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Application of Lean Six Sigma Methodology in Manufacturing. A Systematic Review

Chinedu James Ujam[1*]

[1]*Department of Mechatronics Engineering, Federal University Otuoke, Bayelsa State, Nigeria*

[*]*Corresponding author*

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Abstract

This study assessed and examined the body of existing literature to gain a deeper understanding of the lean six sigma (LSS) methodology and its applications in manufacturing. Lean manufacturing seeks to improve an organization's production and process efficiency by eliminating waste. Six Sigma, on the other hand, is an improvement approach that could reduce operational and process variance in an organization. Despite the fact that lean-six-sigma has historically been applied primarily in developed countries, its importance in manufacturing procedures and managerial endeavors cannot be understated. This paper's goal is to demonstrate the advantages of these ideas and how they may be used in various sectors to boost output, cut waste, raise the caliber of products, and guarantee stakeholder and consumer happiness. The article also discusses the several lean six sigma methodology techniques that small and medium-sized businesses have used to increase the quality of their products and the efficiency of their processes. Any industry may use lean-six-sigma to boost productivity by continuously improving company operations. Any manufacturing sector would benefit from this study's answer on how to operate successfully in a dynamic market system and competitive business environment. Other researchers might also utilize it to improve their literature. The findings of this study on how to function effectively in a competitive business environment and dynamic market system would be helpful to any manufacturing sector. It may also be used by other researchers to enhance their work.

Keywords: Lean principle, Six Sigma, Methodology, DMAIC Technique

1. Introduction

Applying both lean and six-sigma principles to manufacturing processes in an effort to boost productivity is known as lean-six-sigma. Lean manufacturing was initially taken from the Toyota Production System when Toyota began to expand its presence in the auto industry in the 1980s. One of the best management techniques for boosting productivity is lean-six-sigma, according to a recent ranking. Eliminating waste and processes that don't increase customer satisfaction is the concept behind the lean manufacturing approach. As a result, the organization will become more effective and efficient. However, six-sigma is necessary to

reduce process variability. In the 1980s, Motorola developed the six-sigma continuous improvement methodology to reduce manufacturing operation variability and improve quality standards [1]. The lean manufacturing approach aims to improve customer satisfaction while decreasing waste and non-added value. Producing the best possible product and what the customer wants are the main goals of six-sigma [2].

Mohammed [3] examines how the use of lean tools in construction projects impacts safety concerns in the Gaza Strip. A questionnaire survey was used to learn more about the opinions of contractors and clients regarding the application of lean tools in construction projects. The results showed a significant flaw in the use of lean construction equipment in the building projects as well as a lack of knowledge about it. Training will be essential to applying lean construction principles successfully. However, the study area utilized in the report to demonstrate the theoretical and empirical investigation was a construction company.

There has been criticism of the tools created by Richard [4], who concentrated on the conceptual models of construction management. This study suggests that in order to solve the issue of waste in projects, project teams must employ trustworthy and realistic modeling tools. Examined is the importance of this technology, which was applied in the building sector as a component of the lean construction methodology. Waste and non-value-added operations are major contributors to production costs in the construction industry. Reducing process waste is the aim of lean construction. Furthermore, implementing lean methods and tools will boost output, cut down on waste, and save a lot of money. This study contributed to the body of knowledge and practice pertaining to waste elimination or delay management and acted as a standard for future advancements. Six Sigma employed statistical analysis in conjunction with other qualitative techniques to identify and address operational defects. It provides a method for determining the root cause of any problem pertaining to a process. A study by [5] claims that the six sigma processes include focusing on customer needs, employing project management tools and methodology, measuring and reporting financial results, and using additional, more advanced data analysis tools. Thomas [6] described how the Six Sigma methodology was applied in the operating department of the National Bank. He concentrated on the evolution of Lean Six Sigma and its impact on operational efficacy. The findings of the data collection showed that Lean Six Sigma improved operations, process, management style, and variation reduction.

The Six Sigma methodology was created by Nayan [7] and provides tools and techniques to boost output and minimize process defects. In order to determine the root cause of a problem, six-sigma uses several conventional quality tools, such as statistical process control, cause and effect diagrams, Pareto or control charts, and benchmarking, according to Breyfogle III [8]. With the help of the six-sigma methodology, the business may expand beyond quality to other crucial areas in order to concentrate on what the customer wants. Furthermore, it has been demonstrated that when lean and six-sigma are applied independently, organizations frequently fail to see the anticipated improvement. Six-sigma identifies and eliminates waste, but it provides no tools to improve or optimize system performance. Lean approaches, on the other hand, offer instruments for system optimization but do not incorporate statistical analysis, which is essential for improving system performance. Combining the two concepts is required to improve organizational and operational results, including higher customer satisfaction, given the previously mentioned drawbacks of each strategy. Ultimately, overall manufacturing costs dropped, productivity increased, and product quality improved. In order to improve operational effectiveness and efficiency and attain total customer satisfaction, Kanakana [9] states that the objective of integrating the concepts of lean manufacturing and six sigma is to eradicate waste and other non-value-added operations.

Lean-Six-Sigma Methodology

The integration of these two approaches started in 1997 when the BAE system introduced lean

manufacturing and six sigma for the first time in the aerospace industry [10]. The company dubbed the program the lean six sigma approach in an effort to maintain market share and lower variance in the product processes. According to the results, the BAE system greatly improved lead time, dependability, productivity, and savings. Two years later, Maytag Corporation reengineered one of its production lines using the methodology. Manufacturing costs were reduced by millions of dollars thanks to this tactic [11].

Smith [10] claims that the IBM Consulting Group is skilled at implementing the lean-six-sigma methodology. The company used two techniques to find the system problem. Lean methodology was used to identify waste, and six-sigma was used to reduce variance and boost reliability.

To implement lean flow and offer substantial improvement opportunities, Rockwell Automation Power System combined a 5s program, lean principles, and a value stream mapping approach. [12]. A modified version of the Define, Measure, Analyze, Improve, and Control (DMAIC) technique was used in papers submitted to the Electronic Copies Convention Company. In order to reduce manufacturing costs, boost productivity, and reduce error rates, the DMAIC method integrates lean concepts at every stage [13]. The Northrop Grumman Company integrated exercise with Lean Thinking and Kaizen practices. The company also applied the six-sigma methodology to address higher-quality problems and validate fixes [14]. Examining the lean-six-sigma methodology's benefits, applications, and tools in the manufacturing industry is the main objective of this paper. Shahrul [15] looked into how the innovative Lean Six Sigma concept could be used. He applied the Lean tools and the six sigma concept developed during the initiative's analysis phase to minimize and ultimately eliminate the variation found. The integrated approaches were utilized by small and medium-sized enterprises (SMEs), particularly in the label printing industry. The evolution of the framework depends on the particular corporate environment that it is a part of.

The structure of the system helps to manage advancements, identify problems, and provide suitable solutions for problems. The issues brought up and their solutions are given a lot of weight in this approach. The conclusion of this paper demonstrated that the application of the lean-six-sigma framework has provided a systematic and focused approach that facilitates problem identification, the creation of workable solutions, and the maintenance of accomplishments. Abdullah [17] looked into the use of lean management and six sigma techniques to improve production performance in industrial pharmaceuticals. The study evaluated factors related to applying lean six sigma to improve the management and performance of a specific pharmaceutical industry. This article focused on how satisfied the pharmaceutical industry was with the lean six sigma methodology. A lean six sigma framework was created by Rathilall [18] to increase the competitiveness of a small number of auto component manufacturers. The study examines how the company can create a productive production process by combining six sigma and lean technologies into a unified strategy. According to the results, the approach offered the company a great opportunity to combine operations utilizing both technologies in order to fulfill customer requests and maintain a high standard of management. Lean six sigma is a methodology that aims to eradicate waste and process variation by utilizing the DMAIC concept. This strategy produces satisfied customers in terms of product quality, delivery time, and related expenses.

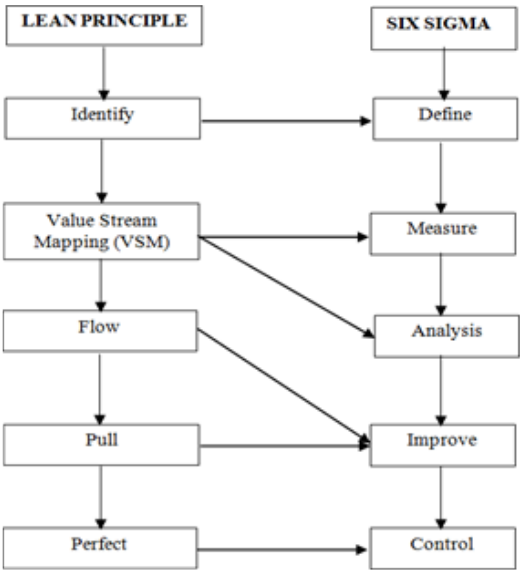

Figure 1. The relationship of Lean Principles and Six Sigma Model [16].

Benefits of Lean-Six-Sigma (Lss)

1. Cost Reduction: Lean Six Sigma assists in locating and getting rid of process waste, which lowers labor costs, material costs, and overhead.

It reduces the cost of error correction by reducing defects and rework.

2. Enhanced Productivity and Efficiency: Using Lean Six Sigma principles to optimize processes and streamline workflows results in quicker turnaround times and higher output. Reducing delays and bottlenecks enables more effective use of resources..

3. Better Quality: Lean Six Sigma techniques concentrate on locating and removing the underlying causes of flaws to produce goods and services of a higher caliber.

Statistical process control techniques and data-driven analysis guarantee constant quality and minimize variances.

4. Increased Customer Satisfaction: Lead times are shortened, quality is improved, and service is delivered more effectively, all of which increase customer satisfaction.

Lean Six Sigma promotes loyalty and a favorable brand image by successfully meeting customer needs and expectations.

5. Greater Employee Engagement: By incorporating staff members in process improvement projects, Lean Six Sigma empowers them. Opportunities for training and development improve their abilities and expertise, which raises their motivation and job satisfaction.

6. Better Decision-Making: Lean Six Sigma minimizes reliance on intuition and conjecture by relying on data-driven decision-making. Better results are achieved as a result of making better, more informed decisions.

7. Increased Flexibility: Lean Six Sigma gives businesses the instruments and techniques to swiftly detect

and address problems, enabling them to adjust to shifting consumer and market demands. In dynamic environments, this agility is essential for preserving a competitive edge.

8. Competitive Advantage: Lean Six Sigm gives businesses an advantage over competitors by streamlining operations, cutting expenses, and raising quality.

Long-term sustainability, greater profitability, and a larger market share can result from this.

9. Cycle time reduction as a result of consistent speed and process output control:

10. Defective products and work-in-progress have decreased.

11. A decrease in delivery time and an increase in stakeholder and customer satisfaction. Less manpower and equipment are required.

12. Development of goods and services and expansion of market share.

13. Six sigma solutions were used for validation situation.

14. Complex problems were handled using lean manufacturing, while hander problems like variation control were handled by six-sigma.

Various Methodology Tools and Applications of Lean Six Sigma

Author (Year)	Topic	Objective	Study Area	Methodology / Tools	Result
Panayiotou et al. (2022)	Standardized toolset for LSS	Implement LSS in SE European manufacturer and develop standard DMAIC toolset	Small-scale manufacturing projects	DMAIC, Yin's case-study method	Financial, operational, organizational gains; proposed toolset supports wider LSS adoption
Siregar et al. (2019)	LSS in general manufacturing	Review LSS objectives, tools, fail factors	Indonesia manufacturing sectors	Lit review	Defined objectives (cost, waste reduction), common tools, failure drivers identified
Albliwi et al. (2015)	Systematic review, manufacturing	Explore themes, gaps in LSS literature	Manufacturing (2000–2013)	Lit review of 37 papers	Highlighted benefits, motivations, limitations, and research gaps
Priya et al. & others via axle study (2021)	Axle production improvement	Eliminate waste, reduce defects in axle line	Automotive axle manufacturing	DMAIC, VSM, 5S	Non-value time reduced; defect rate dropped from 9.19% significantly
Na Li (2020)	LSS in Chinese SMEs	Identify critical success factors & challenges	Three Chinese manufacturing SMEs	DMAIC, DMADV case-study & interviews	Developed Lean–iceberg model with six propositions to support sustainable LSS
Roque da Silva et al. (2018)	Multiple-case LSS study	Integrate LSS concepts in	Three São Paulo	DMAIC, SIPOC, VSM	Demonstrated theory–practice

		production systems	industrial firms		alignment and performance improvements
Olayinka et al. (2023)	Process optimization	Explore complementary nature of Lean & Six Sigma	Various manufacturing sectors	Comparative case analysis	Showed hybrid LSS improves both quality and waste reduction
Ferreira & Cunha (2022)	Ranking LSS tools	Evaluate LSS tools by use, difficulty, impact	Portuguese industry via consultant survey	Survey (37 tools)	VSM, VOC, Hoshin Kanri top-ranked; data supports implementation planning
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(Chem sector) Bibliometric MDPI (2021)	LSS in chemical manufacturing	Map trends, drivers, barriers	Chemical manufacturing	Bibliometric & case review	Identified limited adoption; benefits include cost & waste reduction; called for sector expansion
Bosch Kaggle (2016)	Big data + LSS	Predict production failures in assembly line	Bosch production line	Advanced analytics, ML	Early failure detection, yielding cost savings

Complementary lean techniques were identified using the DMAIC methodology.

Given all of the advantages of LSS, a study was carried out with Nigerian Breweries as a study area in order to take advantage of the chance to enhance its production line procedures. One of the biggest companies on the Nigerian stock exchange is a Nigerian brewery. Both alcoholic and non-alcoholic drinks are among the company's well-known, premium brands [2]. The study's primary goal is to streamline all bottling procedures in order to cut down on waste and non-value-added production line operations. Lead time and other non-value-added processes were reduced by 37.7%, according to the results. Cycle time and customer satisfaction both saw notable improvements.

Conclusion

This study showed how the industry's production process and product quality were changed by lean manufacturing concepts and six sigma tools and practices. Combining the two concepts results in lean-six-sigma, a powerful tool that can impact an organization's operations as well as stakeholder and customer satisfaction. Despite the fact that lean-six-sigma has historically been applied primarily in developed countries, its importance in manufacturing procedures and managerial initiatives cannot be understated. The current volume of research on lean-six-sigma is evidence that its extensive history has diverted attention from academics and increased interest in many areas of study. Lean-six-sigma can be applied to any industry to boost productivity through ongoing improvements in stakeholder and customer satisfaction as well as business operations.

Declaration of Conflicting Interests

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