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ENHANCEMENT OF IN-HOUSE SUPPLY CHAIN MANAGEMENT PERFORMANCE THROUGH LEAN TOOLS IN TWO-WHEELER ROCKER ARM MANUFACTURING

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ABSTRACT
This study investigates the application of Lean Manufacturing (LM) principles to enhance in-house Supply Chain Management (SCM) performance for Two-Wheeler Rocker Arm (TWRA) components in a manufacturing environment. Baseline data revealed average Losses in Supply of 20.92% over three months. Following the implementation of Lean tools-specifically 5S (Sort, Set in Order, Shine, and Standardize and Sustain) and Visual Management-the average Losses in Supply decreased to 17.70%, representing a 3.02% improvement. The findings indicate that systematic Lean interventions and process monitoring can significantly improve internal SCM performance without structural changes or major capital investment.

Keywords: Supply Chain Management, Lean Manufacturing, Two-Wheeler Rocker Arm, Losses in Supply, 5S, Visual Management

1.0 INTRODUCTION
Lean Manufacturing emphasizes the elimination of waste and non-value-added (NVA) activities to improve productivity, quality, and customer satisfaction (Womack and Jones, 1996). In manufacturing firms, internal SCM is critical for meeting production requirements, ensuring material availability, and delivering components on time. Inefficiencies in material flow, inventory visibility, and process delays often lead to supply failures and increased operational costs (Shah and Ward, 2003).
This research applies Lean tools-5S and Visual Management-to internal SCM processes for TWRA manufacturing to reduce Losses in Supply and improve overall operational performance
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Statement of Novelty:
This study presents a unique application of Lean tools exclusively within the in-house supply chain of a Two-Wheeler Rocker Arm (TWRA) manufacturing system. Unlike prior research, which mainly focuses on production line improvements, this work analyzes SCM-driven losses in supply using real industrial KPIs and examines how 5S and Visual Management (VM) can reduce supply failures without altering any process design or production layout. The study provides evidence, supported by 16 months of data, that structured Lean interventions in SCM can reduce Losses in Supply by 3.02%, demonstrating measurable supply reliability improvements.
To the best of our knowledge, no earlier study integrates SCM loss analysis, KPI-based Pareto evaluation, and Lean workplace tools within the TWRA component supply chain, making this research a novel contribution to Lean-driven internal SCM optimization.

2.0 LITERATURE REVIEW

Lean Manufacturing (LM) has been widely applied across manufacturing industries to enhance productivity, minimize waste, and improve operational efficiency (Womack & Jones, 2003). Key LM tools such as 5S, Value Stream Mapping (VSM), Just-in-Time (JIT), and Kaizen have demonstrated effectiveness in optimizing production processes across diverse industrial settings. For instance, Sharma and Gupta (2019) reported that implementing 5S and VSM in an automotive component manufacturing unit significantly reduced production lead times and minimized in-process inventory, highlighting the value of structured workplace organization and visual process control.

Kumar et al. (2020) emphasized that Lean tools can optimize in-house supply chain processes by improving material flow and minimizing bottlenecks. Their study highlighted the use of Process Flow Analysis (PFA) and Pareto Analysis (PA) to prioritize process improvements, resulting in measurable gains in operational performance. Similarly, Patel and Singh (2018) noted that supply chain efficiency relies heavily on timely delivery, inventory management, and effective tracking of supply losses. Even minor delays in material flow were shown to increase production costs and reduce overall customer satisfaction.

Further research has investigated the integration of Lean principles with engineering modifications to enhance process efficiency. Reddy et al. (2021) applied Lean tools alongside process redesign in a machining industry, observing a reduction in idle time and cycle time. Mohan and Rajan (2017) focused on in-house SCM optimization, reporting that systematic monitoring of Key Performance Indicators (KPIs) and continuous improvement strategies significantly reduced supply losses and improved internal supply reliability.

Despite these contributions, limited research has specifically examined the application of Lean principles to in-house SCM of Two-Wheeler Rocker Arm (TWRA) components. Most existing studies focus on general manufacturing or automotive assembly processes, with few addressing the combination of Lean tools, bottleneck analysis, and SCM performance measurement in a real-time industrial environment (Verma & Joshi, 2020). This gap underlines the need for a targeted study to enhance SCM efficiency for TWRA components through Lean implementation, using KPI and Pareto Analysis metrics to assess performance improvements.

Key insights from prior literature include:

- **Lean Thinking:** Identifying value, mapping the value stream, enabling flow, implementing pull, and pursuing perfection to systematically reduce waste (Rother & Shook, 2003).
- **Value Stream Mapping (VSM):** A widely used tool to visualize both material and information flows, distinguishing value-adding from non-value-adding activities (Hines & Rich, 1997).
- **5S and Visual Management**: Shown to reduce lead times, WIP, and production disruptions in automotive and discrete manufacturing contexts (Modi & Jha, 2010; Kumar & Kumar, 2013).
- Lean Supply Chain Integration: Applying Lean principles to supply chain operations improves coordination of material, information, and financial flows, enhancing overall SCM performance (Liker, 2004; Dutta & Dey, 2011).

Research Gap: There is a lack of studies applying Lean tools specifically to in-house SCM of automotive components, combining SCM performance metrics with process flow analysis. This study aims to address this gap by systematically implementing Lean tools to improve supply reliability and operational performance in TWRA manufacturing.

3.0 CASE STUDY

3.1 Problem Definition/Purpose

The in-house SCM is unable to consistently meet customer demand and faces a high percentage of Losses in Supply due to manufacturing difficulties of Component TWRA. This issue has raised

management concerns, prompting necessary interventions to prevent supply failures and delays in fulfilling customer orders (Chopra & Meindl, 2021; Christopher, 2016).
The purpose of this research is to investigate the application of Lean Manufacturing (LM) tools, techniques, and strategies in the manufacturing industry. Specifically, the study aims to:

1. Identify bottleneck issues or "Wastes" in the production process (Ohno, 1988; Womack & Jones, 1996).
2. Analyze the causes of these bottlenecks (Verma & Joshi, 2020).
3. Explore how LM strategies can reduce or eliminate bottlenecks to ensure timely delivery of Component TWRA and improve SCM performance (Imai, 1997; Rother & Shook, 2003).

3.2 Design/Methodology/Approach Adopted
The research methodology involved a combination of literature review and qualitative case study analysis conducted at an automobile manufacturing company in Bangalore, India (Kumar et al., 2020; Mohan & Rajan, 2017).

- The Plan-Do-Check-Act (PDCA) cycle and Define-Measure-Analyze-Improve-Control (DMAIC) framework were used to structure the study and guide the implementation of improvements (Imai, 1997; Juran & Godfrey, 1999).
- Content analysis was applied to examine qualitative data collected from SCM and production teams (Slack et al., 2010).
- Key Performance Indicators (KPI) were used to gather Losses in Supply data for Component TWRA (Patel & Singh, 2018). Pareto Analysis (PA) was employed to quantify supply losses (Chopra & Meindl, 2021).
- A process study was conducted to identify bottlenecks and Wastes in the manufacturing workflow (Reddy et al., 2021).
- Lean tools, including 5S and Visual Management (VM), were implemented to address issues identified by SCM and production teams (Sharma & Gupta, 2019).
- A flow chart was developed to document each step in the manufacturing process of Component TWRA (Maynard, 2012).
- Time study was performed for all stages of production, capturing data on cycle time, production lead time, idle time, and takt time (Slack et al., 2010).
- Value Stream Mapping (VSM) was applied to differentiate Value-Added (VA) and Non-Value-Added (NVA) activities and simulate material flow through the manufacturing process (Rother & Shook, 2003).

3.3 Findings
I Observations from this case study revealed that poor or inadequate supervision is a primary factor contributing to bottlenecks and Wastes in Component TWRA manufacturing (Verma & Joshi, 2020). Several Wastes were identified, and strategies for reducing them-such as eliminating or optimizing specific manufacturing operations-were proposed. Implementation of Lean tools such as 5S and VM showed potential to streamline workflow, reduce bottlenecks, and improve overall SCM performance (Imai, 1997; Sharma & Gupta, 2019).

3.4 Data Collection (Work done so far)
Data were collected over a period of sixteen months (Month 1 to Month 16) from the SCM and production teams, which includes: Losses in Supply: Percentage of supply failures for Component TWRA, including component defects and unmet customer demand, collected from the SCM team (Patel & Singh, 2018).

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3.4.1 Cumulative Line-Wise Losses in Supply of Component TWRA Manufacturing Line – Reference Data Collected from SCM Team (Before Implementation)

The SCM is unable to meet customer demand and faces high losses in supply due to manufacturing difficulties. It was observed that the average percentage of Losses in Supply for the first three months (1st month, 2nd month, and 3rd month) is 20.92%. The percentage of Losses in Supply was calculated using the standard formula (Chopra & Meindl, 2021; Christopher, 2016), as shown in Equation (1), and the results are presented in Table I.

Table I: Cumulative line-wise percentage of Losses in Supply for three months (Source: Developed by Author)

Sl. No.	Line-Wise Losses	No. of Components Loss (Defects)	No. of Components Fail to Supply	Total Customer Demand of the customers	% Losses in Supply (supply/ total demand)	Changes/Implementation in Process
	1st month	1,160	37,832	2,00,000	18.92 %	No changes in process and No implementation
	2nd month	1,286	48,618	2,00,000	24.31 %	
	3rd month	1,188	28,637	1,50,000	19.09 %	
1	**Total**	**3,634 pcs.**	**1,15,087 pcs.**	**5,50,000 pcs.**	**20.92%**	

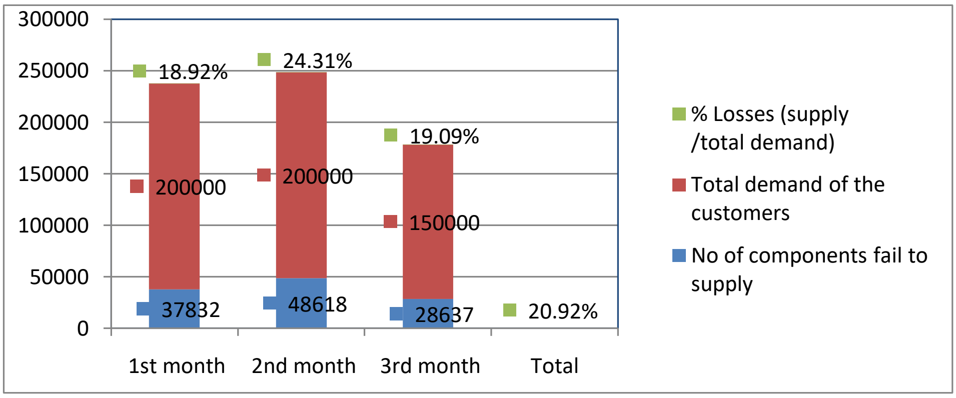

Figure 1: Graphical representation of percentage Losses in Supply using Pareto chart for three months (Source: Developed by Author)

The formula used for calculating the percentage of Losses in Supply is:

$$\text{Percentage of Losses in Supply} = \frac{\text{Total no components fails to supply}}{\text{Customer demand quantity per month}} \times 100 \quad .....(1)$$

Percentage of Losses in Supply = (115087/550000) X 100

Percentage of Losses in Supply = 20.92% (average percentage)

This calculation aligns with standard SCM Key Performance Indicators (KPIs) used to measure supply chain efficiency (Chopra & Meindl, 2021; Christopher, 2016).

Pareto Analysis (PA) was carried out to identify the major contributors to supply loss and assess SCM performance. PA is widely used to focus on the vital few issues that cause the majority of problems in supply chain and manufacturing processes (Juran & Godfrey, 1999). The graphical representation of percentage Losses in Supply using a Pareto chart for the three months is shown in Figure 1.

From the 4th month onwards, continuous improvement lean tools like 5S and Visual Management (VM) were implemented in the current production and process workflow without changing the existing process. VM helps in identifying non-value-added activities, streamlining process flow, and improving visibility of bottlenecks (Rother & Shook, 2003). Simultaneously, detailed process studies were carried out, and the SCM team performance, measured by percentage of Losses in Supply, was continuously monitored.

3.4.2 Cumulative Line Wise Losses in Supply of Component TWRA Manufacturing Line After Implementing 5S and VM System in the Manufacturing Process - Data Collected From SCM Team- (After Implementation)

Table II: Shows the Cumulative Line Wise percentage of Losses in Supply for the periods of 4th month to 16th months (Source: Developed by Author)

Sl. No.	Line-Wise Losses	No. of Components Loss (Defects)	No. of Components Fail to Supply	Total Demand of the Customers	% Losses in Supply (supply/ total demand)	Changes/Implementation in process made
	4th month	1,237	38,698	2,00,000	19.349 %	
	5th month	1,348	40,221	2,00,000	20.1105 %	
	6th month	1,193	39,268	2,00 000	19.634 %	
1	**Total**	**3,778 pcs.**	**1,18,187 pcs.**	**6,00,000 pcs.**	**19.697%**	
	7th month	1,356	38,934	2,00,000	19.467 %	
	8th month	1,109	27,684	1,50,000	18.456 %	No changes in process and 5S and VM Lean tool is implemented
	9th month)	1,187	28,049	1,50,000	18.699 %	
2	**Total**	**3,642 pcs.**	**94,667 pcs.**	**5,00,000 pcs.**	**18.933%**	
	10th month	1,268	32,897	1,75,000	18.798 %	
	11th month	1,159	31,684	1,75,000	18.105 %	
	12th month	1,306	40,083	2,00,000	20.041 %	
3	**Total**	**3,733 pcs.**	**1,04,664 pcs.**	**5,50,000 pcs.**	**19.029 %**	
	13th month	1,318	37,821	2,00,000	18.910 %	
	14th month	1,298	35,084	2,00,000	17.542 %	
	15th month	1,187	29,854	1,75,000	17.059 %	
	16th month	1,204	30,043	1,75,000	17.167 %	
4	**Total**	**5,007 pcs.**	**1,32,802 pcs.**	**7,50,000 pcs,**	**17.706 %**	

From 4th month to 16th month data is collected from supply chain process and percentage of Losses in Supply is calculated (equation 1) and it's shown in Table II. The calculation of percentage of Losses in Supply for the four months (13th month to 16th month) has shown below:

$$\text{Percentage of Losses in Supply} = \frac{\text{Total no components fails to supply}}{\text{Customer demand quantity per month}} \times 100 \quad \ldots\ldots (1)$$

$$\text{Percentage of Losses in Supply} = (132802/750000) \times 100 = 17.70\% \text{ (average)}$$

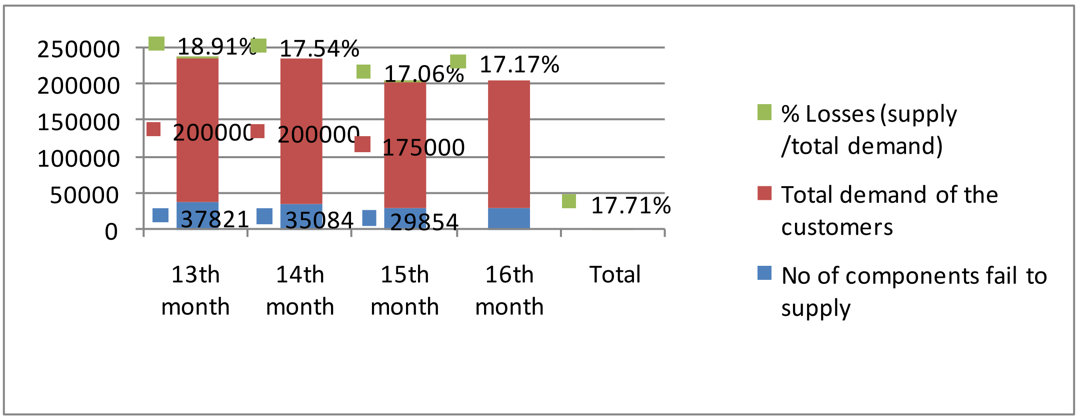

Figure 2: Graphical representations of percentage Losses in Supply using Pareto chart of 13th month to 16th month after implementing 5S and VM system in the manufacturing process(Source: Developed by Author)

Every month PA is carried out to know the performance of SCM team, it was observed that the percentage of Losses in Supply is gradually reduced. After implementing 5S and VM system in the manufacturing process of Component TWRA (Refer Figure 2).
From the 4th month to the 16th month, the data related to Line-wise Losses in Supply was collected from the Supply Chain Management (SCM) team, and the percentage of losses was calculated using Equation (1). The cumulative values for each four-month interval are presented in Table II. After implementing the 5S and Visual Management (VM) system in the Component TWRA manufacturing line, a gradual reduction in Losses in Supply was observed. The percentage of Losses in Supply for the 13**th** to 16th month is calculated as follows:
A Pareto analysis was performed every month to review SCM performance, and the results showed a continuous reduction in supply losses following the implementation of 5S and VM practices (Refer Figure 2). Pareto charts were used to identify the major contributors to losses and prioritize improvement actions (Juran & Godfrey, 1998). Implementation of 5S and VM helped improve workplace organization, visibility of abnormalities, and process discipline, thereby contributing to reduced non-value-added activities and better supply compliance (Hirano, 1995; Galsworth, 2017).
The PDCA cycle and DMAIC framework were used as planning tools to guide the research methodology and provide a structured sequence of improvement steps (Deming, 1986; George et al., 2005) A Process Flow Chart (PFC) was prepared to understand the workflow, and the basic characteristics of the Component TWRA manufacturing system were documented. The load capacities at each stage and total buffer (WIP) quantities were recorded. A detailed time study was conducted across all stages to determine total lead time, process cycle time, idle time, and takt time (Niebel & Freivalds, 2009).
The Visual Management (VM) tool-Value Stream Mapping (VSM)-combined with 5S, was applied to identify value-added (VA) and non-value-added (NVA) activities and to visualize the material and information flow Rother & Shook, 2003; Hirano, 1995). The Current State VSM (CSVSM) illustrated the actual operating conditions, enabling classification of VA/NVA activities and identification of delays and idle times for elimination.

3.5 Result and Discussion

The comparison of the percentage of Losses in Supply before and after implementing 5S and Visual Management (VM) tools-without making any structural changes to the existing production workflow-shows a significant improvement (Refer Figure 3). The Losses in Supply decreased by 3.02%, reducing from 20.92% to 17.70% (Refer Table I, Table II, Figure 1, and Figure 2). The effectiveness of 5S and VM in reducing waste and improving operational stability is well established in lean literature (Hirano, 1995; Rother & Shook, 2003).

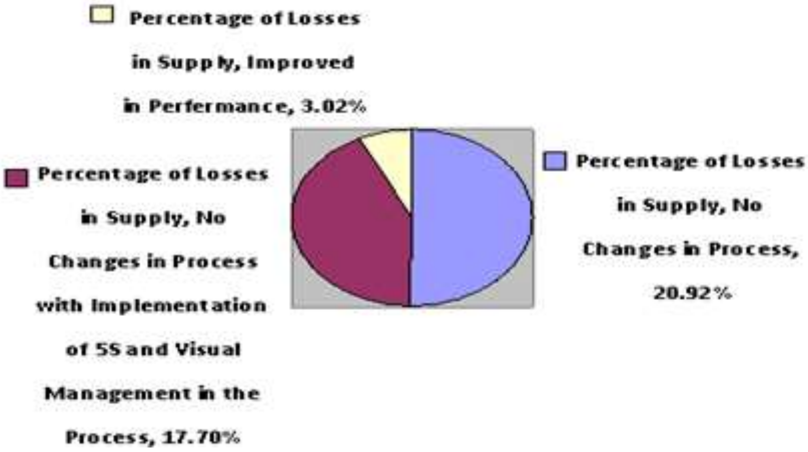

Figure 3: Shows the Pie Chart for comparison of percentage of Losses in Supply before and after implementing 5S and VS in Manufacturing Process of Component TWRA (Source: Developed by Author)

3.6 Conclusion

This case study was carried out to improve the performance of the Supply Chain Management (SCM) process. Lean tools-specifically 5S and Visual Management (VM)-were applied to the existing production workflow without making any structural or engineering changes. As a result, the percentage of Losses in Supply was reduced by 3.02%, improving from 20.92% to 17.70% (Refer Table I, Table II, Figures 1, 2, and 3). The effectiveness of Lean tools in reducing waste and stabilizing processes is consistent with previous studies (Hirano, 1995; Rother & Shook, 2003).

The research methodology was structured using the PDCA cycle combined with the DMAIC framework, which provided a systematic approach to problem identification and improvement (George et al., 2005). Data collection from the SCM and production departments supported Process Flow Analysis (PFA), load capacity assessment, and a detailed time study.

3.7 Future Work

Future work will include collecting deeper and more continuous datasets from SCM and its interfacing departments-production, engineering, and quality-to comprehensively analyze SCM performance. Additional Lean principles and tools should be implemented in the current workflow to further reduce Losses in Supply, minimize inventory levels, improve on-time delivery, enhance process and manufacturing lead time, and strengthen overall organizational performance. Detailed root cause analysis of the identified bottleneck processes and evaluation of post-implementation results will be considered in subsequent research.

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Data Availability: All that support the findings of this study, testing, and trials were conducted within the company's Production, Quality, and SCM departments. The company and component details have been kept confidential in accordance with the confidentiality agreement.

Conflict of interest: "The authors declare that there is **no conflict of interest".**

Ethical Declarations: This study was conducted using process and production data provided by the participating company. No experiments were performed on humans or animals, and no personal data were collected. Therefore, ethical approval and informed consent were not required for this research.

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