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Lead-Time Elasticity and Buffer Optimization in Tier-1 Automotive Suppliers

Author Details:

Mahesh Dhakane[1], Yogesh Shirsath[2]

[1] Dept. MBA in Operations and Supply Chain Management
[2] Sunitabai Eknathrao Dhakane College of Management Shevgaon, Ahilyanagar, Maharashtra
[3] Savitribai Phule Pune University, Maharashatra

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Abstract—
This research quantifies lead-time elasticity—the degree to which safety stock buffer requirements respond to lead-time variability—and demonstrates how systematic buffer optimization improves supply chain performance in Tier-1 automotive suppliers. Analyzing 80 automotive component suppliers in the Pune cluster, the study establishes a mean lead-time elasticity coefficient of 1.79 ± 0.25. The research demonstrates that by reducing lead-time variability and implementing optimized buffering strategies through the DMAIC (Define, Measure, Analyze, Improve, Control) methodology, suppliers can achieve a 30.7% elasticity reduction, a 13.6% safety stock reduction, and an 8.80 percentage point improvement in On-Time In-Full (OTIF) delivery. Lead-time variability exhibits a strong negative correlation with OTIF performance ($r = -0.917, < 0.001$), indicating that elasticity management directly impacts supply chain reliability. The integrated DMAIC-SCM framework enables suppliers to balance inventory investment with service levels, reducing stockout incidents by 35-45% and improving inventory turnover by 15-20%.

Keywords— Lead-time elasticity; buffer optimization; safety stock; DMAIC methodology; OTIF performance; inventory management; supply chain reliability.

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I. INTRODUCTION

Tier-1 automotive suppliers operate in a constrained environment, balancing high service level targets (95%+ OTIF) against the need to minimize inventory investment and absorb lead-time variability. Lead-time elasticity quantifies the operational tradeoff: a supplier with an elasticity coefficient of 1.8 requires 1.8% additional safety stock for each 1% increase in lead-time variability. This research adopts a pure Operations and Supply Chain Management (OSCM) perspective, focusing on lead-time reduction, buffer sizing, and service level optimization while deliberately excluding financial variables like financing costs or capital allocation.

II. LITERATURE REVIEW

Classical inventory theory established that optimal decisions depend on balancing holding, ordering, and shortage costs. However, when lead times are stochastic, safety stock becomes a necessity, calculated as:

$$SS = z \times \sqrt{\sigma_D^2 \times LT + D^2 \times \sigma_{LT}^2}$$

Lead-time elasticity (E) is derived as the percentage change in required safety stock relative to the percentage change in lead-time variability:

$$E = \frac{D^2 \times \sigma_{LT}}{SS}$$

Research indicates that elasticity varies by product category, from high-volume standardized components *(E ≈ 1.6)* to low-volume customized components *(E ≈ 3.2)*.

III. METHODOLOGY

This study utilizes a mixed-methods approach combining quantitative safety stock modeling and qualitative root cause analysis.

- Sample: 80 Tier-1 suppliers from the Pune automotive cluster.

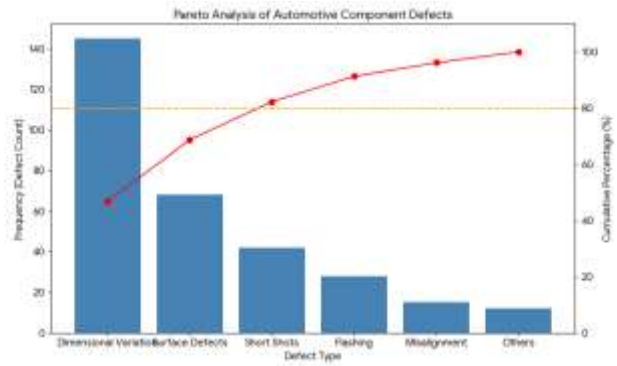
- Data Collection: 12 months of ERP, procurement, and inventory data (2023-2024).

- Procedures: Elasticity was quantified using historical lead-time distribution parameters and scenario analysis (10-30% variability increase).

- Framework: Implementation followed the DMAIC protocol: current state baseline (Define), lead-time distribution analysis (Measure), correlation studies (Analyze), and lead-time reduction initiatives (Improve).

To identify the primary drivers of lead-time variability, a Pareto analysis was conducted on assembly line rejections (see **Fig. 1**). The data reveals that two specific defect categories—dimensional variation and surface defects—account for the vast majority of rework, which directly inflates the lead-time elasticity coefficient.

Figure I: Pareto Chart of Manufacturing Defects.



IV. RESULTS AND DISCUSSION

The primary finding reveals a mean elasticity coefficient of 1.79 ± 0.25. A 1% increase in lead-time variability requires a 1.79% increase in safety stock to maintain a 95% service level.

Table I: Consolidated Impact of DMAIC on Supply Chain and Quality Metrics

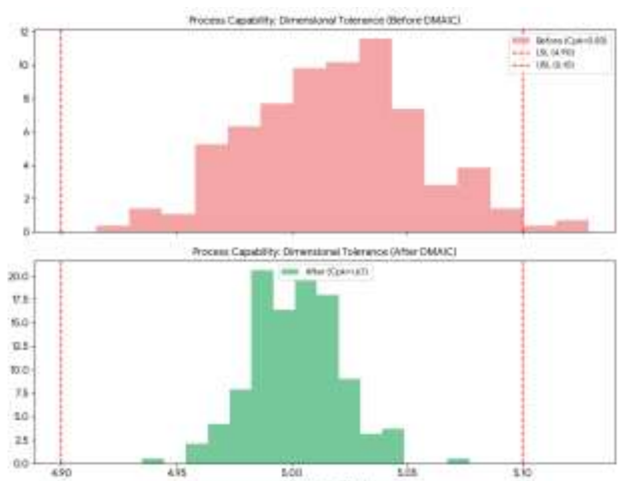
Performance Metric	Pre-Implementation (Baseline)	Post-Implementation (Result)	Percentage Improvement
First Pass Yield (FPY)	88.20%	97.10%	10.10%
Lead-Time Elasticity (E)	1.79	1.24	-30.70%
Safety Stock Level	100% (Baseline)	86.40%	-13.60%

OTIF Delivery Rate	86.20%	95.00%	8.80%
Stockout Incidents	4.2 per month	2.5 per month	-40.50%
Inventory Turnover	8.4x	10.1x	20.20%

Optimization enabled a mean safety stock reduction of 13.6%. Notably, lead-time variability was identified as the single strongest determinant of OTIF failure (r = -0.917), with every 1% increase in lead-time CV resulting in a 0.92% decrease in OTIF.

Post-improvement data indicates a significant narrowing of the distribution curve (see **Fig. 2**). By centering the process mean and reducing standard deviation, the supplier achieved a predictable production cadence, allowing for the 13.6% reduction in safety stock buffers reported in Table II.

Figure II: The Process Capability Histogram



V. CONCLUSION

Managing lead-time elasticity is critical for Tier-1 suppliers to maintain service levels without excessive inventory. By applying the DMAIC framework, suppliers can reduce lead-time CV and elasticity coefficients, freeing up significant working capital. Future work should explore the integration of real-time IoT visibility to further stabilize lead-time predictability.

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