheets-for-Equipment/Arai-Sekine/p/book/9781563271915
15. Almorsy L, Khalifa M. Lean Six Sigma in Health Care: Improving Utilization and Reducing Waste. Stud. Health Technol. Inform. 2016; 226:194-197.
16. Hirano H. 5S for Operators: 5 Pillars of the Visual Workplace. Taylor & Francis, 1996.
17. Emiliani ML, Stec DJ. Leaders lost in transformation. Leadersh. Organ. Dev. J. 2005; 26(5):370-387. doi: 10.1108/01437730510607862.
18. Mak WM. The 5 S's: the foundation of total quality management. Total Quality Management. Springer Netherlands, 1995, 603-606. doi: 10.1007/978-94-011-0539-2_106.
19. Dillon AP. A Study of the Toyota Production System | From an Industrial Engineeri. [Internet]. 2019 [cited 2023 May 08]. Available from: https://www.taylorfrancis.com/books/mono/10.4324/9781315136509/study-toyota-production-system-andrew-dillon
20. Anderson D, Concas G, Lunesu MI, Marchesi M. Studying Lean-Kanban Approach Using Software Process Simulation. In: Agile Processes in Software Engineering and Extreme Programming. Springer, 2011, 12-26. doi: 10.1007/978-3-642-20677-1_2.
21. Bodek N. Kaikaku: The Power and Magic of Lean. PCS Press, 2004.
22. Serrat OD. The Five Whys Technique. Asian Development Bank; 2009 [cited 2023 Jun 07]. Available from: https://www.adb.org/publications/five-whys-technique
23. Rother M, Harris R. Creating Continuous Flow: An Action Guide for Managers, Engineers & Production Associates. Lean Enterprise Institute, 2001.
24. Costa R, Lopes I. Productivity Improvement in Manufacturing Systems Through TPM, OEE and Collaboration Between Maintenance and Production: A Case Study. In: Advances in Production Management Systems. Artificial Intelligence for Sustainable and Resilient Production Systems. Springer International Publishing; 2021. p. 261–268. doi: 10.1007/978-3-030-85914-5_28.
25. Nakajima S, Bodek N. Introduction to TPM: Total Productive Maintenance. Productivity Pr, 1988.
26. Tapping D, Luyster T, Shuker T. Value Stream Management: Eight Steps to Planning, Mapping, and Sustaining Lean Improvements, 2002.
27. Boutbagha M, El Abbadi L. Production Leveling or Heijunka: A Bibliometric Study. In: 2022 IEEE International Conference on Electronics, Control, Optimization and Computer Science (ICECOCS). IEEE; 2022. doi: 10.1109/ICECOCS55148.2022.9982975.
28. Albliwi SA, Antony J, Lim SAH. A systematic review of Lean Six Sigma for the manufacturing industry. Bus. Process Manag. J. 2015; 21(3):665–691. doi: 10.1108/BPMJ-03-2014-0019.
29. Lawal AK, *et al*. Lean management in health care: definition, concepts, methodology and effects reported (systematic review protocol). Syst. Rev. 2014; 3:103. doi: 10.1186/2046-4053-3-103.
30. Kobus J. Demystifying Lean IT: Conceptualization and Definition, 2016.
31. Hoerl R, Snee R. Statistical Thinking: Improving Business Performance. 2nd ed. 2012.
32. He Y, Tang X, Chang W. Technical decomposition approach of critical to quality characteristics for Product Design for Six Sigma. Qual. Reliab. Eng. Int. 2010; 26(4):325–339. doi: 10.1002/qre.1077.
33. N V, S S. Lean Six Sigma. In: Six Sigma Projects and Personal Experiences. InTech, 2011. doi: 10.5772/17288.
34. S PhD TV. Lean Six Sigma: International Standards and Global Guidelines. 2nd ed. Productivity Press, 2018. doi: 10.1201/b19260.
35. Kumar M, Antony J, Tiwari MK. Six Sigma implementation framework for SMEs – a roadmap to manage and sustain the change. Int. J. Prod. Res. 2011; 49(18):5449-5467. doi: 10.1080/00207543.2011.563836.
36. Patil R, Suryawanshi G, Shinde A. Lean Six Sigma Exploring Future Potential and Challenges. 2016, 7(3).
37. Tranfield D, Denyer D, Smart P. Towards a Methodology for Developing Evidence-Informed Management Knowledge by Means of Systematic Review. Br. J. Manag. 2003; 14(3):207-222. doi: 10.1111/1467-8551.00375.
38. Bhaskar HL. Lean Six Sigma in Manufacturing: A Comprehensive Review. IntechOpen; 2020. doi: 10.5772/intechopen.89859.
39. Trubetskaya A, McDermott O, Brophy P. Implementing a customised Lean Six Sigma methodology at a compound animal feed manufacturer in Ireland. Int. J. Lean Six Sigma. 2023 Jan;ahead-of-print(ahead-of-print). doi: 10.1108/IJLSS-08-2022-0169.
40. George M, Rowlands D, Kastle B. What is Lean Six Sigma? McGraw-Hill.
41. Banawi A, Bilec MM. A framework to improve construction processes: Integrating Lean, Green and Six

Sigma. Int. J. Constr. Manag. 2014; 14(1):45-55. doi: 10.1080/15623599.2013.875266.
42. Garza-Reyes JA. Lean and green – a systematic review of the state of the art literature. J. Clean. Prod. 2015; 102:18-29. doi: 10.1016/j.jclepro.2015.04.064.
43. Kumar S, Luthra S, Govindan K, Kumar N, Haleem A. Barriers in green lean six sigma product development process: an ISM approach. Prod. Plan. Control. 2016; 27(7-8):604-620. doi: 10.1080/09537287.2016.1165307.
44. Sreedharan V. R, S G, Raju R. Development of a Green Lean Six Sigma model for public sectors. Int. J. Lean Six Sigma. 2018; 9(2):238-255. doi: 10.1108/IJLSS-02-2017-0020.
45. Hussain K, He Z, Ahmad N, Iqbal M, Taskheer mumtaz SM. Green, lean, Six Sigma barriers at a glance: A case from the construction sector of Pakistan. Build. Environ. 2019; 161:106225. doi: 10.1016/j.buildenv.2019.106225.
46. Kaswan MS, Rathi R. Analysis and modeling the enablers of Green Lean Six Sigma implementation using Interpretive Structural Modeling. J Clean. Prod. 2019; 231:1182-1191. doi: 10.1016/j.jclepro.2019.05.253.
47. Nasution AA, Siregar I, Anizar, Nasution TH, Syahputri K, Tarigan IR. Lean Manufacturing Applications in the Manufacturing Industry. MATEC Web Conf. 2018; 220:02005. doi: 10.1051/matecconf/201822002005.
48. Sharma R, Kasher M, Zhang L, Mani N, Lai B. Application of Lean Manufacturing Principles in Optimizing Factory Production. 2018 IEEE MIT Undergraduate Research Technology Conference (URTC). 2018, 1-4. doi: 10.1109/URTC45901.2018.9244796.
49. Chowdary BV, George D. Improvement of manufacturing operations at a pharmaceutical company: A lean manufacturing approach. J. Manuf. Technol. Manag. 2012; 23(1):56-75. doi: 10.1108/17410381211196285.
50. Venkat Jayanth B, Prathap P, Sivaraman P, Yogesh S, Madhu S. Implementation of lean manufacturing in electronics industry. Mater. Today Proc. 2020; 33:23-28. doi: 10.1016/j.matpr.2020.02.718.
51. Laureani A, Brady M, Antony J. Applications of Lean Six Sigma in an Irish hospital. Leadersh. Health Serv. 2013; 26(4):322-337. doi: 10.1108/LHS-01-2012-0002.
52. Jie JCR, Kamaruddin S, Azid IA. Implementing the Lean Six Sigma Framework in a Small Medium Enterprise (SME) – A Case Study in a Printing Company.
53. Adeodu A, Kanakana-Katumba MG, Rendani M. Implementation of Lean Six Sigma for production process optimization in a paper production company. J. Ind. Eng. Manag. 2021; 14(3):661. doi: 10.3926/jiem.3479.
54. Ismail A, Ghani JA, Ab Rahman MN, Md Deros B, Che Haron CH. Application of Lean Six Sigma Tools for Cycle Time Reduction in Manufacturing: Case Study in Biopharmaceutical Industry. Arab J Sci Eng. 2014; 39(2):1449-63. doi: 10.1007/s13369-013-0678-y.
55. Alsyouf I, Kumar U, Al-Ashi L, Al-Hammadi M. Improving baggage flow in the baggage handling system at a UAE-based airline using lean Six Sigma tools. Qual Eng. 2018; 30(3):432-52. doi: 10.1080/08982112.2018.1437180.
56. Prashar A. Process improvement in farm equipment sector (FES): a case on Six Sigma adoption. Int J Lean Six Sigma. 2014; 5(1):62-88. doi: 10.1108/IJLSS-08-2013-0049.
57. Desai DA, Kotadiya P, Makwana N, Patel S. Curbing variations in packaging process through Six Sigma way in a large-scale food-processing industry. J Ind Eng Int. 2015; 11(1):119-29. doi: 10.1007/s40092-014-0082-6.
58. Pillai AKR, Pundir AK, Ganapathy L. Improving Information Technology Infrastructure Library Service Delivery Using an Integrated Lean Six Sigma Framework: A Case Study in a Software Application Support Scenario. J Softw Eng Appl. 2014; 7(06):483-97. doi: 10.4236/jsea.2014.76045.
59. Akbulut-Bailey A, Motwani J, Smedley E. When Lean and Six Sigma converge: A case study of a successful implementation of Lean Six Sigma at an aerospace company. Int J Technol Manag. 2012; 57:18-32. doi: 10.1504/IJTM.2012.043949.
60. Sunder VM, Mahalingam S. An empirical investigation of implementing Lean Six Sigma in Higher Education Institutions. Int J Qual Reliab Manag. 2018; 35(10):2157-80. doi: 10.1108/IJQRM-05-2017-0098.
61. Baag PK, P K, Sarkar A. Application of Lean Tool for Process Improvement of Bank Branches. IIM Kozhikode Soc Manag Rev. 2019; 8(2):131-42. doi: 10.1177/2277975219836502.
62. Herbert L. Lean Six Sigma Challenges and Opportunities, 2008.
63. Alblooshi M, Shamsuzzaman M, Khoo MBC, Rahim A, Haridy S. Requirements, challenges and impacts of Lean Six Sigma applications – a narrative synthesis of qualitative research. Int J Lean Six Sigma. 2021; 12(2):318-67. doi: 10.1108/IJLSS-06-2019-0067.
64. Cornelissen R, Trienekens J. What are the main challenges when implementing lean and how do industry and company characteristics influence these challenges?