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Journal of Procurement and Supply Chain Management
ISSN 2958 - 4078 (Online)
Vol.4, Issue 1, pp 48 – 59, 2025

Inventory Optimization in Global Automotive Manufacturing Supply Chains

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Article's History

Submitted:5th May 2025
Revised:1st July 2025
Published:4th July 2025

Abstract

Aim: With rapid growth in the automotive industry, especially in the manufacturing of electric vehicles (EVs), efficient inventory management has become an eminent tool to minimize production cost, increase supply chain resilience, achieve higher fill rates, and inventory turnovers. This study aims to examine and evaluate effective inventory optimization strategies in global automotive manufacturing supply chains, with a particular focus on electric vehicle production, where demand fluctuations, supply chain disruptions, and stiff competition pose unique challenges.

Methods: The study employs an empirical analysis of inventory models including Reorder Point (ROP), Economic Order Quantity (EOQ), and service-level-based optimization, using real-world data and simulation to assess performance under varying supply chain conditions.

Results: The findings indicate that incorporating storage space constraints significantly impacts inventory turnover and service levels, particularly in facilities supporting electric vehicle production. EOQ and ROP models demonstrated optimal performance under stable demand, while service-factor models were more resilient under high volatility.

Keywords: *Inventory optimization, just-in-time (JIT), Just-in-case (JIC), reorder point (ROP), safety stock, economic order quantity (EOQ).*

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Journal of Procurement and Supply Chain Management
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1.0 INTRODUCTION

Inventory management is an integral part of supply chain management which plays a crucial role in driving operational efficiencies, product innovations and meeting evolving customer expectations. Automakers are managing complex global supply chains with thousands of parts being supplied by multiple suppliers and distribution centers.

Key inventory management themes in the automobile sector include demand forecasting, inventory turns, safety stock management, inventory storage space optimizations, just-in-time (JIT), and lot sizing procedure. Demand forecasting is predicting vehicle demand shifts, regional trends and vehicle model/variant mix requirements within a certain period (Zhang *et al.,* 2024). Inventory turn is measuring the efficiencies in the inventory consumptions and replacements (Munichiello, n.d.). Safety stock management is planning buffer stock to manage demand and supply uncertainties without overstocking. Inventory storage space optimizations is managing warehouse footprint by minimizing storage and capital lock-up. Just-in-time (JIT) is minimizing on-hand inventory at operations while ensuring consistent supply of components (Banton, n.d.). Lot sizing procedure is determining the right lot sizing procedure with suitable ordering frequency, inventory levels, and operational efficiency to minimize the total expected cost (Schenker, 2020).

Having a single piece flow or JIT is challenging when there is a supply chain dependency on external suppliers who have multiple customers and a wide variety of parts to be manufactured. To avoid supply chain disruptions, some amount of inventory must be stored as a buffer at the source of consumption. Storage space is limited in any storage facility or warehouse. The space constraint situation forces the companies to plan for the right quantity and variety of parts to fulfill the overall operational need. Although historical transactional data can support planning efforts, it is often insufficient to account for dynamic demand patterns and supply uncertainties. Inventory optimization plays an important role in maximizing the probability of achieving the business goals by adjusting the metrics e.g. fill rate, inventory turnover, in-stock rate, etc.

EV industry is facing unique supply disruptions amid US-China tariff war (Darley, 2025), prompting a shift from Just-in-Time (JIT) to Just-in-Case (JIC) inventory strategies (Banton & Kvilhaug, n.d.) especially for critical components such as batteries and semiconductors. For practical relevance, this study examines the real-world applications of inventory optimization in a growing automotive industry. By exploring key concepts such as demand forecasting, lot-sizing strategies, outsourcing inventory management, and logistics cost optimization, we will highlight how manufacturers and suppliers can enhance efficiency, reduce waste, and improve overall supply chain resilience.

2.0 FACTORS INFLUENCING THE INVENTORY MANAGEMENT

Upstream and downstream demand fluctuations create challenges for inventory management, often leading to the bullwhip effect. While stockouts and excess inventory cannot be eliminated, their risks can be minimized by understanding the key influencing factors. Some of the key factors influencing inventory management are described hereafter.

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2.1 Demand Fluctuations

If demand for the new product grows at a steady rate, then it is relatively easy to predict the level of inventory to be stocked. Demand fluctuations could arise due to the customer response to the new vehicles. Unfortunately, in most cases, the demand grows erratically, which poses a challenge for the demand planners to predict the right inventory stocking parameters.

To avoid uncertainty and risks, it is recommended that a higher buffer stock be stored (Pohl, 2025). Higher buffer stock takes a toll on the storage space. When demand reduces drastically, it has cascading effects on the inventory of end products and spare parts. It leads to a higher level of bad inventory and causes trouble to the whole company as they need to make a trade-off between investing in infrastructure to store slow-moving inventory or they need to make space for the new and frequently used parts. In some cases, they need to move the parts and products within the network where there is a demand at additional logistics expenses. There are a few parts which are not preferred to be relocated due to fragile in nature e.g. windshields, glass; once they are out of the original packaging, they can easily be damaged in material handling transportation.

The following are a few commonly used terms and equations used for inventory optimizations when it is related to demand forecasting. One of the most commonly used equations are pipeline forecast, reorder point (ROP), and safety stock. Pipeline forecast: Pipeline Forecast is the forecasted demand during the lead time (Servigistics, n.d.). A reorder point, or ROP indicates an inventory item's minimum stock level at which new stock should be ordered to avoid a stockout (Turovski, 2023). Safety stock is an additional quantity of a product kept in the warehouse to avoid an out-of-stock situation. It protects against variations in demand (Kesavan, 2024). Reorder point (ROP) equals safety stock plus pipeline forecast. Stock Max equals ROP plus Economic order quantity (EOQ).

ROP, Max Stock, EOQ and lead time for shipment are the main inputs for MRP (Material Replenishment Planning) (Latham, 2023). These parameters are loaded in the MRP application to enable auto-replenishment within the internal network (Kenton, 2024). To better understand pipeline forecasts, let us consider an example. The example is that if the demand forecast for a component is 200 pieces per week and the replenishment lead time is 2 weeks then the pipeline forecast would be 400 pieces. (200 pieces * 2 = 400 pieces). ROP acts as a threshold to send a signal for replenishment. If inventory falls below the ROP it triggers a replenishment PO (purchase order). A higher ROP reduces the probability of stockouts but may strain storage capacity, requiring further optimization. There are further layers of optimization done on top of system-generated forecast parameters.

2.2 Storage Spaces

Storage space always remains at the center of planning for the inventory to be stocked. If space is constrained, then it’s always advisable to utilize a major chunk of the storage capacity with frequently ordered and critical items. Inventory can be classified based on the ordering frequency, also known as Fixed Order Interval (FOI) (Modula, 2025). Items ordered greater than biweekly frequencies can also be stored based on the size and cost of the item. The relationship between Order Frequency (N), Annual Demand (D) and Order Quantity (Q), can be explained with the following equation.

Order Frequency (N) = D / Q

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Time Between Orders (T) = Number of working days per year / N

For frequently ordered items, there is room for optimization. Every shipment has a logistics cost associated with it. By increasing the Order quantity (Q), we can have fewer shipments for a steady demand item which can lead to cost savings in terms of overall lower shipment cost and a lower unit price for the item with a larger order quantity (Q).

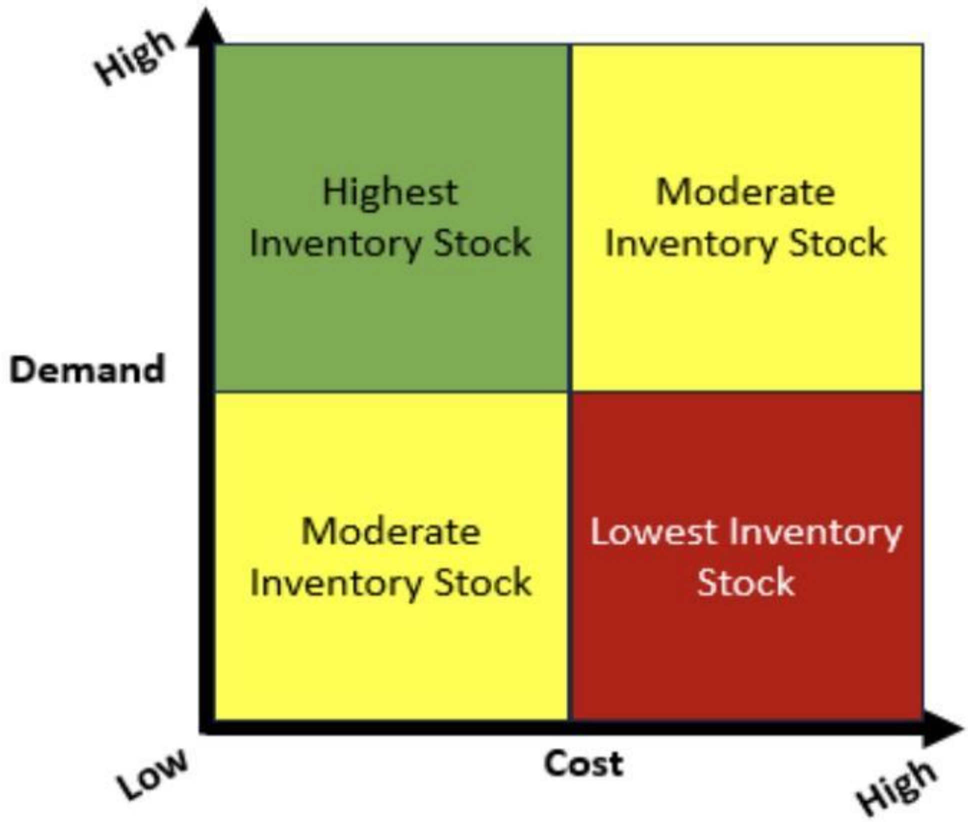

Figure 1: The Recommended Inventory Stock Based on Demand and Cost

Source: Author

2.3 Cost of the Product

Cost of the item influences the quantity of specific items to be planned for stock. as shown in Figure 1. Overall inventory is expected to be optimized based on the total cost to allow a large pool of frequently ordered items to be stocked. It's recommended that the costly items not be preferred to be stocked due to obsolescence and high inventory carrying cost though they might have higher ordering frequencies. After-sales services typically involve fewer high-cost parts in regular demand. Exceptions are applicable to any recurring field failures of vehicles due to design and quality issues. ABC analysis is often used in conjunction with the strategies for order frequency (N) and the time between orders (T) to prioritize inventory management. ABC Inventory Analysis is a method used to categorize inventory based on its importance. It ensures that resources are focused where they have the biggest impact (Cassano, 2025).

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- A items: High value, low frequency (The top 10-20% of items that account for 70-80% of total inventory value)
- B items: Moderate value and frequency (After classifying A items, the next 30% of items that make up 15-25% of total value
- C items: Low value, high frequency (The remaining 50-60% of items that contribute 5-10% of total value).

The ABC classifications is explained with an example in table 1 and Table 2.

Table 1: Sample Data Showing the Annual Usage, Unit Cost and Total Value of EV Items at a Service Center

Item Name	Annual Usage Qty	Unit Cost	Total Value (Usage × Cost)
Front Fascia	500	$600	$300,000
Hydraulics Dampers	300	$800	$240,000
TPMS Valve	1,200	$50	$60,000
Half Shafts	250	$200	$50,000
M5 Bolt	5,000	$5	$25,000
Rivet	4,000	$4	$16,000

Table 2: ABC Categorization Based on Inventory Value Contribution, and Recommendations for the Stocking Plan

Category	Items	Total Value	% of Inventory Value	Stocking Strategy
A	Front Fascia, Hydraulic Dampers	$540,000	78%	Tight control, Just-in-Time (JIT) restocking, low buffer stock
B	TPMS Valve, Half Shafts	$110,000	16%	Moderate forecasting, regular orders
C	M5 Bolt, Rivet	$41,000	6%	High buffer stock, fewer replenishment cycles

From Table 2, it's clear that A-items, while few in number, account for nearly 80% of the total inventory value - justifying a more rigorous stocking strategy.

2.4 Quality Issues

Design and quality issues are not ruled out on any product especially when it's making a new entry into the market. It leads to planned FSA (Field Service Actions). It temporarily triggers a demand spike for the involved product as shown in Figure 2. It tends to skew the demand forecasting. If not properly signaled as outliers, such spikes may skew forecasting models, resulting in persistent overestimation of demand. It leads to the overstocking of bad inventory at the warehouse.

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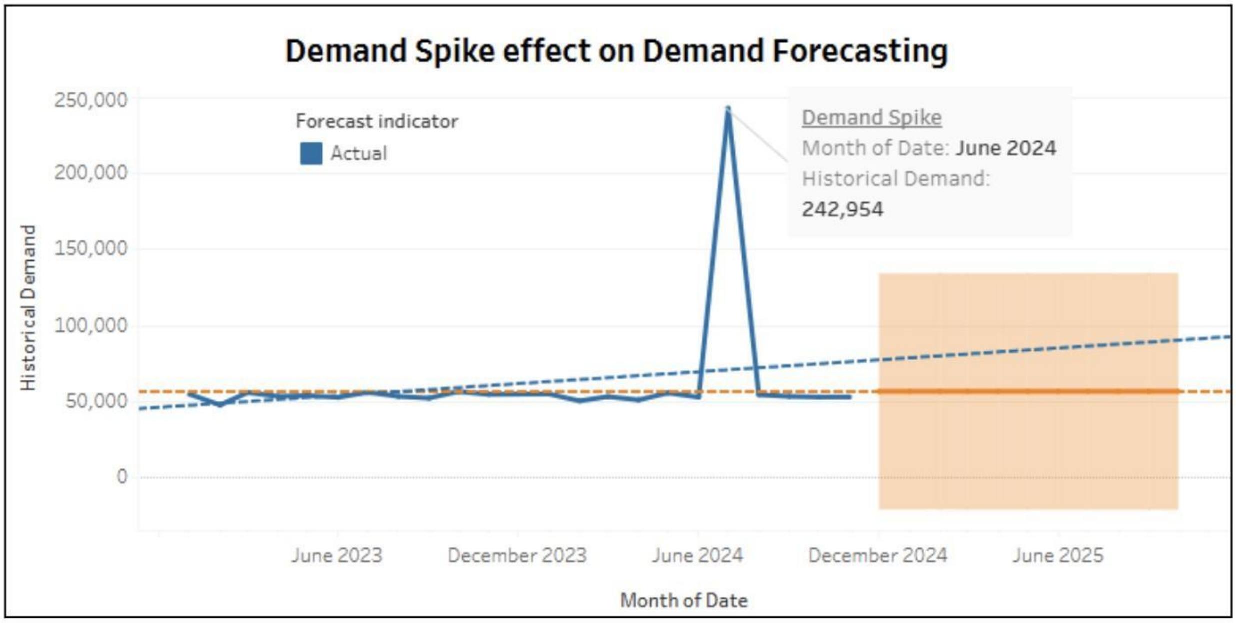

Figure 2: The Effect of an Abnormal Demand Spike on the Forecast

Source: Author

As Figure 2 illustrates, a demand spike in June 2024 has significantly increased the forecast and shows an increasing trend month over month. On the contrary, the historical data, except for the abnormal demand spike, show a flat trend.

2.5 Logistics Cost

Packing and shipping charges are the major components of the logistics cost. High logistics cost makes suppliers and customers think about having fewer shipments to reduce the overall cost of the manufactured components. This leads to an increase in the lot size for the shipment which adds extra burden to the storage locations. Most companies request suppliers to quote for the pricing with different batch sizes and also request suppliers to suggest the economical batch size to be competitive during the RFQ (Request for quotations). The relationship between purchasing cost, logistics cost and lot size can be represented by an equation (Olofsson, n.d.). It shows how the order Quantity (EOQ) influences the ordering costs and holding costs to minimize total logistics costs (Fernando, 2024). The equation for total logistics cost as a function of lot size (order quantity).

Total Cost (TC) = Purchasing cost + Ordering Cost + Holding cost (Olofsson, n.d.)

$$Ordering\ Cost = P \times D = \frac{D \times S}{Q}$$

$$Holding\ Cost = \frac{Q}{2} \times H$$

$$TC = P \times D + \frac{D}{Q} \times S + \frac{Q}{2} \times H$$

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Where:

TC = Total annual logistics cost

P = Unit piece cost

O = Ordering cost

D = Annual demand

Q = Lot size (order quantity)

S = Fixed cost per order

H = Annual holding cost per unit

This equation shows that with the increase in lot size (Q), ordering costs ($\frac{D \times S}{Q}$) decrease due to fewer orders placed. However, holding costs ($\frac{Q}{2} \times H$) increase with larger lot sizes due to more inventory being stored. The optimal lot size (EOQ) occurs at the point where ordering cost and holding cost are balanced, minimizing the total logistics cost. The optimal lot size can be found by differentiating the addition of ordering cost and holding cost concerning Q and setting it to zero, which yields the EOQ formula:

$$EOQ = \sqrt{\frac{2DS}{H}} \qquad \text{(Boyd, 2023)}$$

This equation demonstrates the trade-off between ordering costs and holding costs, allowing companies to adjust the lot size for their inventory management to maximize the cost savings through optimizations.

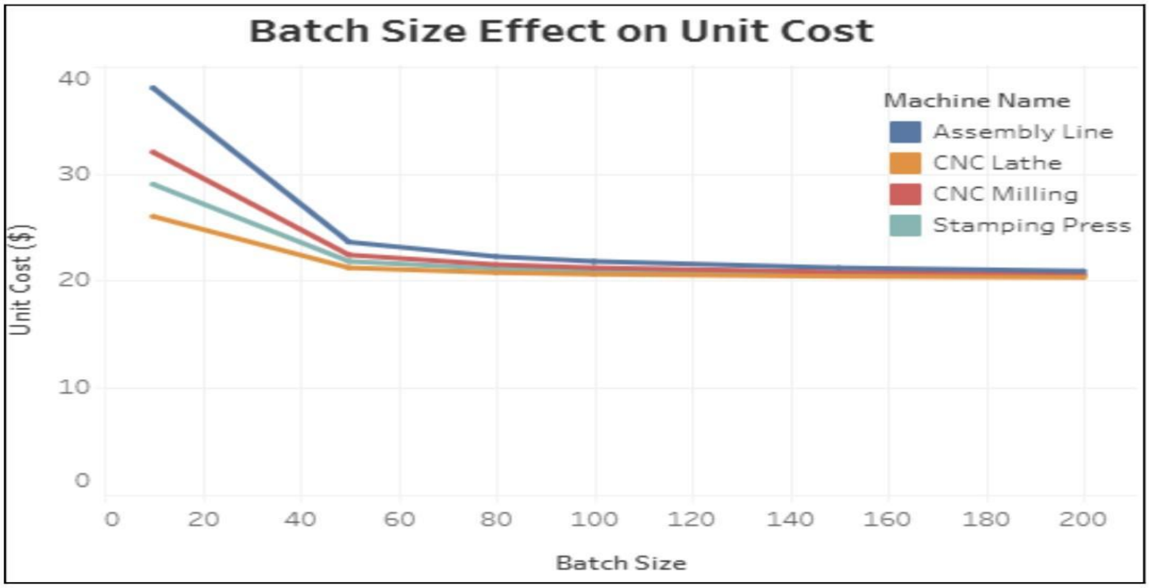

Figure 3: The Effect of Production Batch Size on the Unit Cost of the Product

Source: Author

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2.6 Production Batch Sizes

During the manufacturing of products, suppliers determine the production batch sizes for optimized resource utilization. Manufacturing processing time at any machine has two components called setup time and machining time. The effect of the production batch size on the unit cost of the product is shown in Figure 3. When machine setup time is higher, then a higher production batch size is ideal for maximum productivity with lower cost. For such products, the supplier has to fix a higher EOQ (Economic Order Quantity) and it gets transferred to their customer. In that case, inventory optimization is constrained by production requirements in high setup time environments and some cases it's inevitable to have a large inventory of slow-moving items due to this reason (Wiggins, 2023). EOQ further increases if the logistics costs are higher.

2.7 Supply Chain Disruptions

Demand forecasting becomes even more complex for specialty materials or products, where the probability of supply chain disruptions is higher. Companies that rely on such parts often add more buffer stock to mitigate the risk and impact of disruptions on end-product production. However, this also increases inventory burdens, requiring warehouses to adapt to large shipment influxes and the storage of these parts. The relationship between these factors can be described by the following equation.

$ss = z \times \sqrt{\frac{L}{T}} \times \sigma demand$ (RĂDĂŞANU, 2016)

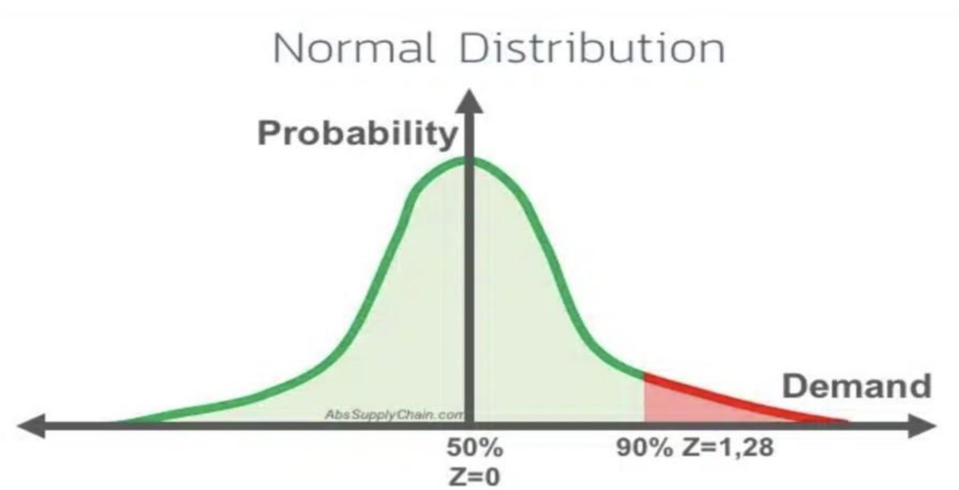

Figure 4: The Distribution Inventory Burdens

Source: Thieuleux, n.d.

SS stands for safety stock while Z represent coefficient of service or service factor. It is from a normal distribution demand curve (Fig. 4) showing Z for a desired Fill Rate on the X-axis

σ_{demand} = Demand variation or uncertainty in demand/supply

L = Total Lead Time while T = time used for calculating the standard deviation of demand

With the increase in σ_{demand} and L, there is a cascading effect on safety stock. It increases the safety stock in the warehouse or at the point of consumption. To lower such risks, it's ideal to have an active alternate supplier for such commodities. It is advised in strategic sourcing to select a minimum of two suppliers with similar quotes for production, with the demand being divided between the two suppliers. It becomes more challenging if there is a material shelf life involved with a product such as rubber, oil, etc. If such a product is not consumed up to the recommended date, it gets scrapped and leads to financial loss. A demand planner has to account for such losses and needs to make necessary adjustments in forecasting to minimize the impact.

3.0 CHALLENGES

Field service actions (FSA) or vehicle recalls are a common occurrence in the automotive industry. In 2024 alone, the National Highway Traffic Safety Administration (NHTSA) reported more than 450 separate recall campaigns, affecting more than 28 million vehicles (Reyes, 2025). Whenever it happens, it takes precedence due to business impact. Most of the inventory is diverted towards the FSA and there is not enough time to get the required parts from the suppliers which leads to consuming the network inventory and straining the network balance for some time. Suppliers are expected to step up to fulfill the demand in a short time which is difficult and it compels them to do a mass production for the required parts in large batch sizes. Large shipments of the required components for FSA or recall cause an increase in the requirement for additional storage spaces at the warehouse and service centers. This kind of short-term consumption spike of specific components could lead to higher inventory replenishments in the future, if not detected or marked as an outlier in demand forecasting models. It could lead to overstocking of the parts involved in the FSA and recall process after their completion.

Supply chain disruptions pose another challenge to inventory optimization. Disruptions can be due to natural calamities, labor strikes, geopolitical conflicts, or issues at the supplier's manufacturing facility. These factors are hard to predict and take a toll on inventory planning and optimization efforts. The impact of supply chain disruptions can be minimized through some of the following strategies.

3.1 Dual Sourcing

Supply chain risk with the sole supplier for a commodity is always high. It is advisable to have at least two independent suppliers identified and awarded the contract with a reasonable split of total demand. It enables better handling of unexpected demand surges and supplier-specific disruptions. Additionally, dual sourcing mitigates the risk of single-supplier monopolies in pricing and contract negotiations.

3.2 Insourcing

Insourcing involves producing a component or assembly within the company rather than relying on external suppliers. This approach offers several benefits for reducing supply chain risks, including greater control over technology, faster response to changes in demand, and reduced dependency on outside vendors. Though insourcing may not be cost-efficient sometimes but it is necessary, especially for the critical components.

3.3 Buffer Inventory

Maintaining an extra stock of critical items is a common strategy to address supply chain disruptions and sudden increases in demand. However, this approach can reduce inventory turnover, raise inventory holding costs, and occupy valuable warehouse space for extended periods, ultimately limiting overall storage capacity. Conventional forecasting models are good to build upon but with ever-changing demands, the conventional model's accuracy is compromised. As shown in Figure 2, the sensitivity of the demand forecast model to outliers or demand spikes adds to the woes. It is recommended to evaluate different models that fit continuously and to get better results (*Traditional Forecasting Models And Their Limitations*, n.d.).

4. CONCLUSION

Demand forecasting and inventory management are getting better with advanced forecasting tools and algorithms. Offsetting the inventory by involving third parties or distributors reduces the burden up to a certain extent. Some distributors offer their services to store large quantities of items at a nominal charge. Distributors act as an intermediary entity that deals with suppliers and customers. Distributors can leverage economies of scale to negotiate lower prices with suppliers. However, this advantage comes with potential risks, including demand obsolescence and extended lead times, which must be carefully managed.

Inventory optimization in the ever-changing automotive sector involves more than just keeping the proper amount of inventory on hand, it also requires taking strategic decisions to effectively balance supply, demand, and costs. Scenario analysis and sensitivity analysis are among the best methods for striking this balance. By simulating multiple inventory strategies, scenario and sensitivity analysis help companies prepare for a variety of market situations, supply chain disruptions, and demand changes. Businesses can make data-driven decisions to reduce risks and take advantage of opportunities by examining possible outcomes under various assumptions, such as changes in supplier lead times, production limitations, unforeseen demand spikes, target fill rates, inventory turnover, or logistics bottlenecks.

Inventory optimization largely depends on accurate demand forecasting. Traditional forecasting approaches, built on historical data and standard statistical models, often lack the agility to address the evolving complexities of the automotive market. AI-powered predictive analytics offer a more sophisticated alternative, leveraging vast and diverse datasets - ranging from sales performance and market trends to consumer behavior - to deliver more accurate and adaptable forecasts. By incorporating machine learning algorithms, these models reveal hidden patterns and emerging trends, significantly improving demand prediction accuracy and enabling more responsive, data-driven supply chain decisions (Putha, 2022).

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