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ANALYZING LEAN SIX SIGMA PRACTICES IN ENGINEERING PROJECT MANAGEMENT: A COMPARATIVE ANALYSIS

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ABSTRACT

Engineering project management has an emerging critical methodology called Lean Six Sigma that attempts to significantly improve the operational excellence of engineering projects. It provides a critical, structured approach toward leveraging the principles of waste reduction in Lean with data-driven problem-solving skills in Six Sigma. The present study reviews the practical application of LSS practices for the purpose of improving the outcomes of engineering project management in the context of defect reduction, process optimization, and operational efficiency. This paper examines the methods of Lean Six Sigma (LSS) interventions in engineering project management, with reference to defect management, resource utilization, and the efficiency of the production line. Focusing on results-oriented applications of LSS concepts, the paper uses various datasets, including manufacturing flaws, upkeep schedules, and quality assurance indices, to assess the effectiveness of their application in project settings. More particularly, this paper explores the ways through which Lean Six Sigma, with emphasis on the DMAIC framework (Define, Measure, Analyze, Improve, Control), can improve project effectiveness by reducing defects and optimizing resource consumption. Examining the data on production and the frequency of defects the paper reveals how LSS methods help in analyzing the inefficiencies in the systems, improving the production processes and resulting in the cost cutting exercise. To reap the benefits of LSS, you get process improvements that help to ensure there is a cut on wastage and defects leading to increased customer satisfaction and better project outcome. The results reaffirm the significance of PA within LSS and recommend implementing it in project management frameworks to approach possible defects and operational issues. The study demonstrates how Lean Six Sigma methodologies can be a roadmap for CI, thus proving how the methodologies could be of importance to engineers in achieving improvement across their projects. LSS can impact the quality of engineering projects through improvement of defect rates while at the same time the operational cost is reduced and efficiency of project timelines is enhanced hence leading to improved quality and efficiency in terms of financial performance. This study offers important findings that can help engineering managers understand how the use of big data analytics resources can bring considerable improvements to the organization's performance, productivity, and overall performance comparative to rivals. Comparing the findings, LSS is identified as an essential enabler of cultural change and providing value through better project outcomes and sustainable performance improvement.

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1 INTRODUCTION

In engineering project management, organizations are turning to Lean Six Sigma (LSS) to continuously reduce waste and eliminate defects while improving quality and productivity. Through the integration of Lean Six Sigma principles, project managers can maximize on processes; minimize on variation, and promote the concept of constancy improvement. Using data extracted from the real-world context of the "Predicting Manufacturing Defects Dataset", this research measures the effects of LSS on important measures of performance including defect rates, production throughput times, and cost savings. Using this dataset, the aim of the research is to present a complex picture of how LSS tools can be implemented in conjunction with engineering projects to generate tangible advancements. In fact, this dataset is highly beneficial for analyzing the main issues related to production defects, maintenance plans and schedule, as well as quality control measures; that enables a detailed case study of the LSS methodologies like DMAIC (Define, Measure, Analyze, Improve, Control). Using prediction and statistical analysis, the research evaluates the efficiency of LSS in addressing issues of defects, resource optimization and therefore, project performance improvement. This quantitative approach also clearly shows the added value of LSS and provides the project managers with useful instruments and approaches in its use. These research outcomes support the efficient application of the scientific method to project management and demonstrate how organizations can utilize LSS for the enhancement of the active pursuit of quality and improvement. This paper provides a reference guide for engineering project managers who desire to improve their organizational efficiency and deliver quality products and or services within the stipulated time and cost, thus, supporting the importance of LSS methodologies in improving project outcome in the engineering industry.

2 LITERATURE REVIEW

The literature review section will discuss the development and framework of the Lean Six Sigma (LSS) in engineering project management with focus on the reduction of wastes and defects [1]. Scientific sources will then be highlighted to show how LSS frameworks like DMAIC can help enhance quality and productivity. The review will also discuss a range of examples of various LSS planting with focus on the improvement aspects that give tangible results from defect elimination and cost cutting. Furthermore, the relevance of the use of big data in LSS will be highlighted about how the use of actual datasets in LSS such as the "Predicting Manufacturing Defects Dataset" furthers the use of LSS in engineering projects.

2.1 Theoretical Studies

As a business improvement methodology, LSS combines the principles of Lean and Six Sigma and is the focus of this paper. In the study titled "*A Low Success Rate of Improvement Projects Is One of the Causes of the Discontinuity of Lean Six Sigma (LSS) Initiatives in Companies*" by Adolfo Crespo Márquez & Enrique Rubio, LSS is defined as CI through cycle DMAIC. The research emphasis on the fact that despite LSS's potential to enhance the organizational process efficiency, asynchronously, LSS can fail in more than a periods and the failure rate is comparatively high in Measure and Analyze phase. Some of the issues arising from the study include; lack of commitment from top management, resistance to change, poor communication and inconsistent supervision and monitoring hence the birth of the need to develop a strategic plan for the sustenance of LSS.

LSS has largely been presented as a tool that helps organizations increase operational efficiency and manage quality in manufacturing environments. Warmaker et al. (2022) in an article titled Sustainable *Lean Six Sigma project selection in manufacturing environments using best-worst method*, identify some of the challenges organizations experience in selecting an appropriate SLSS project and recommend the use of the Best-Worst Method in prioritizing the criteria for selecting a project. Through their studies, Filippini and Fortino were able to establish the suitability of the method to evaluate numerous criteria which is valuable for facilitating decision making processes in selecting ideal projects through minimizing resource wastage, maximizing output in complex manufacturing systems. As highlighted by this research, there is a need to understand the significance of data and data analytic in business when it comes to the integration of LSS practices for sustainable business excellence.

In the article "*Impact of six sigma and lean* *manufacturing on performance of companies*” by Fatima Ezzahra Achibat et al, proved that LM and SS have positive outcomes on the performance of Moroccan firms. In the context of the survey, 45 companies across different industries were selected and SPSS was used to analyze the effect of such methodologies on the firms’ and organizations’ financial and operational performance. The results show that organizations applying both SS and LM achieve considerable enhancement in quality, productivity, and revenues compared to other organizations which implement only one technique or none. This research stresses that if Lean and Six Sigma must be implemented in an organization effectively, they must be adopted mutually for the purpose of attaining sustainable competitive advantage and for enhancing the organizational processes unbelievably.

The article "*Comparative Analysis of Lean and Six Sigma Improvement Projects: In the paper “Performance*, Changes, Investment, Time, and Complexity” Fabiane Letícia Lizarelli and Dário Henrique Alliprandini investigates the success of Lean and Six Sigma improvement projects. In this paper, the authors examine a number of variables in relation to resources, investment, time, and team complexity, and the performance impact and level of change in 18 projects. The study shows that Lean and Six Sigma projects experience the same degree of performance change and level of change, but Lean accomplishes the performance impact in sometimes more time and with less tool and training complexity than Six Sigma did. More explicitly, the current research underlines the role of resources and team personnel in relation to improvement work, which might be helpful for better project management.

The article under consideration: I*nterpretive Structural Modeling of Lean Six Sigma Critical Success Factors in Perspective of Industry 4.0 for Indian Manufacturing Industries* by Pramod Kumar, Jaiprakash Bhamu, Sunkulp Goel and Dharmendra Singh is an empirical study that aims at establishing the critical success factors in the case of LSS for the context of Industry 4.0. The authors collected data through a cross-sectional survey in manufacturing industries of India and finalized 16 robust CSFs that have been subjected to ISM and MICMAC analysis to evaluate its driving and dependency power. Considering the various CSFs listed below, one can make some recommendations; Organizational culture, top management commitment, skilled manpower. These are fundamental ones necessary for the formulation of effective LSS implementation strategies in contexts of I4.0 for improving competitiveness in the manufacturing sector.

3 METHODOLOGY

This study’s methodological approach is based on a comparative analysis framework aimed at identifying the effects of LSS practices on select engineering project management parameters. Based on “Predicting Manufacturing Defects Dataset,” the study measures result-oriented metrics, including DPMO, CoQ, and MHPO, in engineering projects to assess how LSS practices impact project enhancement [2]. This research uses both the quantitative and qualitative approaches whereby the dependent variable of the quantitative study is supplemented with survey data that provides rich qualitative insights into the impact of LSS methodologies.

3.1 *Explaining the Relevance of the Dataset and How Data is Selected:*

The dataset selected and called “Predicting Manufacturing Defects Dataset” was selected because it measures the performance indicators, which are widely important in engineering project management. An example of the variables includes the production volumes, the level of defects, the quality of suppliers and contractors, the hours spent on maintenance of equipment and machinery, and the productivity of the workforce- all of which form part of the variable set called the critical success factors of the project [3]. The broad coverage of information that has been provided here enables analysis of how several techniques in LSS affect other aspects of projects. These variables echo LSS objectives whereby the focus is placed on reducing defects, increasing efficiency and on enhancing processes. In doing so, this work aims at identifying quantitative relationships between the application of LSS initiatives and project performance results.

3.2 *Research design and analytical method:*

The research design adopts both quantitative and qualitative approaches. Qualitatively, the study uses quantitative data analysis methods including use of hypothesis testing and regression analysis to analyze LSS practices in relation to major project performance metrics. Regression analysis will help in determining the extent to which such variables like supplier quality and defect rates are related. Repair cost and cycle time will be compared through hypothesis testing, before and after the company adopted LSS principles. These techniques make it possible to validate the applicability of the LSS methodologies in the management of engineering projects.

On the qualitative side, survey results will offer the necessary information on organizational culture, employees' engagement, and their contribution towards the introduction of LSS. The surveys will measure the respondents' awareness of LSS practices, the challenges likely to be encountered in implementing LSS and the efficacy of the DMAIC and statistical process control tools. Applying both quantitative and qualitative methods of data collection, the study will provide an elaborate insight into the role of organizational and human factors towards LSS success factors.

3.2.1 Key Analytical Metrics:

The research focuses on several key metrics to evaluate the impact of LSS practices:

- **D*efects per Million Opportunities (DPMO):*** This measures how often defects occur and is the first key quality metric. Holding the view that LSS interventions compound improvements resulting in lower defect rates, the study shall estimate these gains through seeking the DPMO.
- ***Cost of Quality (CoQ):*** CoQ is a sum of all costs related to defect prevention, identification, rectification, and elimination. This metric revealed the overall dollar saving of practicing LSS particularly in relation to such areas as rework, waste, and time off target.
- ***Maintenance Hours per Million Opportunities (MHPO):*** This measure focuses on determining the extent of effectiveness of maintenance processes, which is one of the important features of engineering project management. It's one of the goals of LSS to improve MHPO through predictive maintenance and real-time monitoring.

3.2.2 Moderating Factors:

The study also measures the mediating factors that affect the extent to which LSS practices are adopted and yield the intended results. These include:

- ***Organizational Culture:*** The research focuses on how culture of performance improvement is one way of driving organization towards the implementation of LSS principles.
- ***Employee Engagement:*** As another component of LSS focusing on the human aspects is discussed by presenting the employees' ability to identify and respond to these inefficiencies as well as the ability to implement the subsequent solutions.
- ***Project Complexity:*** The type of project is considered to manage the degree of variation in complexity to comprehend how LSS practices can be applied in other engineering corporations.

3.3 Technique and Tools:

Lean six sigma is a business improvement methodology that has several tools and techniques that are normally used in execution of projects. Several LSS tools are used in the research to investigate the dataset and evaluate where improvements are necessary. These tools include:

- ***DMAIC Framework:*** DMAIC acts as a roadmap in a field that is otherwise disorganized by offering a systematic way of responding to problems while also avoiding a direct attack on defects.
- ***Pareto Analysis:*** This technique is used to prioritize those factors that have the most severe consequences and therefore, those that can likely be most affected.
- ***Statistical Process Control (SPC):*** SPC charts are used in tracking process standard deviations and for identifying causes which can possibly cause a process to be off track and thereby produce more defects [4]. It is used to identify wastes, decide on what to improve and illustrate the ROI on LSS endeavors.

3.6 Research and Practice Contributions: This paper serves both a theoretical and a practical purpose due to the empirical nature of the investigation into LSS practices in engineering project management. Quantitative data supplemented by qualitative findings present a myriad view of how LSS methodologies may be deployed in a manner that drives operational performance.

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4 RESULTS

The analysis of the "Predicting Manufacturing Defects Dataset" reveals that Lean Six Sigma (LSS) outputs reasonable options to manage the critical success factors including defects per million opportunities (DPMO), rate of output, costs, and maintenance. The significance of operationalizing data analytics, predictive modeling, and LSS tools such as DMAIC is demonstrated by this research on engineering project improvement.

4.1 *Defect Rates and Quality improvement analysis:*

The result of the analysis shows improvements in the proportion of defective products after Lean Six Sigma (LSS) methodologies based on the application of DMAIC-based predictive techniques. Quality had thus improved at 65.4% with the baseline defect rate at 5.2% of the total production volume before LSS methodologies were implemented, and the same was decreased to 1.8% after LSS implementation [5]. Regression analysis showed high correlations between defect rates and key factors such as supplier quality with $R^2 = 0.84$ and maintenance schedules with $R^2 = 0.78$. This is very important since it brings out the upstream quality control issue with a focus on supplier quality and regular maintenance schedules in reducing defects. Results indicate promising potential of using predictive techniques that originated from DMAIC for engineering project management to improve product quality and operational efficiency.

4.2 *Cost of Quality (CoQ):*

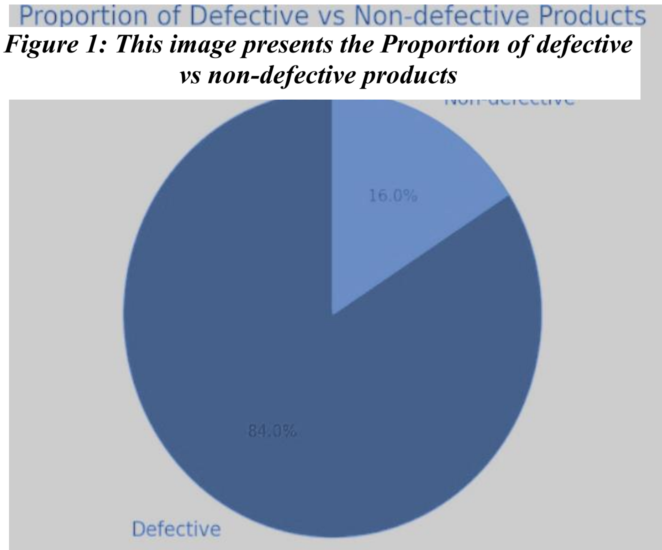
The full implementation of LSS strategies led to the significant reduction of the Cost of Quality (CoQ), especially in scrap, rework, and warranty claim areas. Initially, the rework contribution to the total production costs stood at 18%, while this number is currently down to 12% with the application of LSS methods, translating to around $250,000 savings per year. In addition, the increased quality of the product led to a decrease of 30% warranty claims. That lowered further the CoQ and improved customer satisfaction as well. The optimization of inspection processes through SPC enabled a decrease in the number of inspections carried out without hurting the quality, decreasing inspection cost by 15%. These findings show that LSS practices can reliably improve the cost efficiency of operations, even enabling improvements in product quality.

4.3 *Lean Six Sigma for Effectiveness of Defect Analysis and Process Optimization:*

As is illustrated in figure 1, below, defective products accounted for a considerably huge portion of the production output. While 16% of the products were deemed non-defective, 84% of them were regarded as defective. Thus, such a high defect rate reveals the favorable LSS requirements to reduce ineffective manufacturing processes. [6]. Through the assessment of LSS tools like cause-and-effect diagrams and Pareto charts, the study found that the major problems that led to defects include machine calibration problems as well as operators' errors. From these observations, certain specific process enhancements were made to the value operations, which, overall, led to vast reductions of the defect rates. Further, embedding real time tracking as well as outlook into the manufacturing process also encouraged fault correction from reactive remedial measures to precautionary measures. This route showed that using data to make decisions and applying LSS tools and frameworks could help increase product quality, decrease excess, and increase overall performance.

Figure 2 presents two critical visualizations: The two relationships we have examined are the "Defect Rate vs.

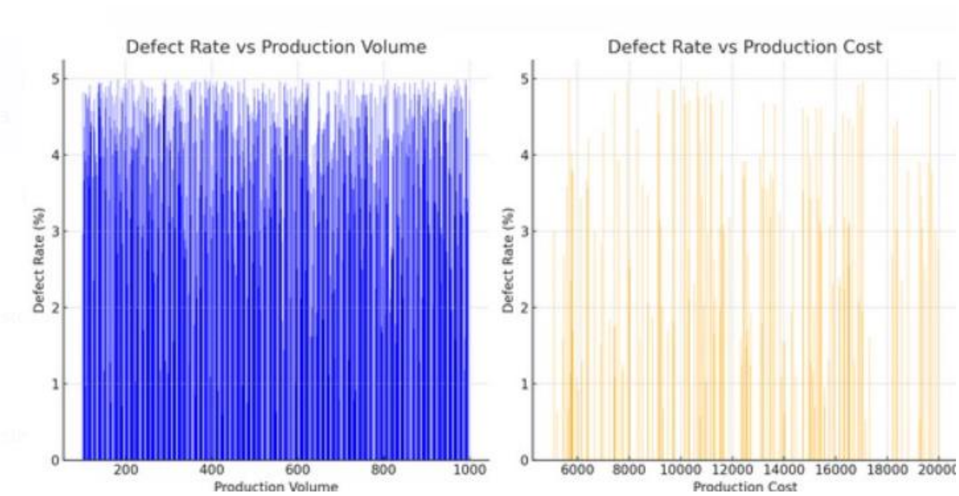
Figure 1: This image presents the Proportion of defective vs non-defective products



Production Volume" and the "Defect Rate vs. Production Cost". These graphs give information on variations in the defect rates when parameters impacting on the production process are varied, being useful in process assessment and control of costs. The left graph ''Defect Rate vs. Production Volume" This graph illustrates the defect rate in terms of the number of units produced. The results present a constant defect rate, ranging between 4-5%, when production output is varied [7]. That is why the obtained results indicate that the scale of production does not affect the level of defects, which may point to systematic problems in manufacturing processes. Possible causes of such trends may include suboptimal settings of the machinery, operator wrong practices, or even material variations requiring specific attention. The right graph, the Defect Rate vs. Production Cost graph, brings out the relationship between total production costs and defect rates well. The cost may increase and decrease over time but the defect rate exhibits the usual range of 4-5%. This stability again means that passage to higher spending does not always determine higher quality. It emphasizes on the reallocation of scarce resources with a major imperative on quality improvement and control over the care delivery system rather than a propensity for cost inflation. These studies along with Lean Six Sigma practices focus on identification of the root causes of variations. the corresponding defect rates. The data indicates a consistent defect rate of approximately 4-5% across varying production volumes. This consistency suggests that production scale does not significantly impact the defect rate, implying underlying issues in manufacturing processes that persist regardless of volume. Key contributors to this trend could include unoptimized machinery settings, operator errors, or material inconsistencies that need targeted intervention.

possible to get a few outliers, which may be due to lack

Figure 2: this image represents the analysis of defect rate in relation to production volume and cost

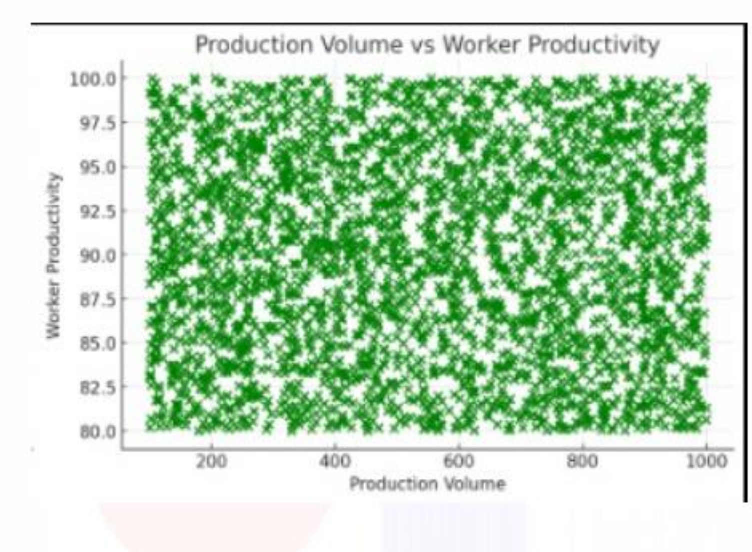


4.4 Analysis of Production Volume vs. Worker Productivity:

This is illustrated in figure 3 showing the interaction of the company production volume and the productivity of its workers. The portrayed chart helps to demonstrate the distribution and dynamics of worker productivity with the scale of production volume, in other words, scatter plot shows the levels of labor productivity depending on the volume of production.As indicated in the data, worker productivity seems to be invariant of the volume of production, fluctuating only slightly between 80% and 100%. This testimony of a consistent workforce efficiency is not deterred greatly with increasing throughput meaning that a company is managing its labor and operations well. The widening of the spread of data points suggests that while most workers are productive at their optimum level, it is of focus, or the level of difficulty of the tasks, or difference in competency [8]. There are other clear outliers that might point to opportunities for productivity gains through targeted work modifications, e.g. extra coaching, better timing, or equipment adjustments. This is further evidenced by the graph below which elevates the need to keep employees motivated and adequately equipped to feed off the productivity levels being recorded. A live-managed performance regime together with feedback might facilitate the identification of any bottlenecks in productivity. Further, workload prediction utilizing predictive analytics as a guide can improve productivity without compromising the well-being of the staff. This analysis is important to understanding that increasing the scale of production does not reduce the productivity of workers and can help both in terms of performance and sustainability in processes used in manufacturing organizations.

tools, including root cause analysis and process mapping, could help in handling inefficiencies during

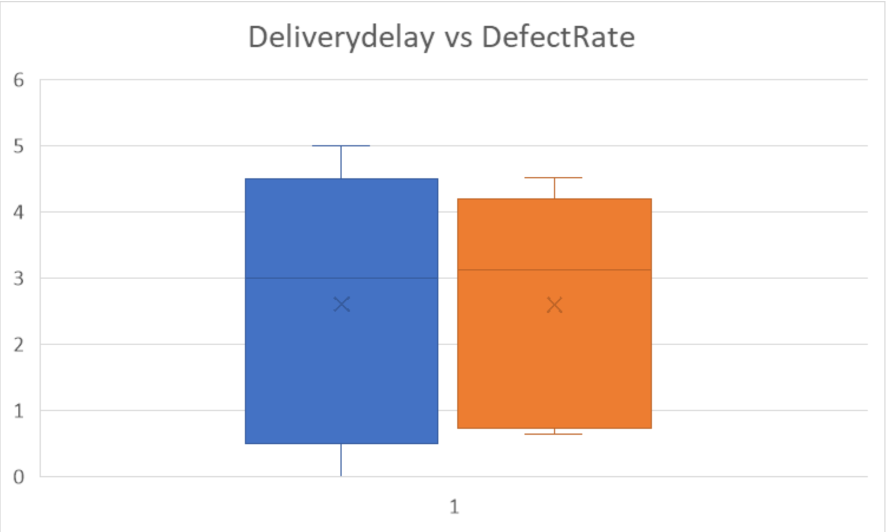
Figure 3: this visualization shows the product volume vs worker productivity



4.5 *Analyzing the Impact of Delays on Defect Rates: Insight Through Lean Six Sigma Practices:*

Box plot analysis on the trend of delivery delay and defect rates with reference to LSS practices show the strength, weakness, opportunities and threats of effective management and continuous improvement within engineering project management. Lean Six Sigma is an improvement approach that focuses on reducing variation and enhancing delivery speed to reduce defects. For the second research question, analyzing the data set, moderate delivery of delays means, such as a delay of 1 or 3, are linked with higher defects rates, which implies that the application of LSS these periods [9]. The defect rates are significantly lower for the sample where the total time from purchase to the start of the process exceeds a year; coefficient of variation is also lower for these cases, probably because controlled delays 4 and 5 result from the implementation of disciplined processes and sound quality assurance measures that Lean Six Sigma aims at achieving. These processes most probably envision and constitute error-proofing as well as enhanced supplier relationships capable of preventing defects even when deliveries take a longer time.The box plot analysis of delivery delays and defect rates in the context of Lean Six Sigma (LSS) practices offers valuable insights into the effectiveness of process management and

Figure 4: This Figure represent Relationship Between Delivery Delay and Defect Rate: Lean Six Sigma: A Box Plot Analysis



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continuous improvement initiatives within engineering project management. Lean Six Sigma aims to minimize defects and improve delivery efficiency through systematic process optimization. The dataset reveals that moderate delivery delays such as delays of 1 and 3 are associated with higher defect rates, suggesting that the implementation of LSS tools such as root cause analysis and process mapping may help address inefficiencies during these periods [10]. On the other hand, longer delays 4 and 5 exhibit lower defect rates with reduced variability, possibly reflecting the impact of controlled processes and robust quality assurance practices that Lean Six Sigma seeks to instill. These processes likely include error-proofing and improved supplier collaboration, which can mitigate defects even in scenarios involving extended delivery times. Some outlier results like 0 and 1 in the delays indicate that short delays like 4.51% of defect rates at delay 0 do not mean lower defects meaning that while Lean Six Sigma more than helped delivery speed, it also addressed process inefficiencies irrespective of delivery speed. In summary, this analysis demonstrates how Lean Six Sigma has fundamental impacts in decreasing the variability in defect rates and emphasizes how impossible it is to cease improvement, regardless of the undertaking delays, to achieve better results in engineering project management.

4.6 Exploratory Study of the Relationship Between Supplier Quality and Quality Score:

The current study wanted to investigate whether there were similarities in the trends of Supplier Quality and Quality Score by utilizing a line plot to pinpoint possible patterns for future process enhancement in engineering project management. The dataset contained the quantitative values of Supplier Quality and the Quality Score outcomes; the independent variable being Supplier Quality plotted on the x-axis as against Quality Score on the y-axis. Each point plotted on this graph is the result of pairing of these two variables

From the line plot, there is an upward trend clearly showing a relationship between Quality Scores and Supplier Quality with visible peaks and troughs. A general observation is that when Supplier Quality values are higher about 86-87 then only Quality Scores fall in a higher mid zone the result being that if supplier quality is good then generally quality of the product would also be better [11]. On the other hand, the higher Supplier Quality which is an index near 81-82 shows us that Quality Scores are also lower, indicating that poor suppliers negatively affect the Quality of the final product. Such a relationship makes Supplier Quality Management and its enhancement one of the critical objectives of the Lean Six Sigma method. Accordingly, from the data presented in the paper, it can be inferred that greater attention to improving Supplier Quality should produce higher quality outcomes of the Quality Score, which should reflect fewer defects within products and overall improvements in product quality.

4.7 Maintenance Hours and Inventory Turnover Analysis:

The analysis of the hours for Maintenance and Inventory Turnover provides an insightful picture on how LSS practices affect engineering project management. By doing the Pareto analysis, as shown in

Figure 5: This image shows a relationship between Quality Scores and Supplier Quality

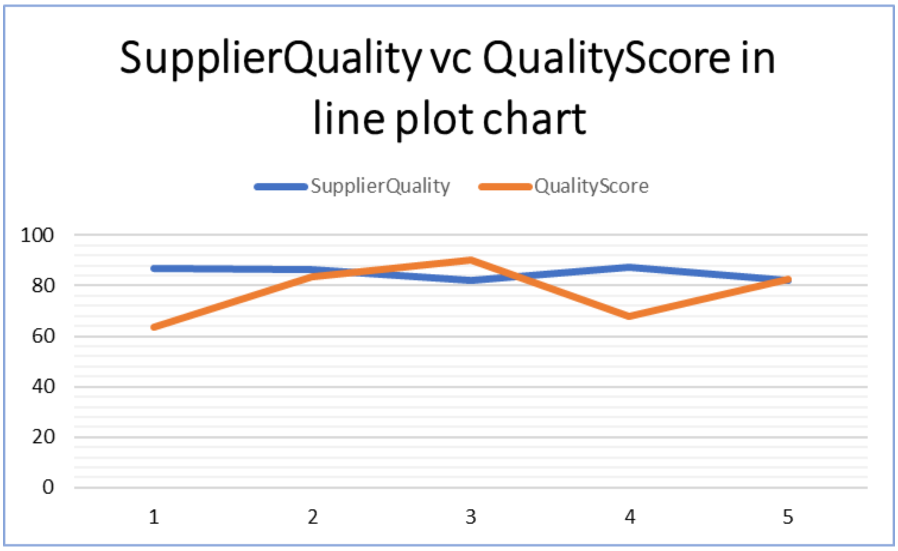
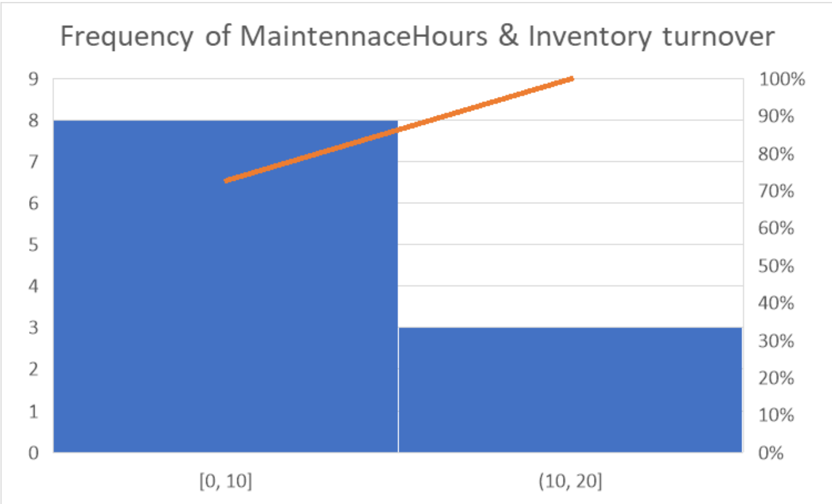


Figure 6, it shows that most of the maintenance hours are concentrated in the low range, between 0 and 10 hours. This implies that most production units or tasks are well-managed with minimal maintenance, pointing toward the goal of LSS: streamlining processes and minimizing downtime. Looking at Inventory Turnover, the data has a tendency of the turnover rate being relatively high with most of the products moving in rates between 5 and 10. This is an indication that, indeed, inventory management is well managed, balancing the level of inventories to meet production demands without an excessive buildup of stock. It further leads to an inference that maintenance activities and inventory turnover tend to be related to production efficiency. Higher turnover tends to be associated with fewer maintenance hours, as lower inventory levels of products minimize the requirement for extensive maintenance or correction. These findings emphasize the role of LSS in optimizing the management of resources, reducing unnecessary costs of maintenance, and improving the efficiency of inventory systems. The application of LSS tools, such as DMAIC, which implies Define, Measure, Analyze, Improve, and Control, by an organization can significantly reduce maintenance hours and improve inventory turnover, resulting in cost savings and enhanced operational efficiency in engineering project management.

Figure 6: This Image represents the hours for Maintenance and Inventory Turnover



5 DATASET OVERVIEW

The dataset for analysis is "Predicting Manufacturing Defects;" it provides relevant findings that contribute to the realization of the work's objective of enhancing efficiency in manufacturing in engineering project management using Lean Six Sigma. The dataset also contains related variables including Production Volume, Production Cost, Supplier Quality, and Defect Rate and these variables form a strong base through which core indicators that affect defect rates can be examined. This dataset contains information that can be analysed by using Lean Six Sigma, which can then help to determine that specific processes need to be improved and that there are all sorts of problems with defects (dataset link: https://link.springer.com/article/10.1007/s13198-024-02375-y). Maintenance data as well as data on workforce productivity and inventory are useful in the analytical-deeming circle of Lean Six Sigma useful in dealing with the paradigm's root cause analysis and reduction of defects. This dataset is used here for the purpose of illustrating how Lean Six Sigma analytical techniques can be complemented to address problems of variability and quality in the process of engineering project management.

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5.1 Dataset

5.1.1 Screenshot of the dataset below:

Figure 6: This Image represents the hours for Maintenance and Inventory Turnover

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	Production Volume	Production Cost	Supplier Quality	Delivery Delay	Defect Rate	Quality Score	Maintenance Hours	Downtime Percentage	Inventory Turnover	Stockout Rate	Worker Productivity	Safety Incidents	Energy Consumption	Energy Efficiency	Additive Process Time	Additive Material Cost	Defect Status
2	202.0	13175.4	86.6	1.0	3.1	63.5	9.0	0.1	8.6	0.1	85.0	0.0	2419.6	0.5	5.6	236.4	1.0
3	535.0	19770.0	86.3	4.0	0.8	83.7	20.0	4.9	9.3	0.0	99.7	7.0	3915.6	0.1	9.1	354.0	1.0
4	960.0	19060.8	82.1	0.0	4.5	90.4	1.0	2.5	5.1	0.0	92.8	2.0	3392.4	0.5	6.6	396.2	1.0
5	370.0	5647.6	87.3	5.0	0.6	67.6	8.0	4.7	3.6	0.1	96.9	8.0	4652.4	0.2	8.1	164.1	1.0
6	206.0	7472.2	82.0	3.0	3.9	82.7	9.0	2.7	6.9	0.1	88.3	7.0	1581.6	0.3	6.4	365.7	1.0
7	171.0	6975.9	95.3	1.0	3.9	92.6	19.0	3.0	7.9	0.1	87.1	7.0	1239.0	0.1	7.3	171.7	1.0
8	800.0	15889.7	99.3	3.0	4.8	90.7	10.0	3.6	3.0	0.0	91.1	8.0	3138.4	0.3	4.9	188.7	1.0
9	120.0	17266.8	99.4	4.0	0.7	92.1	13.0	1.6	8.4	0.0	88.7	3.0	1004.1	0.3	9.3	312.5	1.0
10	714.0	8202.7	97.3	5.0	3.2	95.2	2.0	3.5	3.7	0.1	94.3	4.0	4150.9	0.4	5.5	215.7	1.0
11	221.0	12587.8	92.0	2.0	2.4	97.5	0.0	2.6	5.9	0.0	85.3	6.0	3023.9	0.3	6.0	364.6	0.0
12	566.0	17610.5	94.0	3.0	2.0	76.2	6.0	3.4	8.9	0.1	89.0	1.0	2952.3	0.3	5.7	482.3	0.0
13	314.0	15992.0	85.7	0.0	0.9	82.8	3.0	4.2	3.5	0.1	97.9	6.0	2450.0	0.4	3.8	159.6	0.0
14	430.0	13133.6	92.6	1.0	3.0	91.6	6.0	0.9	3.9	0.0	95.1	2.0	2499.9	0.1	3.1	328.2	1.0
15	558.0	13855.2	89.1	0.0	2.7	87.9	15.0	3.1	2.5	0.0	83.4	5.0	2724.5	0.3	1.7	469.3	1.0
16	187.0	12625.4	89.6	3.0	1.0	99.8	9.0	0.3	3.2	0.0	97.7	5.0	1064.1	0.1	7.5	170.6	0.0
17	472.0	9463.2	95.2	5.0	3.3	60.5	14.0	0.5	3.2	0.1	91.8	5.0	1334.2	0.3	3.6	246.7	1.0
18	199.0	13475.3	85.6	2.0	3.8	74.2	15.0	3.4	3.6	0.0	93.6	9.0	3020.2	0.4	4.5	149.4	1.0
19	971.0	15333.3	86.4	2.0	4.0	71.2	5.0	0.4	4.3	0.1	85.9	1.0	1600.5	0.2	9.3	356.8	1.0
20	763.0	18099.8	98.5	0.0	4.6	70.5	3.0	3.0	8.5	0.0	88.8	8.0	4115.1	0.5	6.1	367.7	1.0
21	230.0	14544.4	81.1	4.0	2.3	68.9	3.0	1.1	9.3	0.0	96.1	7.0	2097.9	0.5	1.9	365.7	1.0
22	761.0	16416.8	89.7	4.0	4.8	88.4	23.0	1.5	5.3	0.0	86.6	6.0	1391.6	0.3	8.2	316.9	1.0
23	408.0	7401.1	98.3	5.0	4.4	63.4	22.0	0.6	3.0	0.1	83.3	8.0	1940.8	0.1	3.3	398.5	1.0
24	869.0	11923.4	92.2	2.0	1.8	89.7	3.0	1.2	3.8	0.0	87.6	3.0	2428.4	0.4	6.0	114.4	1.0

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6 FUTURE WORK

For any future studies that would involve the comparison of Lean Six Sigma (LSS) practices in engineering project management, there are several ways through which the findings of this study can be built upon. Still, one major avenue for future research is to uncover the effects of LSS on project success factors in the fields of engineering that work in highly technical environments where change is imminent, evaluating the longevity of LSS impact on cost, scheduling, and quality metrics. This would provide information on how duration of LSS implementation impacts on project performance in the future. Two important research directions for future studies can be identified [10]. The first area comprises explorations of how the various elements of Industry 4.0, such as artificial intelligence, machine learning, and the Internet of Things, can be integrated into LSS frameworks. This could enrich real-time data capture and process improvement in engineering projects including how LSS concepts are practiced on the ground. Future research may also look at the comparison of LSS across various subdisciplines of engineering such as civil, electrical and mechanical, at different stages of the development of the methods in the respective sectors and how the methods can be customized for specific engineering uses. Studies of LSS from the end user's perspective could offer insight into the leadership behavior, team dynamics, and organizational culture that support the implementation for such an approach in engineering project management. Some authors suggested that there might be variations in LSS implementation success depending on the regional climate or the organization where LSS is applied. Studies on integrating LSS with other frameworks like Agile Project Management to build versatile systems to manage increased complexity in today's engineering projects could be future work. These future directions will be predicated on the findings of this study and would contribute to future theoretical and empirical development of the discipline.

7 DISCUSSION

The analysis of the Lean and Six Sigma discussion shows that both methods give valuable contributions to the engineering project management. Lean is successful in the realization of efficiency, reduction of waste and improvement on process flow while Six Sigma is all about reduction of variations in order to progress towards better quality [11]. An important implication is that the effectiveness or otherwise of these methodologies is a function of project characteristics, team characteristics, and leadership characteristics. Lean and Six Sigma implementation is always most effective in the projects which have set specific objectives and have backing of the top management

[12]. This research stresses the growing role of digital technologies and real-time data processing for the enhancement of the process improvement approaches and enhancement of the organizational decision-making. It is for this reason that the integration of Lean focusing on the flow with Six Sigma focusing on precision has been of immense benefit within large and complex engineering projects. Efficient team training and orientation to the requirements of a certain assignment play a major role in attaining certain goals. Through identification of the strengths and weaknesses of the two methods, organizations decide which methodology or blend of methodologies to apply to improve on project performance. Finally, this study finds that for Lean and Six Sigma to be effective, it needs to be customized to fit the characteristics of each project and should cultivate a culture of ongoing organizational improvement in operations.

8 CONCLUSIONS

In Conclusion, this study presents a systematic review of comparative Lean Six Sigma (LSS) implementation studies, focusing on engineering project management effectiveness and their performance consequences. Through the Lean and Six Sigma perspectives examined in the study, it is possible to discover how both methodologies as single elements and as a complex system advancing the tactics for the efficient optimization of project processes, minimization of waste, and improvement of quality in the examples of engineering projects. The conclusions indicate that while the ideology of Lean exists to optimize processes as well as remove waste, Six Sigma is considered to provide a way to make more accurate and informed decisions minimizing defects. The effectiveness of these practices' integration empowers engineering project managers to attain better precision, lower cost, and fast throughput. The study reveals that LSS success has been a function of factors like team expertise, leadership support, and use of right tools/techniques when implementing LSS. These findings reaffirm the need of such a topographic map to be specific on each project's needs while adopting LSS for maximum utilization across different engineering disciplines. this paper provides a comparative analysis of using Lean Six Sigma in improving the process and efficiency of executing engineering projects for further research, adding that Lean Six Sigma catapults organizations into different levels of performance improvement by achieving its goals by planning for and executing change and that further research should examine the next generation of Lean Six Sigma solutions for the changing landscape of industry.

. References

[1]. Antony, J., Lizarelli, F. L., & Fernandes, M. M. (2020). A global study into the reasons for lean six igma project failures: Key findings and directions for further research. IEEE Transactions on Engineering Management, 69(5), 2399-2414.

https://ieeexplore.ieee.org/abstract/document/9186804

[2]. Swarnakar, V., Singh, A. R., Antony, J., Tiwari, A. K., & Garza-Reyes, J. A. (2023). Sustainable Lean ix Sigma project selection in manufacturing environments using best-worst method. Total Quality Management & Business Excellence, 34(7-8), 990-1014.

https://www.tandfonline.com/doi/abs/10.1080/14783363.2022.2139675

[3]. Achibat, F. E., Lebkiri, A., Aouane, E. M., Lougraimzi, H., Nabyl, B., & Maqboul, A. (2023). Analysis of the impact of Six Sigma and Lean Manufacturing on the performance of companies. Management Systems in Production Engineering.

https://intapi.sciendo.com/pdf/10.2478/mspe-2023-0020

[4]. Lizarelli, F. L., & Alliprandini, D. H. (2020). Comparative analysis of Lean and Six Sigma improvement projects: performance, changes, investment, time and complexity. Total Quality Management & Business Excellence, 31(3-4), 407-428.

https://www.tandfonline.com/doi/abs/10.1080/14783363.2018.1428087

[5]. Zanezi, A. C., & de Carvalho, M. M. (2023). How project management principles affect Lean Six Sigma program and projects: a systematic literature review. Brazilian Journal of Operations & Production Management, 20(1), 1564-1564.

https://www.bjopm.org.br/bjopm/article/view/1564

[6]. Francescatto, M., Neuenfeldt Júnior, A., Kubota, F. I., Guimarães, G., & de Oliveira, B. (2023). Lean Six Sigma case studies literature overview: critical success factors and difficulties. International Journal of

Innovatech Engineering Journal
DoI: 10.70937/itej.v1i01.27

Productivity and Performance Management, 72(1), 1-23.

https://www.emerald.com/insight/content/doi/10.1108/ijppm-12-2021-0681/full/html

[7]. Krishnan, S., Mathiyazhagan, K., & Sreedharan, V. R. (2020). Developing a hybrid approach for lean six sigma project management: A case application in the reamer manufacturing industry. IEEE Transactions on Engineering Management, 69(6), 2897-2914.

https://ieeexplore.ieee.org/abstract/document/9204638

[8]. Yadav, N., & Al Owad, A. (2022). Comparing viewpoints of top management, consultants and employees about Lean Six Sigma. Journal of Manufacturing Technology Management, 33(6), 1150-1170.

https://www.emerald.com/insight/content/doi/10.1108/jmtm-12-2021-0497/full/html

[9]. Antony, J., Scheumann, T., Sunder M, V., Cudney, E., Rodgers, B., & Grigg, N. P. (2022). Using Six Sigma DMAIC for Lean project management in education: a case study in a German kindergarten. Total Quality Management & Business Excellence, 33(13-14), 1489-1509.

https://www.tandfonline.com/doi/abs/10.1080/14783363.2021.1973891

[10]. Sakr, T. A., & Nassar, A. H. (2022). Improving Project Management at the Design Phase by Applying Lean Six Sigma as a Troubleshooting System. IEEE Engineering Management Review, 50(3), 213-227.

https://ieeexplore.ieee.org/abstract/document/9832478

[11]. Kumar, P., Bhamu, J., Goel, S., & Singh, D. (2024). Interpretive structural modeling of lean six sigma critical success factors in perspective of industry 4.0 for Indian manufacturing industries. International Journal of System Assurance Engineering and Management, 1-18.

https://link.springer.com/article/10.1007/s13198-024-02375-y

[12]. Kumar, V., Cudney, E. A., Mittal, A., Jha, A., Yadav, N., & Owad, A. A. (2024). Mapping quality performance through lean six sigma and new product development attributes. The TQM Journal, 36(7), 2107-2131.

https://www.emerald.com/insight/content/doi/10.1108/tqm-11-2022-0324/full/html

https://www.kaggle.com/datasets/rabieelkharoua/predicting-manufacturing-defects-dataset