5th African International Conference on Industrial Engineering and Operations Management, Johannesburg/Pretoria, South Africa, April 23 - 25, 2024
Publisher: IEOM Society International, USA
Published: April 23, 2024 DOI: 10.46254/AF05.20240010

Applying Lean to the Supply Chain in the Railway Industry

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Abstract

The railroad sector, a crucial part of contemporary transportation systems, is required to meet rising demands for effectiveness, economy, and sustainability. This study investigates how to apply lean principles to improve supply chain efficiency that is impacted by the railroad industry. According to the analysis, using lean approaches can result in significant gains in customer satisfaction, cost control, and output. It also reveals significant issues with material accessibility, quality assurance, payment conditions, and supplier inspection procedures. For the supply chain to fully benefit from lean principles, several issues must be resolved. This study intends to offer useful insights for industry stakeholders by looking at case studies, identifying problems, and making recommendations. It provides a road map for organizations to enhance their supply chains, achieve operational excellence, and satisfy changing market needs through thorough analysis and strategic recommendations. This study emphasizes how crucial it is to use lean principles to the railway sector to make it a more effective, affordable, and environmentally friendly method of transportation.

Keywords
Lean Manufacturing, Process optimization, industrial engineering

1. Introduction

By linking far-reaching areas and permitting the massive flow of goods and people, the railway sector serves as a tribute to human ingenuity. Despite its lengthy history and unquestionable significance, the railway industry is currently confronted with a problem that could disrupt operations and impede growth: recurrent material shortages within its complex supply chain. These shortages affect consumer satisfaction and service reliability in addition to disrupting production schedules. The objective of the manuscript is to investigate the implementation of lean principles as a solution to mitigate and resolve the ongoing problem of material shortages in the railway industry's supply chain in reaction to this challenge.

The supply chain for the railroad sector is a maze of interconnected parts that includes everything from the procurement of raw materials to the production of rolling equipment and infrastructure. However, in recent years, the industry has struggled with persistent shortages of essential raw materials. These shortages interfere with manufacturing processes, cause expensive delays, and jeopardize the industry's capacity to satisfy rising demand. Beyond the supply chain, the effects have an impact on customer happiness, service dependability, and the industry's capacity to compete (Acero et al. 2019).

2. Literature review

This literature review's objective is to determine the existing body of work on lean and supply chain management (also known as "lean supply chain management") in the railroad sector. A review of the literature on implementing lean concepts in the supply chain might highlight the possible advantages and difficulties in the context of South African railroad industry. By examining existing research, one can gain insights into how lean practices can optimize production, reduce waste, enhance efficiency, and improve overall performance in this sector (Gunasekaran and Mai 2018).

2.1 Overview of the railway manufacturing industry in South Africa

South Africa's railway industry is essential to the nation's transportation industry. The business creates, manufactures, and maintains a variety of railroad equipment, including locomotives, rolling stock, track systems, and signalling devices. Since the 19th century, South Africa has had a well-established railway infrastructure, making it a crucial source of transportation for both people and goods. Numerous social and economic issues that South Africa is dealing with call for institutional support. Based on its agreements with PRASA and as a proudly South African organization, Gibela supports economic development. The mission of Gibela is to make commuter rail the preferred method of transportation, revitalize the South African rail industry, promote inclusive economic growth, and improve communities. In order to increase the engagement of local suppliers in their supply chains during building and implementation, Gibela has adopted a proactive strategy. Gibela's assistance to South African companies will aid economic change and encourage the revival of the local railroad sector (Bisio and Sandro 2016)

Table 1. Total Market Size for Rail Infrastructure: 2020-2023 (Basset et al. 2018)

	2020	2021	2022 (Projected)	2023 (Projected)
Total Market Size	750	700	700	700
Tota Local Production	140	140	150	150
Total Exports	55	55	58	60
Total Imports	700	800	750	770
Imports from the U.S.	320	280	230	240
Exchange Rate: 1$	16,44	15,9	16	

Unit: $thousand

Total Market Size = (Total Local Production + Total Imports) – (Total Exports)

The cost of the independent Richards Bay coal terminal consortium's improvements and the multi-year roll-out of diesel and electric locomotives—both of which were verified in 2010 and 2014—is not accounted for in the figures. Additionally excluded from the figures are the supplementary investments in ports, freeways, and roads. The figures are unofficial estimations gathered from press and industry sources.

2.2 Lean and supply chain

Supply chain management and lean manufacturing are closely interconnected concepts in the realm of operations and production. The success and efficacy of lean manufacturing principles are significantly influenced by the supply chain. This is how they are connected:

- Inventory Management: Lean manufacturing aims to minimize waste, including excess inventory. An efficient supply chain ensures that materials are available in the right quantities when needed, reducing the need for stockpiling and excessive inventory (Jones, 2015)
- Lead Times: A well-managed supply chain with short lead times allows for faster response to customer demands. This aligns with the lean principle of delivering products just-in-time, reducing the need for storing finished goods.
- Demand Forecasting: Accurate demand forecasting within the supply chain helps in aligning production with actual customer needs. Lean manufacturing relies on producing what customers want when they want it, avoiding overproduction (Kiefer et al. 2019)

- Supplier Relationships: Close collaboration with suppliers is crucial for lean manufacturing. A reliable supply chain ensures a steady flow of high-quality materials, minimizing disruptions and defects that can lead to waste. (Hung et al. 2019)
- Flexibility: A responsive supply chain enhances the ability to adapt to changes in customer demand or production requirements. This agility supports the lean principle of being able to quickly adjust to shifts in the market.
- Waste Reduction: A well-organized supply chain reduces the likelihood of supply shortages, overproduction, excess transportation, and other inefficiencies, all of which align with lean's goal of waste reduction.
- Continuous Improvement: Both lean manufacturing and effective supply chain management emphasize continuous improvement. Feedback from the supply chain can lead to refinements in manufacturing processes and vice versa. (Fan and Stefan 2015)

In essence, a well-optimized supply chain is a key enabler of lean manufacturing's principles of efficiency, waste reduction, and customer-centric production. Any manufacturing sector needs inventory as a tool for managing production and operations. The stock of necessary commodities, including as raw materials, tools, finished or semi-finished goods, and spare parts, is known as inventory. In an industrial system, having the proper materials in the right quantity and quality at the proper location and time in the most cost-effective manner is essential.
Lean has been implemented by industrial businesses all around the world to promote improvements within their operations. The Toyota Production System (TPS)'s guiding concepts and practices are referred to as "lean" in general. The "antidote" to muda, the Japanese word for waste, is lean thinking. Anything that the customer is unwilling to pay for is considered waste in this sense. In parallel, the following wastes (muda) in supply chain can be defined:

1. Excess Inventory: At both shippers' and receivers' facilities, inventory build-up in warehouses results in excessive storage space consumption and low labour productivity because of the stumbling blocks this surplus causes (Mastos 2020)
2. Unnecessary Transportation: The redundant movement of goods, personnel, and forklift drivers in Distribution Canters (DCs) makes this waste obvious. When SKUs are not kept in a logical order, it can take longer to find an order, which becomes a significant issue.
3. Waiting Times: When workers are prepared to resume their task but are unable to do so because of the lack of necessary goods, equipment, or the system as a whole, waiting occurs. The parking lots of DCs and delivery locations, where several drivers are lining up at once, are two places where waiting in urban logistics is evident. Another frequent instance of waiting is when loading or unloading cargo for administrative purposes, such as to verify that the delivered goods match the bills.

4. Extra Motion: This muda occurs in the setting of DCs when staff must store products at heights that are uncomfortable from an ergonomic standpoint because inventory is not stored at the proper height level. As a result, employees "Stretch" or stoop over needlessly to choose products. When goods are not loaded onto trucks in the order they will be delivered to stores, transportation waste results.

5. Overproduction: Preparing orders before they can be processed by the next link in the chain is one kind of overproduction waste that can cause unneeded congestion. The shipping industry is significantly impacted by this muda since excess production might impede the flow of orders.

6. Over-processing: This muda comprises packaging and pointless inspections. For instance, doing quality checks regularly at various stages, such as when the order is made, when it is loaded into the truck, when it is unloaded, and when it is delivered to the recipient's premises (right quantity, correct conditions). Another instance of this waste is when employees have to manually or via barcode readers re-enter specific information (Nandakumar and Harikumar 2020).

7. Defects: Choosing the incorrect item or selecting the incorrect quantity of an item may result in an inadequate or excessive supply for the consumer. Another instance of a fault is when goods need to be repaired or thrown away as a result of process damage (during storage or delivery). This has the problem of increasing the number of items returns as a result of improper order delivery, which will necessitate hiring more people to handle. When this kind of mistake is found now of delivery, it necessitates improvised and non-standard activities, which halts the process flow.

8. Unutilized Resources Usage: The waste examples provided above typically result in the usage of resources to a lesser extent than their capability. For instance, an ineffective distribution system that involves waiting periods, reprocessing, and excessive transit means that relatively few consumers may be visited by the same truck since vehicles are loaded much below their maximum capacity. This also holds true for an individual's talent, abilities, and knowledge.

The waste of the bull-whip effect is neither entirely addressed nor remedied by the suggested remedies in the logistics sector, which is the motivation of this study. But in the early 1950s, Taiichi Ohno's renowned production philosophy at Toyota gave rise to waste reduction as a crucial quality improvement initiative. Eliminating waste is a fundamental goal of lean manufacturing as well as quality managementTaiichi Ohno of Toyota Motor Company oversaw the Toyota Production chain (TPS), which aims to eliminate all waste and anomalies in the production chain.
The strategies that aim to reduce waste include production planning, resource management, lean suppliers, continuous flow, Heijunka (level scheduling), PDCA cycle (plan, do, check, act), poka yoke (error proofing), overall equipment effectiveness, and intra-lean management for production. Andon is one of the key components of the Jidoka quality control method to notify management, maintenance, and other workers of a quality or process problem.

3. Research Methodology

The "Research Onion" model created by Saunders et al. (2007) was used to structure the study's usage of both qualitative and quantitative data collection methodologies. This methodology enables you to carefully design your research strategy, working your way from the most superficial layers to the research's core. Epistemology: In order to establish factual facts and relationships, a positivist approach was applied in this study for the quantitative data from the production and supply chain. Recognizing that human views and interpretations play a key part in influencing the data, a constructivist approach is used when analysing the qualitative data from questionnaires. Questionnaires were conducted to gather necessary information on supply chain challenges and lean initiatives to address the problem the railway industry is faced with. Supply chain personnel ranging to material planners, buyers,' industrial engineers, working in the supply chain responded to questionnaires. Production performance indicators were extracted from a railway manufacturing firm and statistical analysis tools were used to analyse the data.

4. Results and Discussion

The information gathered is summarized throughout the data analysis phase. It involves applying lean principles to uncover sources of waste and eliminate waste in the supply chain processes. The study seeks to achieve operational excellence to add value to clients, get a competitive edge. In order to improve the production efficiency of a railroad manufacturing organization, this project used Lean concepts to evaluate several parts of the organization's supply chain. The key techniques employed to get this result were as follows:

4.1 Production performance

Production targets and actual performance are outlined. The sample of the study ranged from 1st of June 2023 to 30th of June 2023.

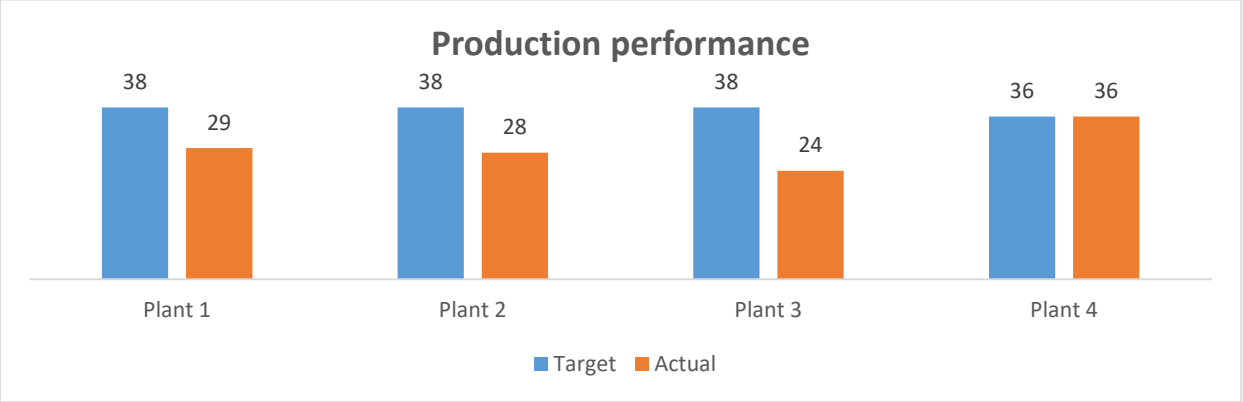

Figure 1. Production performance (target vs actual), plant 1 – plant 4, 1st June to 30th June 2023

Process variation due to unavailability of material, quality issues, environmental factors, machine or equipment breakdowns, and other factors such as employee absenteeism were observed.

Table 2. Reasons for deviations that affect production efficiency

Reasons for deviations (source of waste)	Frequency
Unavailability of material	114
Quality issues	45
Environmental factors	18
Production inefficiency	30
Equipment breakdown	27
other (absent staff, space, capacity)	15

Product efficiency within a plant could be influenced by various factors that increase throughput. One of the great contributors for deviations that affect product efficiency is the unavailability of material.

Below is the contribution of the sources of waste in the production.

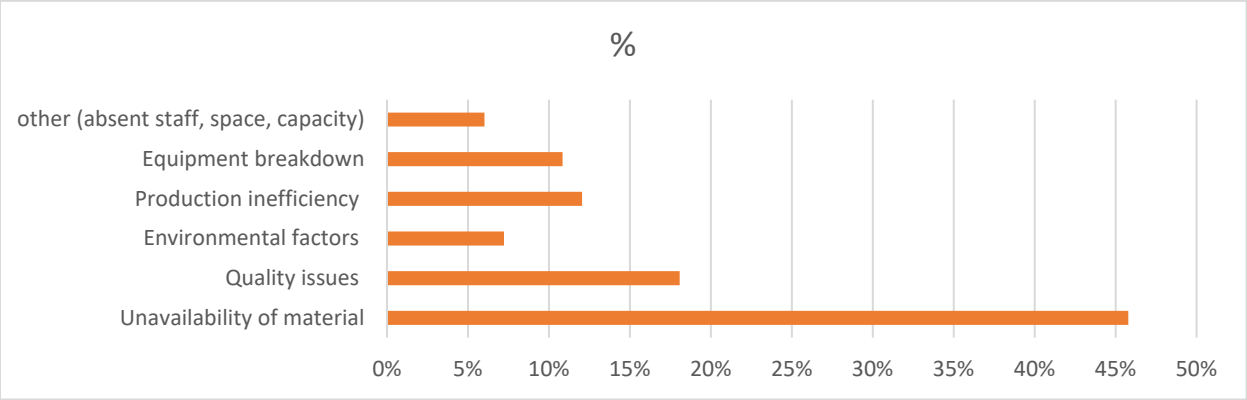

Figure 2. Reasons for deviations (source of waste) in %

A Pareto analysis (chart) of deviations

Pareto Analysis is a valuable tool for identifying and prioritizing the most significant reasons for deviations in a railway manufacturing production process.

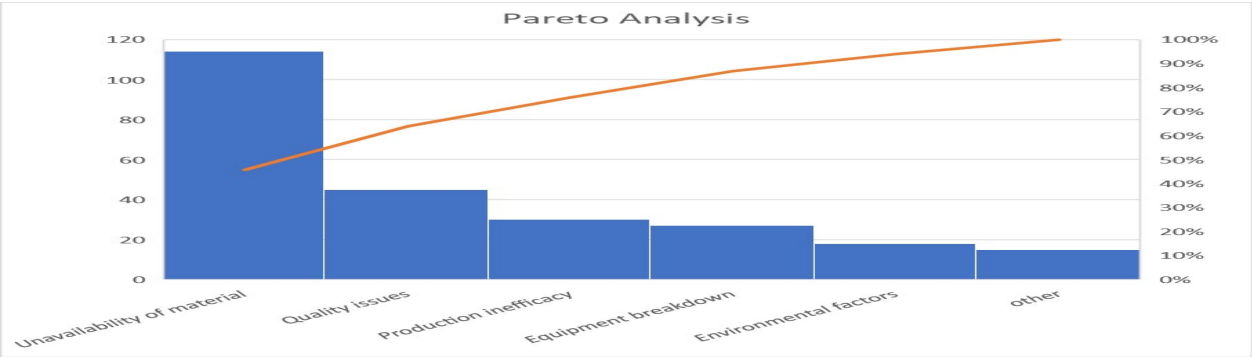

Figure 3. A Pareto analysis chart of deviations

4.2 The results from a questionnaire

Using the 5M + E (Man, Machine, Material, Method, Measurement, and Environment) framework, the cause and effect diagram (Fishbone or Ishikawa diagram) for the problem of "Inventory not available when needed for production" in railway manufacturing is as follows

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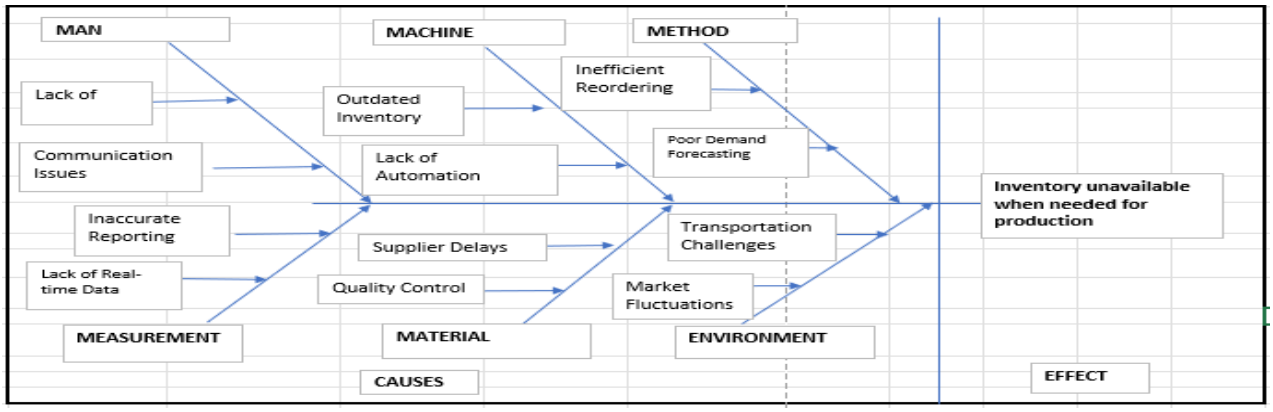

Figure 4. A cause and effect for a problem “material unavailable for production”

Finding the root cause of material not available for production for four most common problem observed by supply chain professionals.

a. Problem: Inventory not available when needed due to supplier capacity not delivering materials on time.

1. Why inventory not available when needed?
   - Because there are frequent delays in receiving supplies from our suppliers.
2. Why do we experience delays in receiving supplies from our suppliers?
   - Because our suppliers are unable to meet our demand consistently.
3. Why are our suppliers unable to meet our demand consistently?
   - Because their production capacity is limited, and they struggle to scale up to our requirements.
4. Why do our suppliers have limited production capacity and struggle to scale up?
   - Because they lack the necessary resources and infrastructure to expand their operations.
5. Why do our suppliers lack the necessary resources and infrastructure to expand their operations?
   - Because they may face financial constraints or have not invested in capacity expansion due to uncertainty in our long-term partnership.

Root Cause: The root cause of the issue "Inventory not available when needed" in relation to supplier capacity constraints is that our suppliers lack the necessary resources and infrastructure to expand their operations, potentially due to uncertainty in our long-term partnership.

b. Problem: Inventory not available when needed due to inventory accuracy issues affecting accurate planning (demand fluctuation).

1. Why inventory not available when needed?
   - Because our planning processes often result in inaccurate inventory projections.
2. Why do our planning processes result in inaccurate inventory projections?
   - Because the data used for planning, including current inventory levels, is often incorrect.
3. Why is the data used for planning often incorrect, especially inventory levels?
   - Because there are discrepancies between recorded inventory levels and actual physical inventory.
4. Why are there discrepancies between recorded inventory levels and actual physical inventory?
   - Because we lack robust inventory management and tracking systems, relying on manual processes that are prone to errors.
5. Why do we lack robust inventory management and tracking systems, relying on manual processes?

- Because there has been a historical reluctance to invest in modern inventory management technology and training for personnel.

Root Cause: The root cause of the issue "Inventory not available when needed" in relation to inventory accuracy affecting accurate planning is a historical reluctance to invest in modern inventory management technology and training for personnel, leading to discrepancies between recorded and actual inventory levels.

c. Problem: Inventory not available when needed, relating to delayed supplier payments.

1. Why inventory not available when needed?
   - Because we frequently experience delays in receiving supplies from our suppliers.
2. Why do we experience delays in receiving supplies from our suppliers?
   - Because we sometimes miss scheduled deliveries due to cash flow problems.
3. Why do we have cash flow problems that lead to missed payments?
   - Because our payment terms with suppliers are not aligned with our cash flow cycles.
4. Why are our payment terms not aligned with our cash flow cycles?
   - Because we have not renegotiated payment terms with suppliers to better match our financial situation.
5. Why haven't we renegotiated payment terms with suppliers to match our financial situation?
   - Because there may be a lack of communication or negotiation efforts with suppliers to adjust payment terms as needed.

Root Cause: The root cause of the issue "Inventory not available when needed" in relation to supplier payments is a misalignment of payment terms with cash flow cycles and a potential lack of communication or negotiation with suppliers to address this issue.

d. Problem: Inventory not available when needed due to quality not standards- Non-Conformance Reports (NCRs).

1. Why inventory not available when needed?
   - Because we frequently encounter delays in the production process.
2. Why do we experience delays in the production process?
   - Because we often receive materials that don't meet the required quality standards, resulting in Non-Conformance Reports (NCRs).
3. Why do we receive materials that don't meet quality standards and result in NCRs?
   - Because there's insufficient quality control in place during the supplier material inspection process.
4. Why is there insufficient quality control during the supplier material inspection process?
   - Because our inspection procedures may be outdated or not adequately enforced.
5. Why are our inspection procedures outdated or not adequately enforced?
   - Because there has been a lack of investment in updating and training personnel in quality control processes.

Root Cause: The root cause of the issue "Inventory not available when needed" in relation to NCRs is a lack of investment in updating and training personnel in quality control processes, leading to insufficient quality control during the supplier material inspection process.

4.2 Analysis of user experience relating to inventory management system

On a scale of 0-10, the overall rating of satisfaction amongst users of inventory management system indicates that the score of 57.5% out of 100% in satisfaction levels.

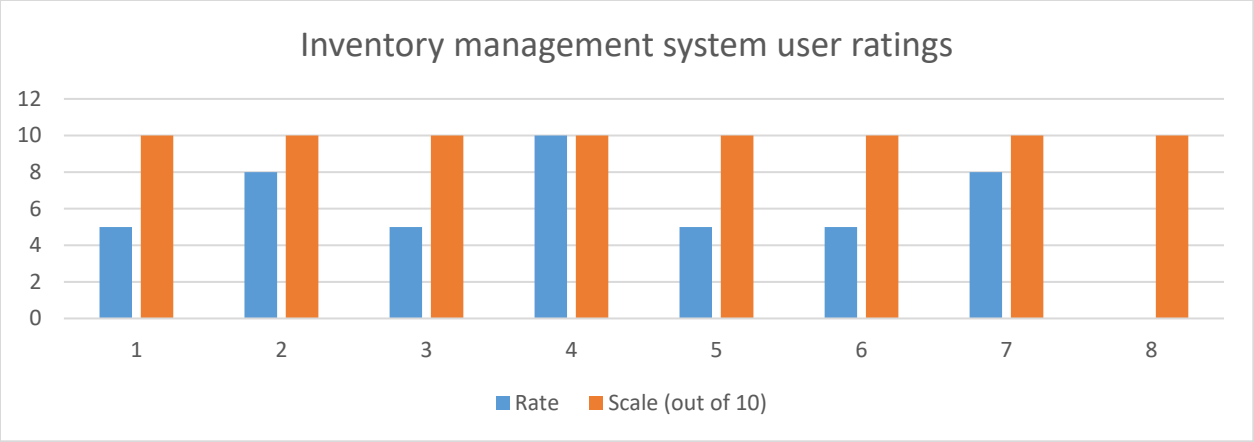

Figure 5. Inventory management system user ratings chart

How frequently do users experience unavailability of material in their production process?

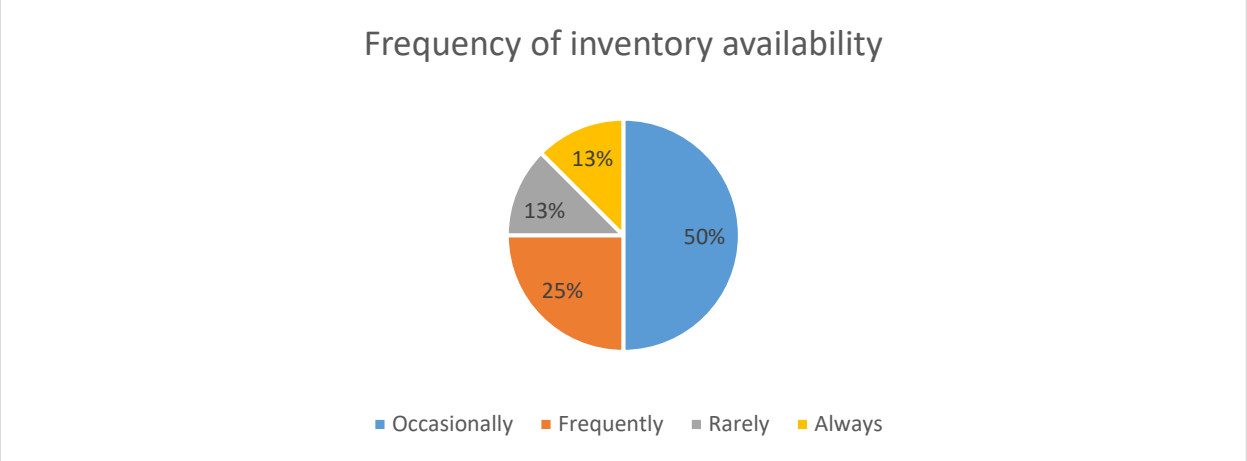

Figure 6. Frequency of inventory availability chart

Lean awareness or training amongst supply chain professionals in the railway industry.

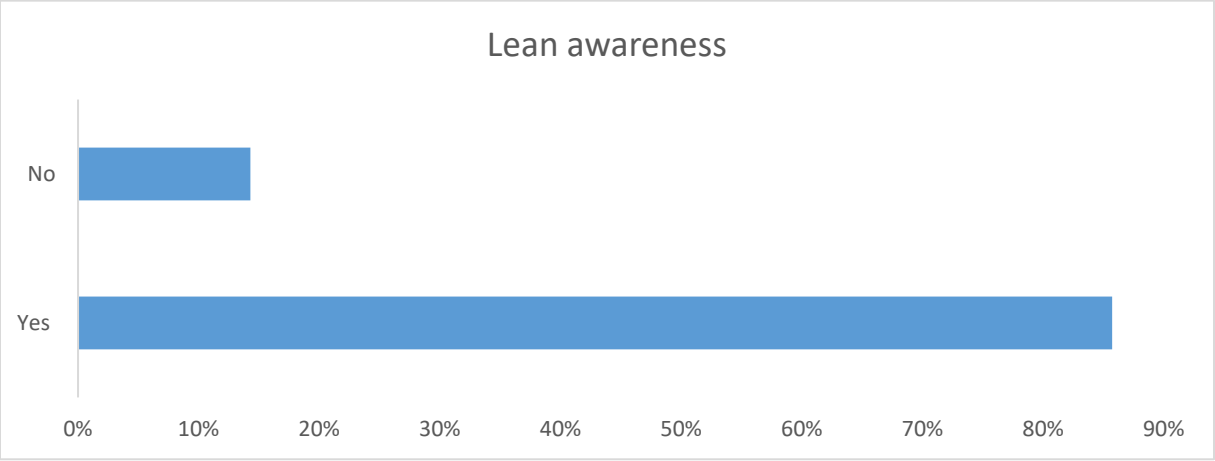

Figure 7. Lean awareness chart

Waste within railway industry's supply chain

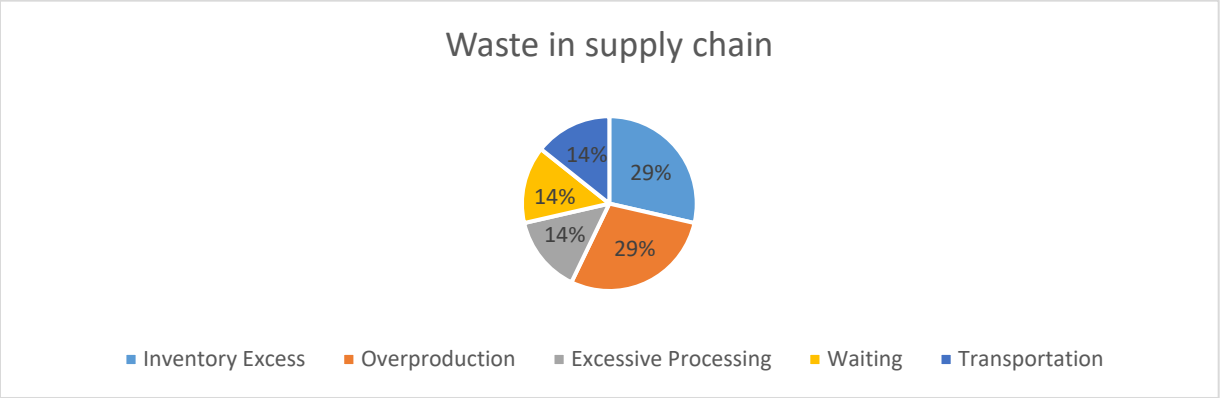

Figure 8. Waste in supply chain

5. Recommendation and Conclusion

5.1 Recommendation for Improving Production Performance

1. Material Availability: Address the issue of material unavailability, which accounts for 46% of the production shortfall and is the most important factor. To maintain a reliable and timely supply of commodities, work closely with suppliers; to minimize disruptions, consider buffer stock or alternate sourcing possibilities.
2. Quality Control: To decrease quality difficulties (18%), concentrate on strengthening quality control procedures. To uphold high standards, implement strict quality controls and spend money on training for production employees.
3. Production Efficiency: By streamlining processes, eliminating bottlenecks, and applying lean manufacturing techniques, you can increase production efficiency by 12 percent. Analyse production procedures frequently to look for possibilities for improvement.
4. Equipment Maintenance: Implement a proactive maintenance strategy to address equipment breakdowns (11%). Unplanned downtime can be drastically decreased with preventive maintenance.
5. Environmental Factors: Look at measures to lessen the production's 7 percent environmental impact. This can entail developing weather-resistant storage options or emergency plans.
6. Human Resources: Address the "other" (6%) category's problems, such as personnel absences and space limitations. Consider cross-training staff to assure coverage and plant space usage optimization.
7. Performance Monitoring: Put in place a reliable performance monitoring system to monitor advancement toward production goals. Review key performance indicators (KPIs) frequently to spot problems early.
8. Continuous Improvement Culture: Encourage an improvement-focused culture within the company. Encourage staff members to discover production problems and offer potential fixes.

It is possible to enhance production performance and work toward attaining production goals in the upcoming months by methodically addressing these problems and putting the suggested actions into practice. For continuous improvement, regular evaluation and strategy modification are required.

5.2 Recommendations for Addressing Inventory Availability Challenges:

1. Supply Capacity Constraints:
   - Work closely with important suppliers to determine their production capacity and match it to your demand projections.
   - To create a more reliable supply chain, think about diversifying your supplier base or negotiating flexible agreements.
2. Inventory Accuracy and Planning:
   - Use cutting-edge technology and inventory management systems to improve accuracy.
   - To address disparities, perform routine cycle counts and reconciliation procedures.
   - Improve supplier communication to guarantee proper planning based on current information.
3. Payment Terms Alignment:
   - Agree upon transparent and advantageous payment terms with suppliers. Make sure that they line up with the production schedules.

- To prevent disruptions caused by payments, check payment terms frequently and make any adjustments.

4. Quality Management during Supplier Inspection:
- Enhance quality control procedures when inspecting suppliers.
- Train inspection teams to achieve complete and uniform evaluations.
- Work with suppliers to enhance their quality control processes.

You may lessen the difficulties with inventory availability and build a more dependable, effective supply chain that satisfies production demands on schedule by addressing these core reasons. For long-term success, regular monitoring and efforts at continual improvement will be essential.

5.3 Based on the data collected from the research questionnaire, here are some key recommendations.

1. Inventory Management System Improvement
   - Gather input from users who gave the inventory management system lower ratings (5/10 or less) in order to address the differing ratings. To increase user happiness, pinpoint particular system improvement areas that need attention.
2. Material Unavailability
   - Consider taking proactive steps to lessen occurrences of material shortages given that 50% of respondents occasionally face a lack of materials. This could entail improving supplier relationships, reorder point optimization, and closer inventory level monitoring.
3. Inventory Review Frequency
   - Recognize that a majority of experts (63%) either check or change inventory levels on a weekly or daily basis. Make sure the frequency of reviews corresponds to trends in demand, and if necessary, think about implementing more dynamic inventory management techniques.
4. Demand Forecasting
   - Recognize that demand projections are reviewed regularly by 67% of professionals. Make that the forecasting method is reliable and adaptable to shifting demand patterns. If necessary, think about purchasing sophisticated forecasting tools.
5. Continuous Improvement Culture
   - Encourage the 83% of supply chain experts who are able to pinpoint areas for improvement to take an active part in programs for continuous improvement. Encourage an innovative and effective culture within the company.

6. ***Lean Training and Awareness***

As 87% of professionals are already trained or aware of lean principles, continue offering training and awareness activities in this area. To increase efficiency and reduce waste, make sure that these principles are regularly used throughout the railway supply chain.

These suggestions are meant to address the problems that have been found and build on the railroad supply chain's current advantages. Organizations can work to improve their operational efficiency and responsiveness by putting these techniques into practice.

7. Conclusion

The study has examined several topics, such as inventory control, material availability, demand forecasting, and supply chain specialists' familiarity with lean concepts in the railway sector. The research has shed light on several key points: The inventory management system's varied ratings serve as a reminder of the necessity for ongoing development. It is obvious that there is room to increase this system's effectiveness. An issue is the frequent material scarcity that 50% of respondents mentioned. It emphasizes the significance of taking preventative action to guarantee a steady supply of supplies and minimize operational disruptions. The wide range of inventory review intervals from daily to quarterly indicates the necessity of integrating inventory management procedures with demand dynamics and responsiveness. Most professionals evaluate demand projections once a week, showing a focus on remaining current with shifting demand trends. This demonstrates dedication to effective supply chain management. The ability to pinpoint areas for improvement demonstrates a supply chain professional's commitment to enacting change and streamlining procedures. The preparedness to use lean approaches for process improvement and waste reduction is indicated by the high degree of knowledge and training in lean concepts (87%) among the workforces. The study shed important light on the health of the railway supply chain now, highlighting its strong points and identifying areas that may use improvement. The railway sector is at a crossroads and can use lean concepts to improve productivity, cut costs, and provide better customer service.

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Biographies

Kemlall Ramdass has worked as a work-study officer, industrial engineer, production/operations manager and skills development facilitator in the clothing, electronics, and textile industries between 1981 and 1999. He joined the academic profession in 1999 as a lecturer with Technikon South Africa. He later moved to UNISA'S Department of Business Management in 2006 lecturing in operations management. He is currently in the Department of Industrial Engineering based at Unisa, Florida Campus. He has a passion for quality and firmly believes that the application of quality management methodologies will highlight deficiencies and instigate the implementation of improvement strategies. He has authored and presented approximately 65 journal and conference papers both nationally and internationally and is a peer reviewer for numerous publications. He has achieved Fellow member status at SAIIE and is a member of PICMET and IEEE. He started studying in 1985 and achieved his doctorate in 2009 with all qualifications being done part-time while employed and with a family. He is a team member of the Identification of Engineering Work (IDOEW) at the Engineering Council of South Africa and appointed on Council at Orbit College.

Simon Phuluwa is a Senior Lecturer in the Department of Industrial Engineering at the UNISA, Florida, Johannesburg, South Africa. He earned Diploma in Industrial Engineering from Pretoria Technikon, South Africa, BTech in Industrial Engineering from UNISA, South Africa, master's in Industrial Engineering, Tshwane University of Technology and DEng in Industrial Engineering from Tshwane University of Technology, South Africa. He has published journals and conference papers. His research interests include demanufacturing, simulation, optimization, circular economy, sustainability and advance manufacturing.