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Analyzing the Root Causes of Inventory Shortages to Develop Data-Driven Strategies for Improved Vendor Responsiveness in Manufacturing

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Abstract - **Material shortage management and supplier reliability are critical determinants of operational efficiency in manufacturing environments. This study investigates the patterns, underlying causes, and systemic drivers of inventory instability across critical components and active suppliers within a manufacturing facility. A comprehensive review of literature highlights that while lean and Just-In-Time (JIT) paradigms reduce holding costs, they heighten vulnerability to supplier delivery variances, unmanaged lead times, and internal quality defects if robust inventory buffers and vendor governance are lacking. To address these challenges, the study established four key objectives: mapping shortage trends across critical parts, diagnosing root causes using structured problem-solving frameworks, formulating data-driven inventory and ERP integration strategies, and strengthening vendor responsiveness alongside master-data accuracy. The research methodology utilized a quantitative, diagnostic approach analyzing 2,184 daily coverage readings (56 parts across 39 working days) combined with supplier master reconciliation and assembly line quality defect records, evaluated through Pareto analysis, Ishikawa (Fishbone) cause-and-effect mapping, and baseline descriptive metrics.**

The major findings reveal a baseline stockout rate of 4.1% (89 instances) affecting 39.3% of tracked parts and 64.7% of suppliers, with extreme concentration: three Class-A suppliers accounted for 65.2% of stockouts, and two specific SKUs from the primary underperforming vendor drove nearly one-third of all shortages while operating with under one day of stock coverage. An 84% reduction in stockout incidence during the study confirmed that disciplined daily tracking mitigates shortages, while quality analysis identified a severe 503,406 PPM defect rate—dominated by welding flaws (87.2%)—that silently eroded stock. Additionally, master data audits uncovered uncertified vendors, missing audit records, and off-master sourcing. The study concludes that stockouts stem from localized vendor failures, unadjusted scrap rates, and manual tracking rather than broad market forces. Practical suggestions include implementing mathematically derived dynamic safety stocks in ERP, deploying an On-Time In-Full (OTIF) Vendor Scorecard, establishing JIT delivery alignment, cleaning master records, and setting automated three-day coverage alert thresholds.

Keywords— Material Shortage Analysis, Safety Stock Optimization, Pareto & Ishikawa Analysis, OTIF Vendor Scorecard, In-House Quality PPM, SAP Master Data Governance.

I. INTRODUCTION

In the highly competitive landscape of modern manufacturing, seamless production operations rely heavily on robust inventory management and an uninterrupted flow of raw materials. Material stockouts and inventory shortages pose significant threats to operational efficiency, often leading to costly production delays, idle labour, and compromised customer fulfillment. As industrial supply chains become increasingly complex, manufacturing plants frequently encounter disruptions driven by unpredictable supplier performance, volatile demand patterns, and misaligned master-data systems. Consequently, identifying and mitigating the root causes of these bottlenecks is a strategic imperative. Addressing these challenges requires a shift from traditional, reactive procurement practices to a comprehensive, data-driven approach that systematically evaluates component availability and supply chain vulnerabilities.

A critical element in preventing material shortages lies in synchronizing internal inventory controls with external vendor responsiveness. Suppliers operate as the backbone of the manufacturing ecosystem, and their inability to consistently meet delivery timelines directly cascades into critical factory-level stockouts. To effectively combat this, organizations must move beyond treating the surface-level symptoms of shortages and instead apply structured problem-solving frameworks to diagnose underlying operational failures. By systematically tracking inventory trends across critical components and establishing rigorous supplier evaluation mechanisms, supply chain managers can identify recurring patterns of failure. Furthermore, ensuring master-data accuracy is essential, as it forms the foundational pillar for reliable enterprise resource planning (ERP) and automated procurement. When data integrity is maintained, organizations can foster stronger, more transparent collaborations with their vendors.

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This research aims to bridge the gap between procurement inefficiencies and production reliability by deeply analyzing inventory shortage trends within a real-world manufacturing environment. By investigating the fundamental causes of material stockouts through systematic data tracking and diagnostic tools, this study seeks to formulate targeted, data-driven strategies that enhance overall supply chain resilience. The ultimate objective is to develop actionable recommendations that improve system integration, elevate vendor responsiveness, and optimize safety stock levels. Through a detailed study of current procurement challenges, this paper outlines a comprehensive framework designed to reduce shortages, strengthen vendor accountability, and ultimately drive sustainable operational efficiency across the manufacturing sector.

II. LITERATURE REVIEW AND THEORITICAL BACKGROUND

A. Literature Review

Kadam, Kadam, Garine, and Kadam (2024) propose a data-driven, Industry 4.0 inventory model with Power BI analytics to forecast needs, flag critical stockouts, and identify underperforming suppliers. Etienne (2005) argues that inventory can be a net destroyer of supply chain responsiveness, with long-run disadvantages for quality responsiveness. Patel (2021) reviews data-driven demand planning—forecasting, machine learning, and real-time data—to improve inventory accuracy and responsiveness under disruption. Etienne (n.d.) further elaborates that inventory often impairs responsiveness to supply uncertainty over the long term. Dixit and Shivhare (2025) present a predictive-analytics framework diagnosing lead time, fulfillment, and turnover issues and modeling stockout risk to support vendor coordination. Makhmudah, Putra, and Rahmawati (2025) use Fishbone and 5 Whys root cause analysis to diagnose component procurement delays and recommend risk-based SOPs and supplier performance evaluation, enabled by integrated information systems. Nadarajan, Rahim, and Saifudin (2019) discuss material shortages causing production stoppages in manufacturing and frames disruption drivers and impacts. Dzreke and Dzreke (2025) quantify how lean inventory buffers can amplify crisis losses, introducing Inventory Risk Elasticity and a RESCUE protocol. Natarajan (2024) offers a data science approach to balance safety stock versus stockouts. Davis (2013) describes demand-driven inventory optimization and replenishment concepts linked to JIT and CPFR-related planning mechanisms. Alegria, Kotis, and McLaughlin (2016) develop prospective inventory systems for preempting medication unavailability, relevant to anticipating shortages structurally. Nag, Han, and Yao (2014) analyze how manufacturing inventory levels align with supply chain strategy patterns using cluster analysis and case studies (World Journal of Advanced Research and Reviews; Supply Chain Forum; etc.)

B. Theoretical Background

This study is grounded in core inventory and supply chain management theories that balance operational efficiency with supply chain resilience. The foundational framework relies on Inventory Management Theory, which navigates the critical economic trade-off between holding costs and stockout risks by using coverage days to assess production continuity. To mitigate demand and supply uncertainty, Safety Stock and Reorder Point (ROP) calculations establish structured buffers that trigger timely procurement before shortages occur. Furthermore, ABC-XYZ Classification categorizes components based on consumption value and demand volatility, ensuring managerial focus prioritizes high-risk materials. Material Requirements Planning (MRP) acts as the systematic engine aligning production schedules with procurement needs, while Economic Order Quantity (EOQ) principles offer a baseline for evaluating procurement lot sizes against dynamic customer schedules.

To address the external dependencies within these systems, Supplier Relationship Management (SRM) principles are integrated to evaluate vendor reliability, quality, and responsiveness through structured performance metrics. The study also incorporates Lean and Just-in-Time (JIT) philosophies, advocating for a hybrid approach that utilizes minimal safety buffers to absorb the logistical uncertainties inherent in complex manufacturing networks. Additionally, the framework addresses the Bullwhip Effect—where minor demand fluctuations amplify upstream—by emphasizing the necessity of transparent communication and rolling forecast sharing. Supported by related concepts such as the Pareto principle, lead time optimization, and On-Time-In-Full (OTIF) metrics, these integrated theoretical pillars provide a comprehensive diagnostic lens for identifying vulnerabilities and developing robust strategies to mitigate inventory

III. MARETIALS AND METHODS

A. Research Objectives

This study evaluates inventory management and supplier performance within a manufacturing plant to achieve four core objectives: (1) study and analyze inventory shortage trends across critical components and suppliers using systematic data tracking methods; (2) investigate the underlying causes of material stockouts by applying structured problem-solving frameworks and diagnostic tools; (3) develop and recommend data-driven strategies for improving inventory management, supplier performance, and system integration to reduce shortages and enhance operational efficiency; and (4) strengthen vendor responsiveness and master-data accuracy by establishing structured evaluation mechanisms.

B. Research Design and Data Collection

A This study employs a mixed-methods research design structured around the DMAIC (Define-Measure-Analyze-Improve-Control) framework. Conducted between April 14 and June 30, 2026, the research executed the diagnostic phases using primary data from a manufacturing plant, while proposing strategies for future implementation. Quantitative data was gathered through a 39-day daily stock monitoring process for 56 critical parts across 17 active vendors, generating a robust dataset of 2,184 coverage readings. This was supplemented by in-house quality rejection data and master-data reconciliation against a 44-vendor approved list.

C. Analytical Framework and Quality Evaluation

The analytical framework integrated these diverse qualitative and quantitative datasets to pinpoint fundamental operational bottlenecks. Root cause analysis was conducted using diagnostic tools such as Pareto charts and Fishbone diagrams, translating raw daily stockout counts, master-data mismatches, and stakeholder feedback into actionable insights. By systematically mapping these vulnerabilities, the study formulated targeted, data-driven solutions—including a proposed shortage escalation procedure, safety stock guidelines,

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and a weighted vendor responsiveness scorecard—designed to mitigate future supply chain disruptions and optimize inventory controls.

IV. DATA ANALYSIS AND DISCUSSION

To study and analyze inventory shortage trends across critical components and suppliers using systematic data tracking methods.

TABLE I.
TOP 10 CRITICAL PARTS BY STOCKOUT FREQUENCY

Rank	*Part / Description*	*Supplier*	*Stockout Instances*
1	DK101713 — M8 BKT Body Perforated	Supplier A	17
2	DK101692 — M6 BKT Guard Pillion	Supplier A	13
3	PA111250 — Weld Pin Nut M6x1.00-7.5HT	Supplier C	10
4	PD591497 — Pipe A K17E	Supplier B	9
5	PD591799 — Sub Assy Pipe A K17N FAB	Supplier B	7
6	DK101140 — Tail Pipe	Supplier D	7
7	PD591526 — Bracket Shield	Supplier E	6
8	PD591826 — Bracket Shield	Supplier G	3
9	CTA to Tube Assembly (DH103796)	Supplier F	3
10	SS441 CTL Tube (1.5x41.30x171mm)	Supplier H	2

Table 1 provides the analysis of daily coverage data across critical components reveals a severe concentration of inventory shortages directly threatening production continuity. As detailed in the table, the shortage phenomenon is not uniformly distributed but highly localized. Part DK101713 from Supplier A experienced an alarming 43.6% stockout rate, operating on a critically low average coverage of just 0.96 days. Its sister component, DK101692, mirrors this vulnerability with a 33.3% stockout rate. Together, these two parts accounted for a disproportionate share of the total recorded stockouts. Conversely, part PA111250 from Supplier C exhibits a different operational failure, showing a 25.6% stockout rate despite a high average coverage of over fifty days, indicating erratic bulk batching rather than lean replenishment. These specific trends highlight that mitigating overall plant stockouts requires targeted, part-specific interventions rather than generalized inventory policies across the entire component base.

TABLE II.
PARETO CLASSIFICATION OF SUPPLIERS (ABC)

	Analytical Category			
Diagnostic Dimension Supplier Pareto Analysis (ABC)	**Class A (Vital Few)** • Shree Automotive Industries • Cre-Met Pvt Ltd • ***Fastenex Pvt. Ltd.***	30 Stockouts (33.7%) 16 Stockouts (18.0%) ***12 Stockouts (13.5%)***	***65.2% of all stockout instances are caused by just 3 suppliers (17.6% of supplier base).***	***Supplier Pareto Analysis (ABC)***
	Class B (Significant) • Jai Shree Shyam Perforators • Pankaj • Cat-Con Pvt Ltd	7 Stockouts (7.9%) 7 Stockouts (7.9%) 6 Stockouts (6.7%)	Cumulative stockouts reach **80.9%** across top 5 suppliers.	
	Class C (Trivial Many) • Remaining 11 Suppliers	11 Stockouts Total (12.4%)	Account for residual minor stockout instances.	
K17E Quality Defect Rejections	Total Production : 8,955 units Defective Units: 4,508 units	In-House PPM: **503,406**	Severe defect rates silently destroy usable inventory buffers.	**K17E Quality Defect Rejections**

From table 2 diagnostic analysis confirms that material shortages stem from a vital few underperforming suppliers combined with severe internal quality rejections. Pareto classification demonstrates Tthat three vendors—Shree Automotive, Cre-Met, and Fastenex—account for 65.2% of all stockout instances, with the top five suppliers accounting for 80.9%. This sharp Pareto distribution confirms that shortages are highly concentrated and addressable through targeted

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interventions. Concurrently, quality analysis on the K17E line revealed an extreme in-house defect rate of 503,406 PPM, with welding-related flaws (Shabby Welding, Weld Run Shift, Welding Missing, Blow Holes) comprising 87.2% of rejections. High internal scrap rates silently erode usable inventory without being reflected in standard stock tracking sheets. Synthesizing these findings through Ishikawa analysis traces stockouts to five core failure drivers: manual tracking, absent safety stocks, unmanaged lead times, missing vendor audits, and unadjusted scrap rates.

TABLE III.
DSYSTEMIC CAPABILITY GAPS AND PROPOSED DATA-DRIVEN STRATEGIES

Operational Strategy Domain Safety Stock Buffer Strategy	**Current System Finding / Deficit**		
	DK101713 & DK101692 operate at 0.96- & 0.90-days coverage with zero policy buffer.	***No mathematically derived safety stock defined in system.***	***Establish dynamic safety-stock buffers calculated against demand variance and scrap.***
High-Volume Delivery Batching	Fastenex: 12 stockouts (4.4% rate) despite 50.24 days average coverage.	Bulk delivery batching causes long surpluses punctuated by abrupt stockouts.	Align supplier delivery schedules with lean, JIT-based replenishment lots.
Lead Time vs. Risk Strategy	10-day lead suppliers show mixed performance (Fastenex Class-A vs. Choraria 0 stockouts).	Lead time alone is an unreliable predictor of stockout risk.	Focus interventions on vendor-specific delivery discipline rather than lead time alone.
SAP / ERP System Integration	Coverage readings tracked manually; no automated alert when stock falls below 3 days.	Total reliance on manual tracking and informal vendor follow-up.	Integrate automated SAP reorder alerts and stockout warning triggers.
Operational Benchmarking	6 suppliers (35.3%) achieved 0 stockouts across the full 39-day period.	Plant lacks a formal mechanism to study and replicate best vendor practices.	Replicate zero-stockout vendor buffer disciplines across Class-A suppliers.
Operational Strategy Domain	Current System Finding / Deficit	Identified Capability Gap	Proposed Data-Driven Strategy

From table 3 the evaluation of plant inventory capabilities provides clear empirical justification for strategic inventory management and ERP system integration. Critical parts such as DK101713 operated with less than one day of stock coverage without any formalized safety-stock buffer, leaving production vulnerable to immediate line stops. Furthermore, high-volume suppliers like Fastenex exhibited irregular delivery batching—maintaining 50.24 days of average coverage yet suffering 12 stockout instances due to erratic shipment intervals. Because analysis showed that lead time alone does not determine shortage risk, strategies must target supplier delivery discipline rather than lead time alone. Crucially, six suppliers achieved zero stockouts across 39 days, proving that high availability is attainable. Implementing dynamic safety stocks, JIT delivery alignment, and automated SAP coverage alerts under three days will eliminate manual tracking vulnerabilities and ensure sustainable inventory stability.

TABLE IV.
SUPPLIER MASTER-DATA RECONCILIATION AND PERFORMANCE RATING ACCURACY

Evaluation Metric / Feature Quality Certification Status	**Master-Data Reconciliation Findings**		
	Only 5 of 17 Active Suppliers (29.4%) hold ISO 9001 or IATF 16949 certification.	***High proportion of uncertified suppliers correlates with material instability.***	***Enforce mandatory quality certification standards for active vendors.***
SQA Assessment Status	Only 2 of 17 Active Suppliers (11.8%) have completed SQA master assessments.	88.2% of active vendors lack formal SQA evaluation records.	Institutionalize mandatory SQA audits for all active suppliers.
Master-Data	3 active suppliers (Omech,	Material sourced from	Clean up supplier master

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Evaluation Metric / Feature	Master-Data Reconciliation Findings		
Quality Certification Status	***Only 5 of 17 Active Suppliers (29.4%) hold ISO 9001 or IATF 16949 certification.***	***High proportion of uncertified suppliers correlates with material instability.***	***Enforce mandatory quality certification standards for active vendors.***
Completeness	Omech /Ub, UB Stainless) absent from vendor master.	unlisted vendors outside formal approval channels.	records and eliminate off-master procurement.
Master Naming Consistency	"Choraria Industries" and "Chorasia Industries" represent 1 vendor under 2 spellings.	Duplicate entries distort inventory tracking and supplier metrics.	Standardize vendor naming protocols across ERP and tracking databases.
Rating System Disconnect	Shree Automotive rated at 85% efficiency despite a 38.5% stockout rate (worst performer).	Legacy efficiency ratings fail to distinguish worst performers from best.	Deploy an OTIF-driven Vendor Responsiveness Scorecard.
Best-Performer Benchmark	6 suppliers (Nash, US Auto, Yes Prosper, etc.) maintained 100% material availability.	Confirms vendor discipline is achievable within the local environment.	Use zero-stockout vendor protocols as a benchmark for vendor coaching.
Evaluation Metric / Feature	**Master-Data Reconciliation Findings**	**Operational Data Accuracy Assessment**	**Strategic Requirement for Governance**

Table 4 shows reconciling active supplier tracker records against the approved vendor master highlights severe data governance weaknesses and demonstrates the need for structured evaluation tools. Only 29.4% of active suppliers hold formal quality certifications, while 88.2% lack complete SQA audit records. More critically, three actively used suppliers (Omech, Omech /Ub, and UB Stainless) were absent from the approved master list entirely, indicating unvetted sourcing outside formal approval channels. Furthermore, the plant's existing efficiency rating system proved unreliable: Shree Automotive was rated at 85% efficiency despite causing 33.7% of all plant stockouts with a 38.5% stockout rate. This inability to flag top operational risks underscores the necessity of replacing subjective ratings with an objective, On-Time In-Full (OTIF) Vendor Responsiveness Scorecard, alongside comprehensive supplier master-data cleanup and structured vendor coaching.

V. FINDINGS, CONCLUSIONS AND SUGGESSIONS

A. Findings

The study analyzed 2,184 daily coverage readings across 56 parts and 17 active suppliers at the manufacturing plant, revealing a baseline stockout rate of 4.1% (89 instances) that affected 39.3% of tracked parts and 64.7% of suppliers. Material shortages were heavily concentrated rather than diffuse: a Pareto analysis demonstrated that just three suppliers accounted for 65.2% of all stockout instances, with the top five driving 80.9%. Furthermore, part-level analysis showed that two specific components from the primary underperforming supplier were responsible for 30 stockout instances, operating with an average inventory coverage of under one day. An 84% reduction in daily stockout incidence between the first and second halves of the study window confirmed that structured daily tracking and vendor follow-up directly improve material availability. Root-cause synthesis via Ishikawa analysis traced these shortages to five structural gaps: manual tracking lacking automated alerts, absence of safety-stock buffers, unmanaged lead times, missing vendor audits, and high internal scrap rates. Specifically, assembly line quality rejections (503,406 PPM)—predominantly welding defects (87.2%)—silently eroded physical inventory buffers. Finally, supplier master data reconciliation highlighted severe data governance deficits: only 29.4% of suppliers held quality certifications, 88.2% lacked assessment records, three active vendors operated off-master entirely, and legacy vendor efficiency ratings failed to identify top operational risks, underscoring the urgent need for mathematically derived safety stocks, an OTIF-driven Vendor Responsiveness Scorecard, master-data cleanup, and ERP-integrated alert thresholds.

B. Conclusions

This study demonstrates that material shortages within the manufacturing plant are primarily driven by localized supplier performance failures, unaddressed internal quality scrap, and structural gaps in inventory control rather than random market disruptions. While the baseline stockout rate of 4.1% reflects broad operational vulnerability across nearly two-thirds of active suppliers, the extreme concentration of stockouts among a vital few vendors proves that focused, data-driven interventions can deliver immediate operational stability. The significant 84% drop in daily stockout frequency over the study window confirms that disciplined tracking and active supplier follow-up are effective short-term mitigations. However, achieving long-term inventory resilience requires replacing manual monitoring with automated ERP coverage alerts and establishing mathematically derived safety-stock buffers that explicitly account for demand variance and high internal rejection rates. Furthermore, severe governance deficits—including uncertified suppliers, incomplete audit records, off-master procurement, and unreliable efficiency ratings—highlight the urgent necessity of standardizing master data and implementing an objective, OTIF-driven Vendor Responsiveness Scorecard. By transitioning from reactive daily expediting to structured safety stock management, rigorous

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supplier evaluation, and integrated enterprise automation, the plant can effectively eliminate stockout risks, protect production continuity, and significantly enhance overall supply chain efficiency.

C. Suggestions

To achieve lasting inventory stability, the plant should implement four practical, multi-stakeholder strategies:

1. **Operations & Purchasing (Dynamic Safety Stock):** Establish automated, mathematically derived safety-stock buffers in the ERP system for high-risk components, factoring in supplier lead-time variance and internal scrap rates to prevent line stops.
2. **Quality & Vendor Management (Tiered Scorecards & Audits):** Deploy an objective, On-Time In-Full (OTIF) Vendor Responsiveness Scorecard linked to monthly supplier reviews. Require mandatory quality audits (SQA) and certification roadmaps for uncertified vendors to align quality expectations.
3. **Suppliers (Collaborative Scheduling & Benchmarking):** Transition high-volume suppliers to fixed, smaller delivery batches (JIT replenishment) rather than irregular bulk shipments. Partner with low-performing vendors to replicate the buffer practices of zero-stockout suppliers.
4. **IT & Store Administration (Master-Data Governance):** Clean up the supplier master to eliminate off-master sourcing, merge duplicate vendor records, and enable automated ERP alerts when stock falls below three days of coverage.

D. Implications of the study

The study's findings carry direct operational implications for key supply chain stakeholders:

- **Plant Operations & Production Planning:** Transitioning from reactive daily expediting to automated, safety-stock-backed inventory management prevents line stoppages, balances shift schedules, and eliminates costly emergency material rushes.
- **Procurement & Vendor Management:** Procurement teams gain objective, data-driven leverage. Replacing subjective efficiency ratings with OTIF-driven scorecards enables targeted vendor development, structured SQA audits, and disciplined contract enforcement for underperforming suppliers.
- **External Suppliers:** Suppliers gain clearer demand visibility and predictable delivery schedules through lean, JIT replenishment alignment, reducing bulk-batching pressures while raising accountability for delivery discipline and quality standards.
- **IT & Material Administration:** Master-data cleanup eliminates off-master procurement, normalizes duplicate vendor records, and enables automated ERP stock alert thresholds, creating a reliable, transparent digital foundation for plant inventory control.

E. Future Scope of the study

The future scope of this study offers several impactful avenues for expanding research and operational capabilities:

- **Predictive & Machine Learning Modelling:** Future research can integrate machine learning algorithms to forecast material shortages, dynamic lead times, and demand spikes by analyzing real-time ERP data and historical supplier reliability trends.
- **Extended Industry & Longitudinal Scope:** Expanding the study across multiple manufacturing facilities, varied product lines, and longer timeframes would validate the generalizability of the findings and account for broader macroeconomic or seasonal supply chain disruptions.
- **Supplier Integration & IoT Automation:** Exploring the implementation of RFID, automated IoT-enabled bin monitoring, and direct supplier portal integration can enable real-time stock visibility and automated reordering without manual intervention.
- **Financial & Cost Impact Analysis:** Further studies can quantify the exact monetary trade-offs between carrying safety stock inventory versus the financial costs of line stoppages, emergency expediting, and scrap rejections.

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