

Inventory Optimization in Manufacturing Projects Using ABC Analysis, EOQ, Reorder Point, and Just-In-Time Principles: An Automotive Industry Case Study

Gaurav Bhandary M, Chandan R, Anand R Pissay, Adarsh R Gowda

Department of Mechanical Engineering, R V College of Engineering, Bengaluru, India

Under the guidance of Dr. Ramaa A and Dr. Mahantesh M Math

Abstract— Inventory management plays a fundamental role in balancing material availability against inventory-related costs in manufacturing operations. In the automotive industry, managing a large number of components with varying demand and procurement costs is particularly challenging, since inefficient inventory control can lead to production delays, excessive carrying costs, and poor utilization of working capital. This study presents an integrated inventory optimization framework that combines Pareto Analysis, ABC Classification, Economic Order Quantity (EOQ), Reorder Point (ROP), and Just-In-Time (JIT) principles to improve inventory control in an automotive manufacturing case study. Using inventory data comprising annual demand, unit cost, ordering cost, holding cost, lead time, and safety stock, Pareto Analysis was first applied to identify high-impact items based on annual consumption value, annual demand, and unit cost. ABC Classification was then used to establish differentiated control priorities, followed by EOQ and ROP models to determine the optimal order quantity and replenishment level. The proposed framework yielded an optimal order quantity of 1,366 units and a reorder point of 2,100 units, reducing total annual inventory cost from ₹264,000 to ₹245,440 — a saving of 7.03% — while also improving inventory visibility and replenishment planning. The results confirm that combining inventory classification with quantitative replenishment models offers a practical and scalable strategy for improving inventory performance in manufacturing organizations.

Keywords— Inventory Management; Inventory Optimization; Pareto Analysis; ABC Classification; Economic Order Quantity (EOQ); Reorder Point (ROP); Just-In-Time (JIT); Automotive Manufacturing; Supply Chain Management; Lean Manufacturing.

I. INTRODUCTION

Inventory management has become one of the most important operational functions in modern manufacturing industries because it directly influences production continuity, cost efficiency, customer satisfaction, and overall organizational performance. Manufacturing companies must maintain sufficient inventory to support uninterrupted production while minimizing the financial burden of purchasing, storing, and handling materials. An imbalance in inventory levels can result in excessive carrying costs, increased working-capital requirements, production delays, or stock shortages, all of which negatively affect organizational competitiveness [1], [2].

The automotive manufacturing industry presents unique inventory management challenges due to the large number of components required to assemble a finished vehicle. A single automobile consists of thousands of individual parts sourced from geographically dispersed suppliers, and critical components such as semiconductors, battery modules, electronic control units (ECUs), motors, and controllers must be available at the right quantity and time to ensure uninterrupted production [3], [4].

Growing market competition, shorter product life cycles, demand uncertainty, and frequent global supply-chain disruptions have increased the importance of scientific inventory management. Traditional methods that rely on managerial experience or fixed replenishment schedules often fail to respond to changing demand patterns, motivating the use of analytical techniques such as ABC Analysis, Pareto Analysis, EOQ, ROP, and JIT [5], [6].

Toyota Motor Corporation's Toyota Production System (TPS) remains the benchmark example of how synchronized material flow and continuous improvement can minimize inventory while sustaining production [6], [8].

Although extensive research exists on these individual techniques, most studies examine them in isolation and overlook the interaction between inventory prioritization, replenishment planning, and production scheduling. This paper addresses that gap by proposing and validating, through an automotive manufacturing case study, an integrated inventory optimization framework combining Pareto Analysis, ABC Classification, EOQ, ROP, and JIT principles into a single decision-support methodology.

II. LITERATURE REVIEW

The Economic Order Quantity (EOQ) model remains one of the most practical mathematical tools for inventory planning, minimizing the trade-off between ordering and holding costs. Despite simplifying assumptions of constant demand and lead time, EOQ continues to underpin many modern inventory optimization models [1], [3], [4]. The Reorder Point (ROP) model complements EOQ by determining replenishment timing based on demand during lead time and safety stock; integrating EOQ with ROP has been shown to reduce stockout risk and improve production continuity [4], [5].

ABC Analysis, grounded in the Pareto principle, classifies inventory items by annual consumption value: Category A items typically represent 70–80% of total value and require strict control, while Category B and C items can be managed with progressively simpler policies [3], [6], [7]. Pareto Analysis provides the graphical basis for this prioritization by ranking items according to their contribution to inventory value, demand, or cost [6], [8].

Just-In-Time (JIT) principles, popularized through the Toyota Production System, emphasize synchronized material delivery and waste elimination, improving inventory turnover and supply-chain responsiveness when supported by reliable suppliers [5], [6], [9]. More recently, Industry 4.0 technologies — artificial intelligence, IoT, and predictive analytics — have created opportunities to enhance forecasting accuracy and enable real-time inventory monitoring [2], [10], [11].

Despite this progress, existing literature predominantly treats EOQ, ABC Analysis, ROP, and JIT as independent techniques and rarely evaluates them together using a single dataset and multiple performance indicators such as annual consumption value, annual demand, unit cost, and total cost reduction [7], [9], [12]. This motivates the integrated methodology developed in the present study.

III. RESEARCH GAP AND OBJECTIVES

Three principal gaps emerge from the literature. First, traditional inventory models generally assume constant demand, fixed lead times, and stable supply conditions, which may not reflect the variability of real manufacturing environments [5], [6]. Second, ABC and Pareto classifications are often applied only for categorization and visualization, without being linked to optimal ordering or reorder policies [4], [6], [7], [8]. Third, few studies combine lean (JIT) principles with quantitative replenishment models such as EOQ and ROP within a single evaluative framework [5], [9].

To address these gaps, this study sets the following objectives: (i) analyze inventory characteristics using annual demand, unit cost, ordering cost, holding cost, lead time, and safety stock data; (ii) perform Pareto Analysis on annual consumption value, annual demand, and unit cost to identify high-impact items; (iii) classify inventory items using ABC Analysis; (iv) determine the optimal Economic Order Quantity; (v) calculate the appropriate

Reorder Point; (vi) integrate JIT principles with the optimized replenishment policy; and (vii) compare the existing and proposed inventory systems in terms of ordering cost, holding cost, and total inventory cost.

IV. METHODOLOGY

This study adopts a quantitative case-study methodology comprising six sequential stages: (1) collection of inventory data, (2) calculation of annual consumption value, (3) Pareto and ABC classification, (4) EOQ calculation, (5) Reorder Point determination, and (6) performance evaluation through cost comparison [3], [4].

A. Data and Parameters

The analysis uses an automotive manufacturing inventory dataset representing components such as semiconductors, battery modules, ECUs, motors, controllers, and fasteners. Table I summarizes the base inventory parameters used throughout the study.

Parameter	Symbol	Value
Annual Demand	D	48,000 units/year
Ordering Cost	S	₹3,500 per order
Holding Cost	H	₹180 per unit/year
Lead Time	L	10 days
Safety Stock	SS	500 units
Working Days	W	300 days/year

Table I. Inventory Parameters

B. Pareto and ABC Analysis

Pareto Analysis ranks inventory items in descending order of annual consumption value, annual demand, and unit cost, and computes cumulative percentage distributions to identify the small subset of items responsible for the majority of inventory investment [7], [8]. Building on this ranking, ABC Analysis classifies items into three categories: Category A (high value, approximately 70–80% of inventory value), Category B (medium value, 15–25%), and Category C (low value, 5–10%) [4], [6].

C. Economic Order Quantity (EOQ)

The EOQ model determines the replenishment quantity that minimizes the sum of annual ordering and holding costs:

$$EOQ = \sqrt{(2DS / H)}$$

where D is annual demand, S is the ordering cost per order, and H is the annual holding cost per unit [3], [5].

D. Reorder Point (ROP)

The Reorder Point defines the inventory level at which a new replenishment order should be placed:

$$ROP = (d \times L) + SS, \text{ where } d = D / W$$

Here d is the average daily demand, L is the supplier lead time in days, and SS is the safety stock [5], [9].

E. Integration of Just-In-Time Principles

The EOQ and ROP outputs were aligned with JIT principles by synchronizing supplier deliveries with production schedules, reducing unnecessary inventory accumulation while preserving material availability, in line with lean manufacturing objectives [6], [10].

V. CASE STUDY AND RESULTS

A. ABC Classification

Table II presents the ABC classification of the principal inventory items in the case study, based on their contribution to total inventory value.

Inventory Item	Category	Contribution to Inventory Value (%)
Semiconductors	A	35
Battery Modules	A	25
Electronic Control Units (ECUs)	A	15
Motors	B	10
Controllers	B	8
Fasteners	C	4
Nuts and Bolts	C	3

Table II. ABC Classification of Inventory Items

Category A items collectively account for approximately 75% of total inventory value despite representing a small share of total items, and therefore require continuous monitoring, accurate forecasting, and close supplier coordination. Category B items ($\approx 18\%$ of value) require periodic monitoring, while Category C items ($\approx 7\%$ of value) can be managed with simplified policies.

B. Pareto Analysis

Pareto Analysis was performed using three indicators: annual consumption value, annual demand, and unit cost. Table III shows the distribution of annual consumption value across the top inventory items.

Item	Annual Consumption Value (₹)	Percentage (%)	Cumulative (%)
A1	50,000	30.0	30.0
A2	36,000	21.6	51.6
A3	24,000	14.4	66.0
A4	17,500	10.5	76.5

Item	Annual Consumption Value (₹)	Percentage (%)	Cumulative (%)
A5	12,000	7.2	83.7
A6	9,000	5.4	89.1
A7	6,000	3.6	92.7
A8	4,200	2.5	95.3
Others	7,890	4.7	100.0

Table III. Annual Consumption Value Distribution

Item A1 alone contributes 30.0% of total annual consumption value; together with A2 and A3 it accounts for 66.0% of inventory investment, rising to 76.5% with the inclusion of A4. This confirms the applicability of the Pareto principle and indicates that optimization efforts should concentrate on the first four items.

WORKSHEET 1

Pareto Chart of Item by Annual Consumption value

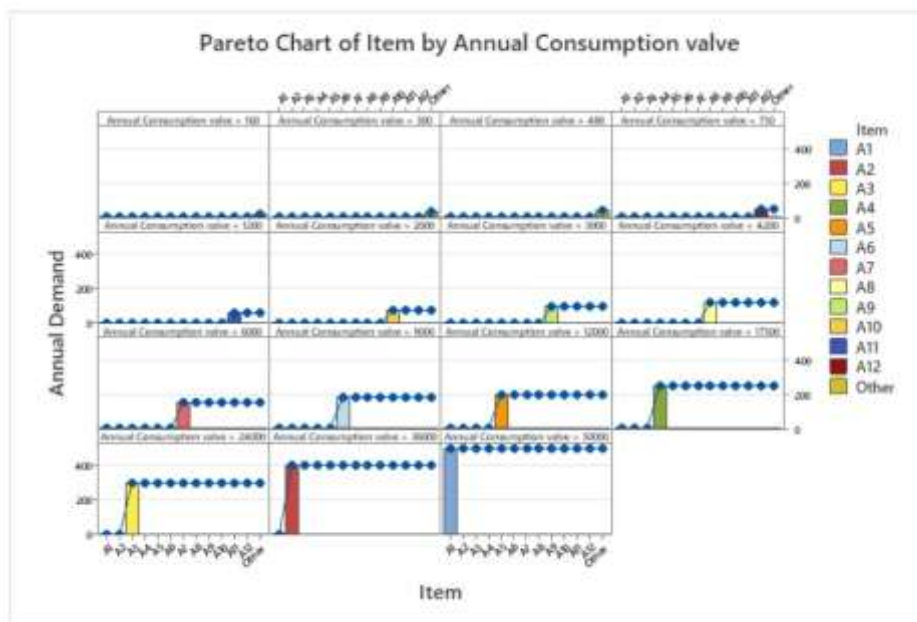


Fig. 1. Pareto Chart Based on Annual Consumption Value

The Pareto chart based on annual demand (Fig. 2) highlights items with the highest consumption frequency, which — unlike consumption value — reflects operational rather than purely financial significance. Items with relatively low unit cost but high demand also warrant close monitoring to avoid production interruptions.

WORKSHEET 1

Pareto Chart of Item by Annual Demand

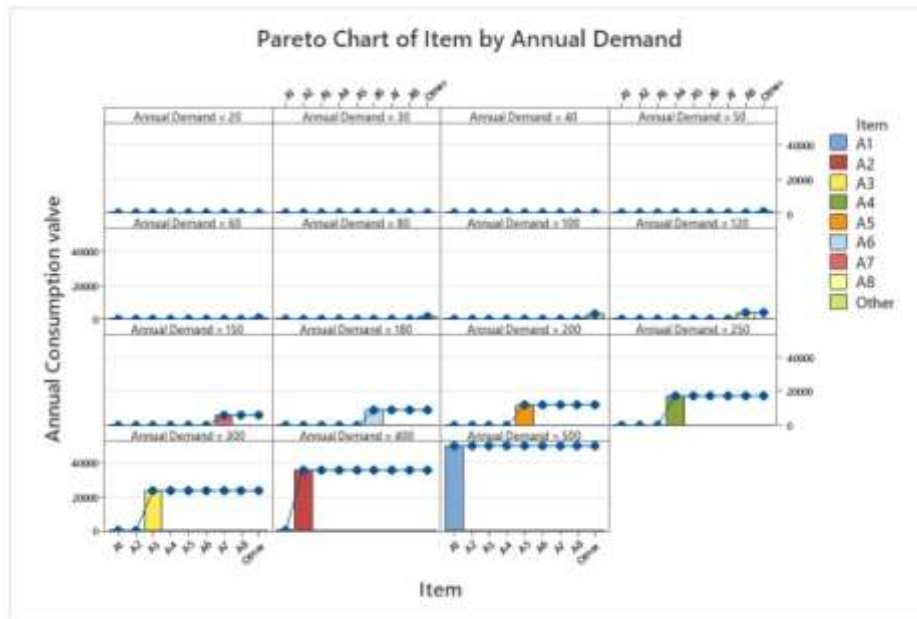


Fig. 2. Pareto Chart Based on Annual Demand

The Pareto chart based on unit cost (Fig. 3) identifies items representing the greatest investment in working capital per unit, which require careful purchasing decisions and supplier evaluation. Considered jointly, the three Pareto perspectives provide a comprehensive basis for differentiated inventory control.

WORKSHEET 1

Pareto Chart of Item by Unit Cost

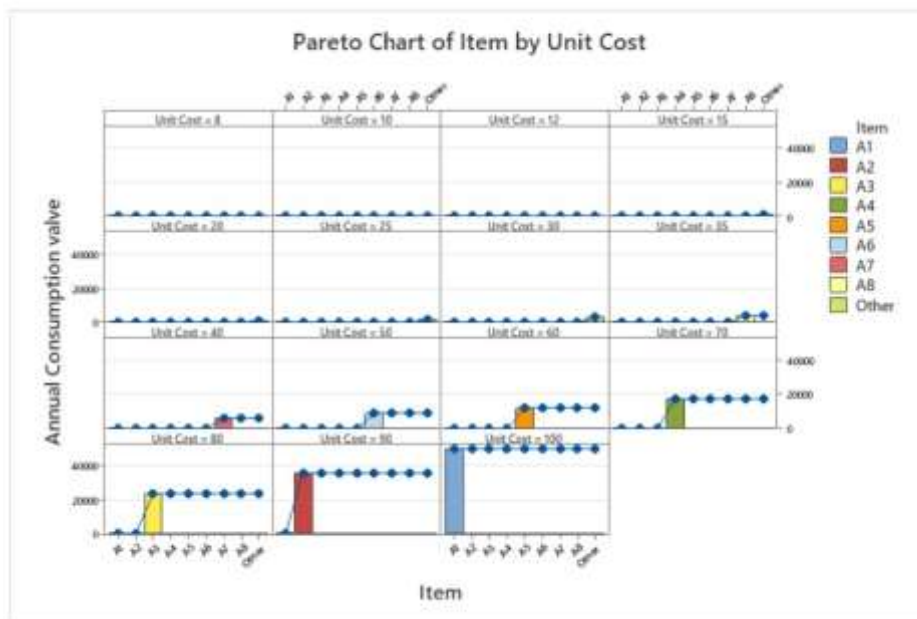


Fig. 3. Pareto Chart Based on Unit Cost

C. Economic Order Quantity (EOQ) Results

Substituting $D = 48,000$ units, $S = ₹3,500$ per order, and $H = ₹180$ per unit per year into the EOQ formula yields an optimal order quantity of 1,366 units per replenishment cycle. Dividing annual demand by this quantity ($48,000 / 1,366$) gives approximately 35 orders per year. A larger order quantity would reduce ordering frequency but increase holding cost, while a smaller quantity would reduce holding cost but increase ordering cost; the EOQ value represents the point at which these two cost components are balanced.

D. Reorder Point (ROP) Results

Average daily demand is $d = D / W = 48,000 / 300 = 160$ units/day. Substituting into the ROP equation, $ROP = (160 \times 10) + 500 = 2,100$ units. A replenishment order should therefore be triggered once inventory falls to 2,100 units, with the 500-unit safety stock providing a buffer against demand or supplier variability.

E. Cost Comparison

Table IV compares the existing fixed-order-quantity policy (2,000 units per order) with the proposed EOQ/ROP-based policy.

Performance Indicator	Existing System	Proposed System	Improvement
Order Quantity (units)	2,000	1,366	Optimized
Average Inventory (units)	1,000	683	↓ 31.7%
Holding Cost (₹)	180,000	122,940	↓ ₹57,060
Ordering Cost (₹)	84,000	122,500	↑ ₹38,500
Total Inventory Cost (₹)	264,000	245,440	↓ ₹18,560 (7.03%)

Table IV. Comparison of Existing and Proposed Inventory Systems

The proposed policy increases annual ordering cost because more frequent orders are placed, but the accompanying reduction in average inventory more than compensates, yielding a net 7.03% reduction in total annual inventory cost.

VI. DISCUSSION

The results confirm that integrating Pareto Analysis, ABC Classification, EOQ, ROP, and JIT provides a comprehensive approach to inventory optimization in automotive manufacturing. Pareto Analysis and ABC Classification identified the items requiring the greatest managerial attention, enabling resources to be concentrated on materials with the largest financial impact and supporting more effective procurement planning.

The EOQ analysis established an optimal replenishment quantity of 1,366 units, reducing average inventory from 1,000 to 683 units and lowering annual holding cost substantially. Although ordering cost increased due to more frequent purchases, the net effect was a reduction in total inventory cost. The ROP analysis further strengthened the policy by identifying 2,100 units as the appropriate reorder level, and the accompanying 500-unit safety stock helps prevent production interruptions without encouraging unnecessary inventory accumulation.

Combining these quantitative models with JIT practices allows procurement activities to be synchronized with production schedules, improving inventory turnover and working-capital utilization. The methodology therefore delivers both operational and financial benefits and is well suited to manufacturing organizations seeking to strengthen supply-chain performance.

VII. CONCLUSION

This study developed and validated an integrated inventory optimization framework combining Pareto Analysis, ABC Classification, Economic Order Quantity, Reorder Point, and Just-In-Time principles for an automotive manufacturing case study. Pareto Analysis confirmed that a small number of inventory items account for the majority of inventory investment, while ABC Classification enabled differentiated control strategies for high-, medium-, and low-priority items. The EOQ model determined an optimal order quantity of 1,366 units, and the ROP model established a replenishment level of 2,100 units, together forming an effective replenishment policy.

The comparative evaluation showed that the proposed policy reduces average inventory from 1,000 to 683 units and total annual inventory cost from ₹264,000 to ₹245,440 — a 7.03% saving — despite a moderate increase in ordering cost. These findings demonstrate that integrating inventory classification with quantitative replenishment optimization yields greater benefits than applying these techniques in isolation, and that the proposed framework is readily adaptable to other manufacturing sectors where inventory investment represents a significant share of operational expenditure.

VIII. FUTURE SCOPE

- Incorporating artificial intelligence and machine learning for adaptive, higher-accuracy demand forecasting.
- Integrating IoT-based sensors and RFID for real-time inventory monitoring and visibility.
- Applying digital twin technology to simulate supplier disruptions and production scheduling scenarios.
- Extending the framework to multi-echelon inventory optimization across suppliers, plants, and distribution centers.
- Validating the methodology in other industrial sectors such as aerospace, electronics, and pharmaceuticals.
- Incorporating sustainability indicators — energy use, warehouse utilization, and carbon emissions — alongside cost measures.

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