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Operational Excellence Through Lean Six Sigma: Strategies and Best Practices

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Abstract

This paper explores the concept of Operational Excellence and its achievement through the implementation of Lean Six Sigma (LSS). We define Operational Excellence and LSS, and delve into the DMAIC phases of LSS, which are the cornerstone of this methodology. We also identify and discuss various types of wastes prevalent in different sectors, highlighting the need for LSS implementation. The paper presents a few case studies that demonstrate the successful application of the DMAIC framework in different contexts. Additionally, we outline essential tools for implementing LSS and discuss critical failure factors that organizations should be aware of. Finally, we conclude by emphasizing the significance of LSS in achieving Operational Excellence and enhancing organizational performance.

Keywords
Lean Six Sigma, DMAIC, Waste reduction, LSS tools, Critical failure factors.

1. Introduction
Lean six sigma is a philosophy or methodology that gained a vast appreciation in the organizations By eliminating the wastes and defects in the products and improving the quality that leading to operational excellence of an organization. The objective of this paper is to understand how lean six sigma helps to achieve operational excellence.

Operational Excellence originated from Treacy and Wiersema's (1995) book, 'Discipline of Market Leaders' (Dahlgaard et al.1999) Operational Excellence refers to a strategy that aims to provide exceptional quality, affordability, ease of purchase, and service in a market or industry (Basu, R., 2004.). Operational Excellence (OE) is a program that focuses on increasing and sustaining business performance through quality management. OE refers to business excellence, but also includes manufacturing, service, marketing, and supply chain. To remain at the top of their sector, companies often require a long-term improvement strategy of five to 10 years. (Gupta et al.2018).

Lean Six Sigma is a synergized managerial paradigm of Lean and Six Sigma. Six Sigma (6σ) is a collection of methods and resources for enhancing processes. In 1986, American engineer Bill Smith introduced it while he was employed at Motorola. Its goal is to attain lower defect levels than what was previously deemed reasonable or necessary. Six Sigma performance is specifically associated with 3.4 Defects Per Million Opportunities (DPMO). (Nonthaleerak2006). In their book The Machine That Changed the World, James P. Womack, Daniel T. Jones, and Daniel Roo from the Massachusetts Institute of Technology introduced the concept of lean manufacturing by contrasting American and Japanese businesses. With the introduction of the Toyota Production System (TPS), the most efficient became Toyota Motor Company. The TPS was praised as the first system to operate in line with Lean principles.(Łukasz Dekier 2012). Lean Thinking is built on the removal of waste. Liker defines lean as a manufacturing strategy that, through waste elimination, shortens the time line between the customer's order and shipment. The foundation of lean philosophy is the identification and elimination of waste or non-value-added tasks, and this concept is frequently brought up in talks surrounding "Muda," the Japanese word for waste. Activities that don't benefit clients or businesses are considered waste. Waste is an expense that the clients are unwilling to bear. It is crucial to raise staff members' understanding of the idea. (Goutam Kumar Kundu 2015).

1.1 DMAIC Phases of Lean Six Sigma

According to six sigma methodology George claims that Motorola identified a pattern for improvement (and the use of data and process tools) that could be organically broken down into the five stages of issue solving, commonly denoted by the acronym DMAIC (da-may-ick), which stands for Define-Measure-Analyse-Improve-Control. (Bhaskaran, E.2014).

1.2 Wastes in different sectors

According to lean philosophy few kinds of wastes that has to be eliminated are as follows

- "Over production
- Waiting
- Transportation
- Inappropriate processing
- Unnecessary Inventory
- Unnecessary / Excess motion
- Defects
- Over Production
- Non-Utilizing Resources /Talent
- Delay
- Duplication
- Unclear communication
- An opportunity lost to retain or win customers
- Service quality errors" (K.A .Harish and M. Selvam 2015)

1.3 Tools for significantly implementing Lean Six Sigma

- **"Statistical process control :-** Statistical process control (SPC) is a popular approach for analysing and monitoring process variations and determining the root cause of trends. Any non-random behaviour demands attention. Taking suitable measures to reduce variation improves process stability and predictability.

- **Value stream map (Vsm) :-** A value stream map (VSM) is a flow chart with "the language of lean" symbols (Bicheno et al., 2004). It helps streamline the flow of inventory and information in industrial organizations. This tool identifies areas of delay, allowing for improved flow and less waste. VSM creates maximum value for customers while minimizing waste. VSM demonstrates the current state of a process, and applying lean principles leads to the intended future state.

- **Root cause Analysis (RCA): -** Root Cause Analysis (RCA) is a problem-solving technique that identifies the root causes of issues or incidents. It can forecast future events. RCA identifies recommended practices that can be followed to address similar symptoms. It is seen as a tool for continuous improvement.

- **5 WHY Method: -** The five why method helps identify the root cause of a problem through a series of questions. It examines the cause-and-effect relationship behind a certain situation. The Five Whys method is crucial for identifying root causes. Research suggests that asking five or more continuous questions can reveal the root reason.

- **Fish bone Diagram: -** A fishbone diagram is a problem-solving tool that identifies the causes of issues. Major categories are used to determine the root cause of a problem. The categories usually include people, methods, machines, materials, measurement, and environment.

- **Pareto Analysis: -** Pareto analysis is a sophisticated statistical tool that identifies key tasks that significantly impact an overall outcome. The 80:20 rule suggests that most issues (80%) are caused by a small number of sources (20%). Concentrating on 20% of critical issues can significantly reduce the number of difficulties." (Awkash Modi et al. 2012)

2. Role Of Lean Sixsigma in Different Sectors

Manufacturing

Over the past five years, Industry 4.0 has been recognized as a strategic paradigm for gaining competitive advantages and improving metrics like cost, productivity, quality, customer happiness, and lead time. (Lu, Y. 2017.) (Agrifoglio et al. 2017)(Khan et al.2013). Operational Excellence approaches, including Lean and Six Sigma, have helped organizations attain efficiency during the past 30 years. increases and improves client satisfaction. The majority of Fortune 500 firms have deployed integrated Lean Six Sigma. Methodology (Treacy, M., &Wiersema, F.1995)

CASE-1: - railcar manufacturing industry based in South Africa

"The project primarily focuses on the assembly of railcar bogies and their framework.

DEFINE: - The issue is job tardiness during the construction of a railcar bogie, leading to increased lead time and decreased process efficiency. The problem definition step aligns with the study's goal of troubleshooting the assembly process, identifying the root cause of waste, and improving it through the LSS approach. The VSM gives an overview of the assembly process, including value-added and non-value-added operations, as well as the essential requirements to meet the benchmark (Table 1-Table 7).

Table 1. The assembly operation of the railcar bogie (SOURCE: - adopted from Ilesanmi Daniyan et al, Heliyon 8 (2022) e09043 ,pgno 5

Pre assembly 1	
Operation	Time (min)
Bogi Frame Welding	1545
center rubbers Assembly	1147
Brake cylinders Assembly	1343
Welding of Brake levers and other components	1037
Brake pipe Assembly	1034
Levers and other components assembly	1121
Other fitting and welding operations	1300
Finishing Operation	
Painting	1142
Honing & buffing	1023
Other finishing operations	616
Pre assembly II	

axle blocks and springs Assembly	1543
Assembly of the traction motor/wheel to the frame	1433
Center frame rubbers Assembly	2886
brake blocks Assembly	1765
Axle block brackets Assembly	1443
brake liners Assembly	1622
Assembly of the center frame	3082
Wicks Assembly	2765
Assembly of the sand pipes and brackets	3874
Assembly of the traction motor cable clamp	2470
Assembly of the snubbers	2087
Assembly of the motor nose rubbers	2754
Other fittingS & assembly operations	2008
Pre-Assembly III	
other sub components Fittings	1000
Time taken to lad assembled bogie on rail car wagon	550
Total	42590

1.process cycle efficiency = [Value added time/Leadtime] x100

- estimated Process Cycle Efficiency is 19.9 % which is less than benchmark of 25 %

Table 2. The value added and non-value-added time of the assembly operation. (SOURCE: - adopted from Ilesanmi Daniyan et al., Heliyon 8 (2022) e09043, pgno 6)

S.No	Activities	No of employees	No of robots	Non value added time (min)	Value added time (min)	Total lead time (min)	Down time (min)	Up time (min)	Total cycle time (min)	Process cycle efficiency (%)
1.	Taking contract, component designing, Material procurement	2	-	31104.00	7776.00	38880	4320	17280	21600	20.00
2.	Designing jig	4	1	43275.60	10724.40	54000	1200	1800	30000	19.86

3.	Manufacturing components	4	1	34875.00	10125.00	45000	8750	16250	25000	22.50
4.	Under frame Assembly	4	1	27486.00	8514.00	36000	7016	12984	20000	23.65
5.	assembly of Bogie frame and components	2	1	34518.74	6521.25	41040	6840	15960	22800	15.89
6.	Pre assembly	5	2	100118.59	20841.40	120960	22464	63936	86400	17.23
7.	All over assembly	5	2	141087.74	40352.25	181440	24192	96768	120960	22.24
8.	Fi operation	4	1	49347.90	13652.10	63000	12206	27169	39375	21.67
9.	Inspection, & supply	1	2	35877.60	7322.40	43200	4800	19200	24000	16.95
10.	Total	31	11	497691.17	125828.8	623520	91788	271347	390135	

Measure

During this phase, primary data was collected to determine lead times and process cycles for major activities like design, parts procurement, jig development, underframe, bogie frame, and component assembly, pre-assembly, overall assembly, finishing, and inspection. We conducted a descriptive statistical study of lead times to assess variations and departures from the mean. Additionally, interviews were done. Furthermore, the PCE for each of the several assembly activities was compared to the benchmark established for 85% using the Pareto chart. This is essential in order to calculate the percentage improvement that the continuous improvement process will need to achieve (Figure 1).

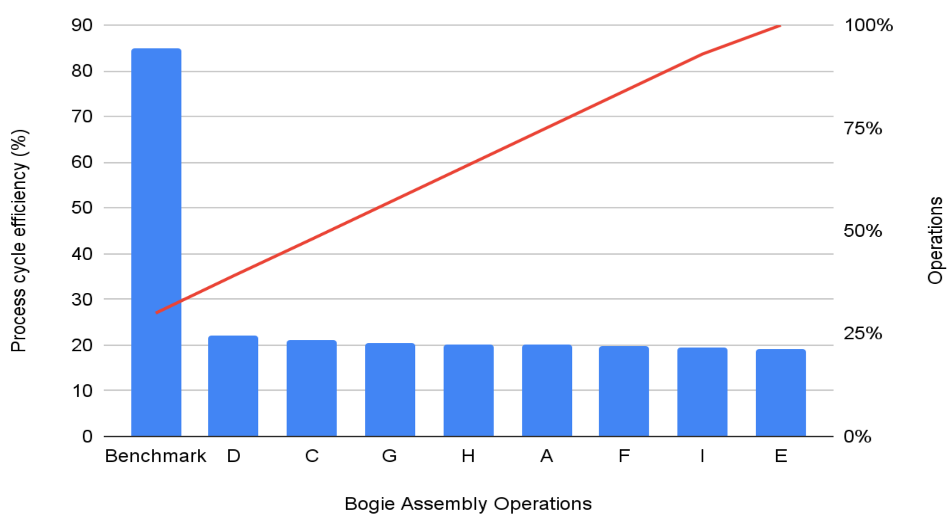

Figure 1. Perito analysis (SOURCE: - adopted from Ilesanmi Daniyan et al., Heliyon 8 (2022) e09043, pgno 7)

Analysis: - The study team, personnel, and management collaborate, discuss, and brainstorm during sessions. A fishbone diagram is used to depict the recognized causes of poor PCE and lead time variations (Figure 2).

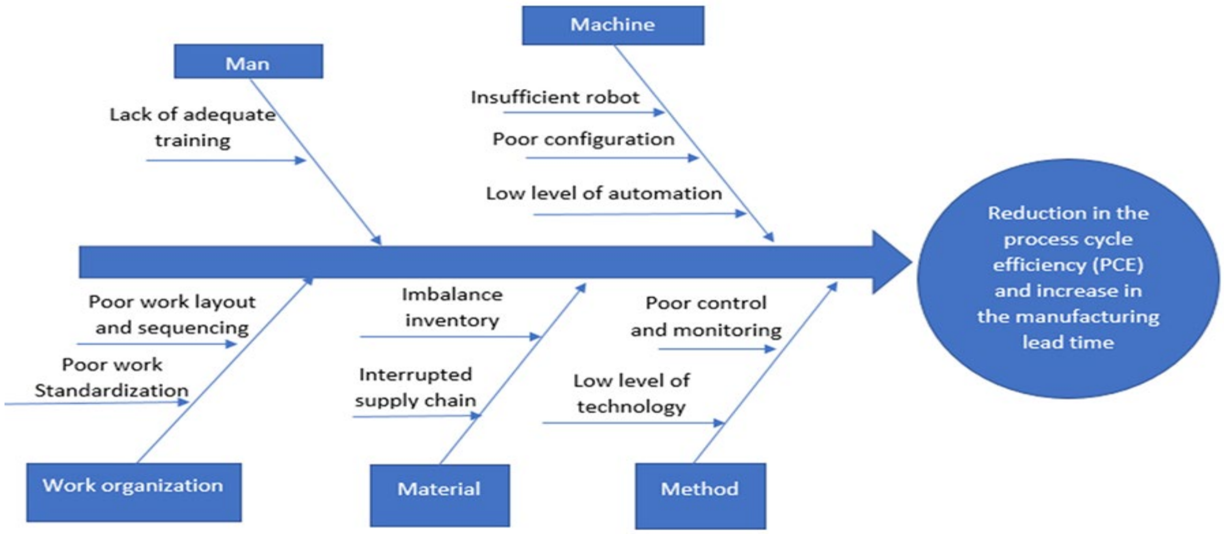

Figure 2. Fish bone diagram (SOURCE: - adopted from Ilesanmi Daniyan et al., Heliyon 8 (2022) e09043, pgno8)

IMPROVE: - The improvement phase was carried out using the Kaizen approach**,** 5S approach, Single Minutes Exchange of Die (SMED) implemented for improving process cycle efficiency [PCE].
CONTROL: - During the control phase, system performance is measured and compared to a benchmark to ensure long-term objectives are not compromised. During this stage, plans were implemented to monitor system performance and address deviations from the idea.
RESULT: - BY following Lss approach PCE had improved from 19.9% to 66.7%. and 27.9 % reduction in lead time is observed" by eliminating the waste, variations, and defects can easily obtain quality output. But Lss has certain limitations

3. Lean Six-Sigma in textile industry
CASE -1: - Romanian garment industries

"Defection rates in the Romanian clothing industry are high due to frequent and varied flaws. The initiative aims to minimize faults, improve quality, and increase productivity Through LSS DMAIC. "This case study is about Defective silk cotton shirts"
DEFINE: - In this phase problem defined using SIPOC flow chart for better visualization

Table 3. SIPOC flowchart for garment industry
Source: adapted from Ruxandra DINULESCU, Adriana DIMA, (2019) pg.716

supplier	Input	Process	Output	Customer
Etic Textiles	• Machines • Threads & Needles • Buttons • UnstitchedClothes • Fabric	• Printing • Stitching • Pressing • Cutting • Packaging	• Silk cotton Tshirt Skirts etc	• Romania people

MEASURE: - This phase aims to map the process, create a data gathering plan, and evaluate baseline performance. Fig presents 10 randomly chosen batches and the number of defective items reported depending on the checked pieces, as well as the percentage of defective items. Main products of garment industry cotton & silk t-shirts has been inspected for defects in summer season (Table 4, Table 5).

Table 4. Number of defective items for the female silk and cotton shirt & sigma level
Source: adapted from Ruxandra DINULESCU, Adriana DIMA, (2019) pg.716

Batch	Checked pieces	Defective	%defective
1	110	15	1.08%
2	160	12	0.87%
3	140	10	0.72%
4	180	14	1.01%
5	140	8	0.58%
6	165	17	1.23%
7	170	12	0.87%
8	110	13	0.94%
9	110	9	0.65%
10	100	7	0.51%

Table 5. Number of defective items for the female silk and cotton shirt & sigma level
Source: adapted from Ruxandra DINULESCU, Adriana DIMA, (2019) pg.716

Total Output	1385
No. of defects	117
Defects %	8.45
Defects per million opportunities	84.476
Sigma level	2.88

Aim of an enterprise will be achieving six sigma level i.e, 3.4 DPMO but this textile industry achieved 2.88 sigma level with 84.476 DPMO.

Analyse

The goal was to examine the data acquired during the measurement phase to identify the fundamental causes of variances, focusing on the most important factors over the inconsequential ones. For this operation, a Pareto chart was created (Figure 3 and Table 6).

Table 6. Defects for the female silk and cotton shirt
Source: adapted from Ruxandra DINULESCU, Adriana DIMA, (2019) pg.718

S.no	Defects	Frequency of Occurrence	Occurrence %
1	Torn shirts	15	19.48%
2	Faded shirts	12	15.58%
3	Missing buttons	11	14.29%
4	Printing errors	9	11.69%
5	Zipper failure	8	10.39%
6	Padlock	6	7.79%
7	Embroidery damage	5	6.49%
8	Dissimilar shirts	5	6.49%
9	hemming	4	5.19%
10	Label mis match	2	2.60%

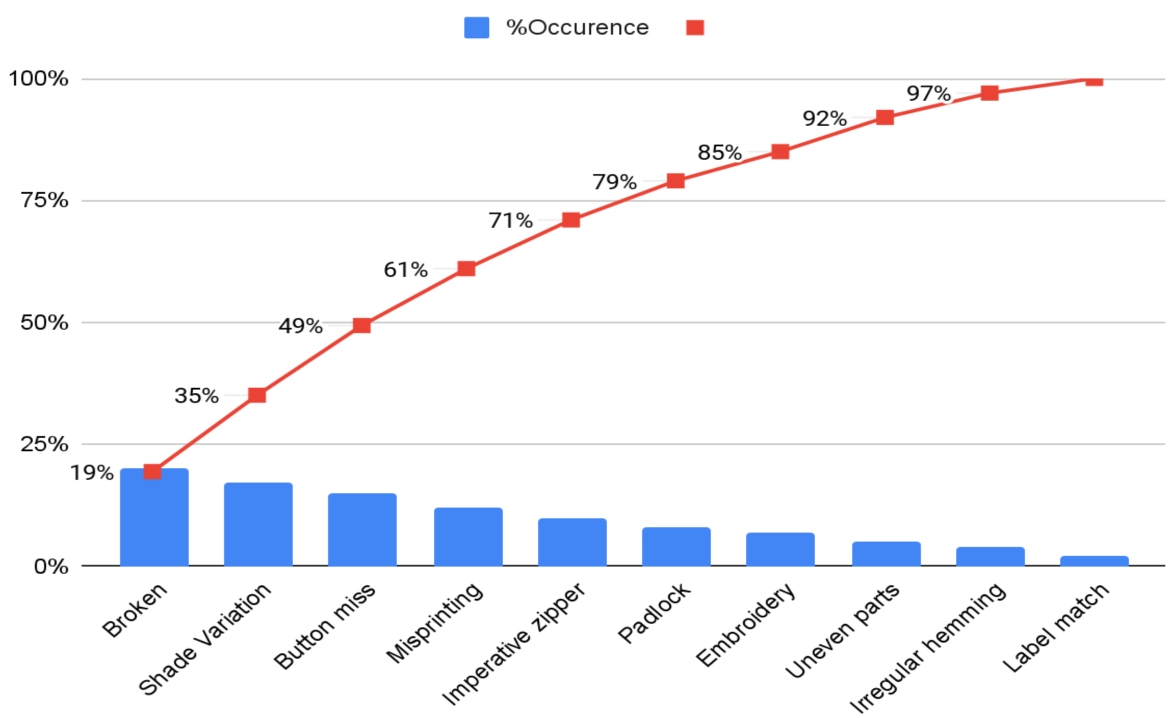

Figure 3. Pereto chart for the defects of female silk and cotton shirt
Source: adapted from Ruxandra DINULESCU, Adriana DIMA, (2019) pg.718

Major defects that observed are as follows

- Broken material;
- Shade variation;
- Button miss;
- Misprinting.

Improve and control

The improve phase aims to eliminate root causes of process variation and standardize actions, while the control phase focuses on maintaining and discussing positive results with managers after implementing Lean Six Sigma." (Daniyanet.al 2022).

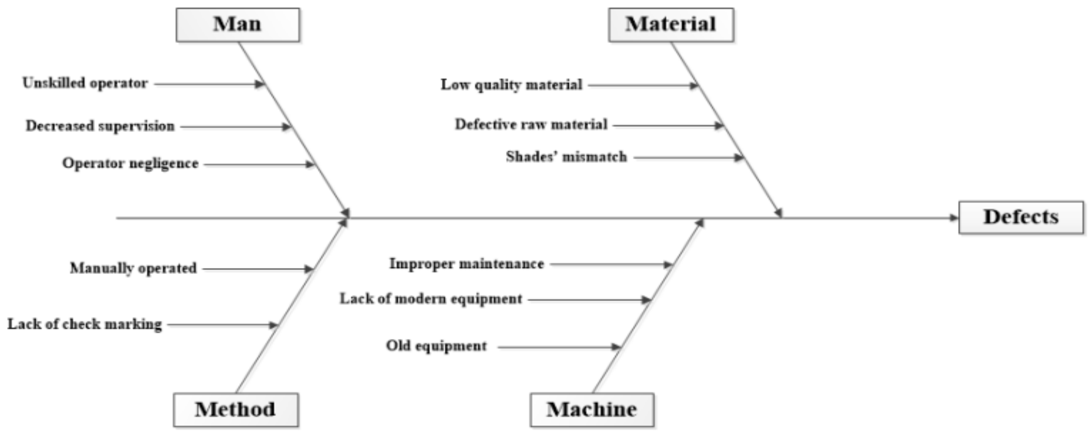

Figure 4. Fishbone diagram
Source: adapted from Ruxandra DINULESCU, Adriana DIMA, (2019) pg.718

Lean sixsigma in paper industry

"This case study was carried out in a private limited liability company that produces papers. The company started out as a printing and publishing business in the South-West region of Nigeria in 2010. The management of the company must improve the production process's efficiency and lead time in order to preserve a positive client-customer connection. Additionally, lower manufacturing waste as a percentage of downtime (Figure 4).

Define

The primary issue of downtime on the production line was discovered using data gathered from self-observation and one-on-one interviews with the production supervisor and some of the machine operators. FIG depicts the estimated percentage downtime in the manufacturing line, taking into account the machine running process stages. The Figure 5 illustrates a Pareto chart of process downtime on the production line (Table 7).

Table 7. Estimation of Percentage Down-Time in the Production Line(**Source**: adapted from Adefemi O. Adeodu.et.al, (2020) pg.40)

Unit	Down time Causes	Down Time (sec)	Average Time	Time of Cycle (sec)	Down Time %	Machine
Design/Plate Cutting	• Damaged plate • Plate with Poor Impression	630 900	765	2880	26.6	Computer

Cutting/ Trimming	• Breakdown of Machine • Misalignment of Job	1334 1800	1567	4680	33.5	MDA
Printing	• Misalignment of Plate • Wetting of ink	116 1200	1158	2880	40	Curd 64/G70
Gluing /Stitching	• Improper Stitches • Diffent Stitch Density	816 900	858	2880	30	Polar-Motta 90
	Overall Down Time		4348	13,320	32.64	

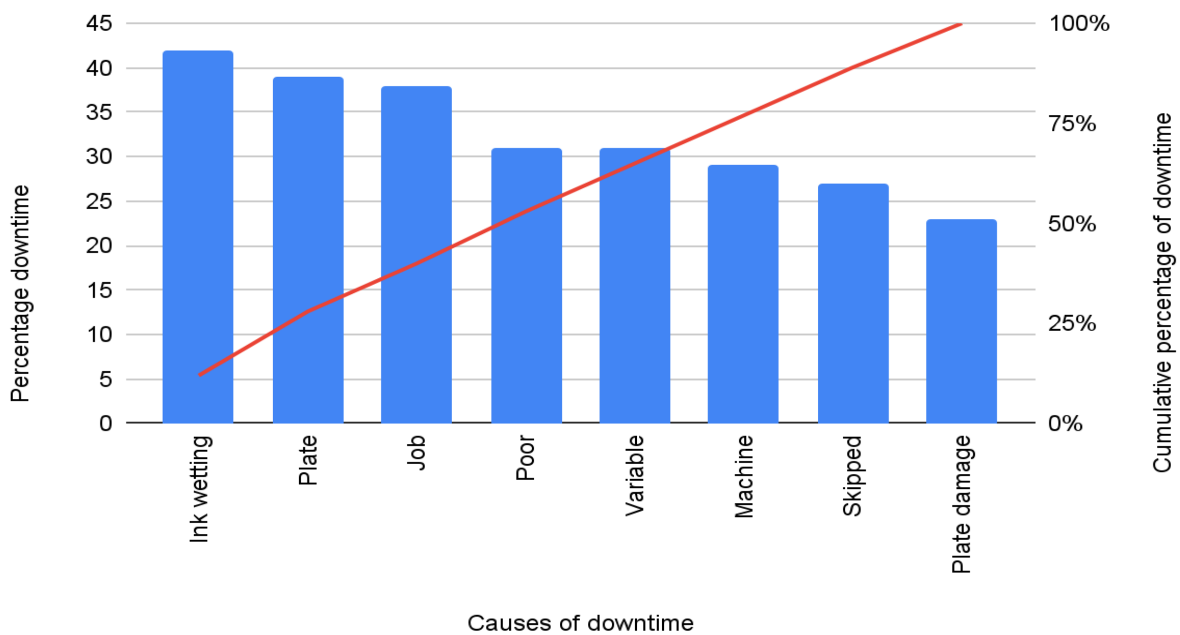

Figure 5. Pareto Chart of the Down Time of the Production Line
(Source: adapted from Adefemi O. Adeodu.et.al, (2020) pg.41)

Measure

This section's principal equipment consists of two printing machines (Curd 64 and G70), which are used to create physical copies of texts and images. Other materials used are cardboard, ink, and lithographic plates. Machine performance was analysed using the Overall Equipment Effectiveness Indicator. Machine performance was analyzed using the Overall Equipment Effectiveness Indicator (OEE). Production data (number of pieces generated per machine) was collected throughout a 4-month period from June to September (Figure 6).

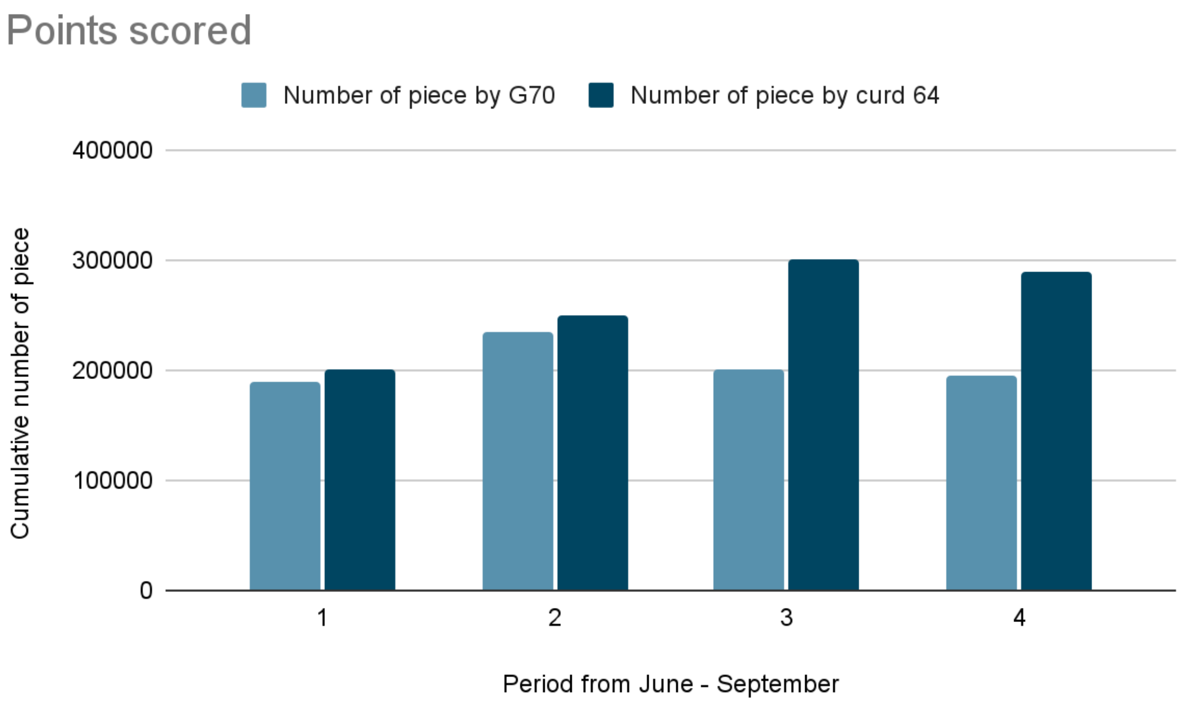

Figure 6. Performance Chat of the Printing Machines
(**Source**: adapted from Adefemi O. Adeodu.et.al, (2020) pg.42)

Analyze

The discovered downtime problem in the production line was examined to determine the root cause using the ISHIKAWA Diagram (Root and Effect Analysis), in order to design improvement and subsequent control (Sokovic et al.2010)(Roriz et al. 2017)(Adeodu et al.2020). The cause and effect analysis was carried out through a brainstorming session, and the causes were divided into four primary categories: work organization, machine (Figure 7),

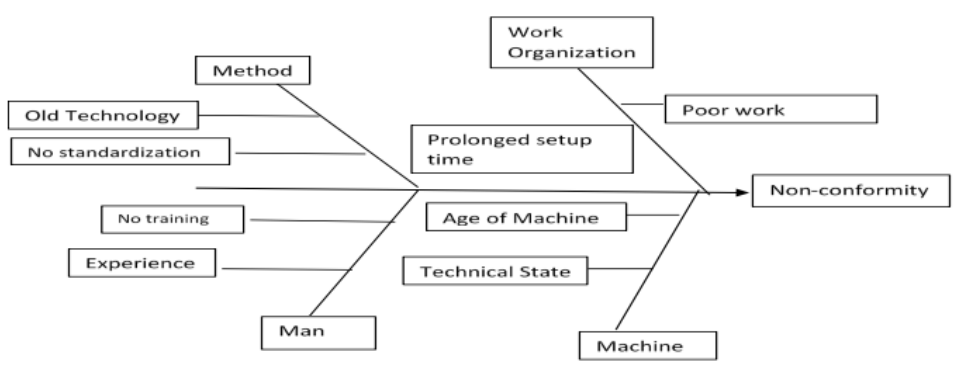

Figure 7. Ishikawa Diagram of the printing Stage
(**Source**: adapted from Adefemi O. Adeodu.et.al, (2020) pg.42)

Improvement Stage

To address the significant issue of downtime caused by lengthy setup periods and manufacturing order changes, Single Minute Exchange of Die (SMED) and 5S procedures were developed and deployed. SMED Implementation This method entailed a preliminary evaluation of the production process, setup time, and changeover of manufacturing orders on the two machines G70 and Curd64 using work measurement and time research methods. The purpose of these methods is to investigate and classify all production, machine setup, and modification of manufacturing order procedures as value-added or non-value-added. Finally, the 5S approach was used to effectively reduce errors that caused a high frequency of downtime due to machine malfunctions.

Control

The improvement must be maintained by implementing control measures such as a standard operating procedure (SOP) in which all necessary details related to achieving high production process performance, particularly in the printing section, are documented and reviewed on a regular basis by the compliance team. Employee training and retraining should be ongoing. (Yadav, V., et al. 2021).

These are a few case studies that demonstrate how lean six sigma is being used in many industries to obtain optimal products, such as shorter product cycle times, fewer defects, and operational excellence. The proper implementation of lean six sigma is also critical. Even when the lean six sigma approach is correct, the project may fail due to a variety of circumstances.

Critical Failure Factors of LSS

We searched and examined literature on LSS-CFFs from various databases, including Scopus, Google Scholar, Emerald Insight, Springer, and Elsevier. Experts from various industrial companies in India provided initial data for the case study. Table 8 shows various CFFS of LSS.

Table 8. Critical failure factors of lss

S.NO	**FAILURE FACTORS**	**REFERENCES**
1	Abscence of standardized practices	Kaswan and Rathi 2021, Sony et al. 2019
2	Absence of a system for measuring performance	Singh et al. 2022, Karim and Arif-Uz-Zaman (2013), Roth and Franchetti (2010)
3	Lack of motivation	Kumar et al. 2011
4	Poor project prioritization and tool selection	Antony and Desai (2009), Aboelmaged (2010), Albliwi et al. (2014)
5	Improper communication	Ruben et al. 2018b
6	Lack of employee engagement	Psychogios and Tsironis (2012), Jeyaraman and Teo (2010), Albliwi et al. (2014)
7	LSS and client needs are not connected.	Rathi et al. 2022
8	Lack of familiarity with LSS methods, tools, and procedures	Antony et al. (2012), Martinez Jurado and Moyano-Fuentes (2014),
9	High implementation cost	Bhasin (2012), Chakravorty (2009)
10	Wrong LSS tool selection	Singh et al. 2022

11	Ineffective training programs	Antony and Desai (2009)
12	Lack of management involvement and awareness	Kwak & Anbari (2006), Psychogios and Tsironis (2012), Pamfilie et al. (2012), Antony et al. (2016), Albliwi et al. (2014),
13	Weak deployment infrastructure	Pedersen and Huniche (2011), Albliwi et al. (2014)
14	Internal opposition to cultural transformation	Bhasin (2012), Psychogios and Tsironis (2012), Albliwi et al. (2014)
15	Lack of Resources	Singh et al. 2021

4. Conclusion

Lean Six Sigma (LSS) is a powerful methodology for achieving operational excellence, but its effective application requires careful consideration of various factors. Proper project selection, complexity evaluation, alternative problem-solving methods, and timely implementation are crucial elements that must be carefully evaluated to ensure the success of LSS initiatives.

Firstly, proper project selection is critical. LSS projects should be aligned with organizational goals and objectives, and should address significant pain points or opportunities for improvement. Projects that are too small or too simple may not be the best candidates for LSS, as the methodology may be overkill. On the other hand, projects that are too complex may require additional resources and expertise.

Secondly, complexity evaluation is essential. LSS projects should be evaluated based on their complexity, and the appropriate tools and methodologies should be applied. For example, simple projects may require only basic problem-solving tools, while more complex projects may require advanced statistical analysis and modeling.

Thirdly, alternative problem-solving methods should be considered. LSS is not the only methodology available, and other approaches such as Kaizen, Total Productive Maintenance (TPM), and Theory of Constraints (TOC) may be more appropriate in certain situations.

Fourthly, timely implementation is crucial. LSS projects should be implemented in a timely manner, with clear milestones and deadlines. Delays can lead to loss of momentum, and can undermine the success of the project.
Finally, a thoughtful and strategic approach to LSS implementation is essential. Organizations should carefully evaluate their readiness for LSS, and should develop a clear implementation plan that aligns with their goals and objectives. This includes developing the necessary infrastructure, training and developing personnel, and establishing clear metrics and benchmarks.

By acknowledging these factors and adopting a judicious approach, organizations can harness the full potential of LSS to drive operational excellence, enhance efficiency, and achieve sustainable improvements. LSS can help organizations reduce waste, improve quality, and increase customer satisfaction, leading to increased competitiveness and long-term success.

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