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A Comprehensive Review of Inventory Management in Automotive Parts Supply Chains

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ABSTRACT

The automotive manufacturing industry plays a pivotal role in China's economy, with a steadily increasing market demand. Effective inventory management is crucial for ensuring service quality, cost control, and supply chain efficiency, particularly in the automotive parts manufacturing sector. This review synthesizes existing inventory classification methods and explores various inventory management strategies under supply chain uncertainties. By critically analyzing the current literature, this study identifies key research gaps and outlines future research directions. The findings provide a theoretical foundation for enhancing the precision and intelligence of inventory management while improving the industry's ability to mitigate supply chain uncertainties.

KEYWORDS

Automotive parts; Inventory classification; Supply-demand uncertainty; Inventory management

1. INTRODUCTION

The automotive industry is one of the largest and most economically significant sectors worldwide. With China's sustained economic growth, infrastructure development, and strong industrial policies, the country's automobile market continues to expand. According to the China Association of Automobile Manufacturers, in 2024, China's automobile production and sales exceeded 31 million units, with new energy vehicle (NEV) production and sales surpassing 12.8 million units—maintaining the world's leading position for the tenth consecutive year. In the face of intensifying market competition, consumer demand diversification, and industry upgrading, automotive manufacturers must adopt more efficient and agile production strategies. Within this context, inventory management of automotive parts plays a crucial role in manufacturing operations, directly impacting service quality, cost control, capital efficiency, and resource utilization.

The Just-In-Time (JIT) production model is widely used in automotive parts manufacturing, requiring components to arrive precisely when needed to align with production schedules. This pull-based production approach is designed to respond to real-time consumer demand. However, it also increases the risk of bottlenecks and product backlogs in downstream processes. Effective inventory management minimizes inventory investment while ensuring timely order fulfillment, bridging the gap between JIT production and delivery timelines. Furthermore, inventory in automotive parts manufacturing includes raw materials, work-in-progress (WIP), and finished goods, requiring cross-departmental coordination to optimize storage levels, minimize excess stock, and improve inventory efficiency. A well-structured inventory system not only ensures seamless supply chain operations but also enhances service quality, cost-effectiveness, and market competitiveness.

The complexity of automotive supply chain inventory management is further exacerbated by rapid product iteration and short product life cycles, making accurate demand forecasting particularly challenging. Supply chain inventories encompass both production inventory and logistics inventory, and effective inventory management is essential for stabilizing supply chain operations. Traditional supply chains predominantly rely on predictive inventory management strategies, using historical sales data and demand forecasts to determine inventory levels. However, forecast inaccuracies often lead to either excessive stock accumulation or shortages, impairing operational efficiency.

In contrast, modern supply chains prioritize agility and responsiveness, leveraging advanced information technologies and logistics systems to enable real-time supply-demand visibility and dynamic inventory adjustments. This transition toward data-driven, intelligent inventory management enhances efficiency, mitigates uncertainty, and improves supply chain resilience.

This study investigates the challenges and advancements in automotive parts inventory management. It begins by outlining the characteristics of automotive parts and analyzing the current state of inventory management in the industry. Next, it reviews research on inventory classification, exploring various classification methods, management strategies, and real-world applications. The study then examines the impact of supply chain uncertainty on inventory management, focusing on supply uncertainty, demand uncertainty, and simultaneous supply-demand uncertainty, and evaluates different inventory management models and their applicability to automotive parts inventory control. Finally, a comprehensive review synthesizes key findings, identifies research gaps, and proposes future research directions to advance theory and practice in automotive inventory management.

2. LITERATURE REVIEW AND STATISTICAL ANALYSIS

A comprehensive literature search was conducted using Web of Science, Google Scholar, and China National Knowledge Infrastructure (CNKI). The search employed English keywords “Auto parts,” “Supply and demand uncertainty,” and “Inventory management”, along with their Chinese counterparts “ Auto parts”, “ Supply and demand uncertainty”, and “ Inventory management”. Over the past five years, a total of 260 relevant studies were retrieved.

To systematically analyze the existing research landscape, the collected literature was categorized based on thematic focus. This review is structured around three key dimensions: inventory classification management, supply chain inventory management under demand and supply uncertainties, and inventory management models. These aspects collectively provide a comprehensive perspective on the current state of automotive parts inventory management and highlight critical research gaps.

3. CURRENT CHALLENGES IN AUTOMOTIVE PARTS INVENTORY MANAGEMENT

3.1. Characteristics of Automotive Parts

3.1.1. Diversity

Throughout a vehicle’s lifecycle, approximately 3,000 different parts may require replacement, contributing to an extensive and highly diverse market. This diversity spans product types, technologies, and application domains. From original equipment manufacturer (OEM) parts to aftermarket alternatives, each category serves distinct functions and market segments.

3.1.2. Hierarchical Structure

The automotive parts industry operates within a pyramidal supply chain, comprising a limited number of large-scale enterprises, a considerable number of mid-sized firms, and a vast array of small-scale manufacturers, corresponding to Tier 1, Tier 2, and Tier 3 suppliers, respectively. This hierarchical organization dictates the division of labor and responsibilities across the supply chain, from raw material suppliers to system integrators. Establishing stable partnerships across these tiers is essential to maintaining supply chain resilience and reliability.

3.1.3. Complexity

Automotive parts encompass a broad spectrum, including individual components, subassemblies, complete assemblies, and body panels. Their production involves a diverse range of materials, technologies, and cross-sectoral collaborations. Components originate from multiple sources, including OEMs, contract manufacturers, replicas, salvaged parts, and refurbished units. The increasing technological and material complexity necessitates sophisticated inventory management strategies.

3.1.4. Uncertainty

Various factors introduce uncertainty into automotive parts inventory management, including fluctuating market demand, competitive dynamics, technological advancements, and global supply chain disruptions. Economic conditions and consumer preferences influence demand unpredictably, while competitive strategies and technological shifts further complicate inventory forecasting. Additionally, raw material availability, logistics constraints, and supplier reliability introduce further variability, necessitating robust inventory buffers.

3.1.5. Market Segmentation

The automotive parts market is divided into the OEM supply market and the aftermarket service sector. The aftermarket is highly fragmented, characterized by diverse, small-batch orders requiring agile inventory and procurement strategies. Conversely, the OEM supply market is dominated by a few major suppliers, characterized by large-volume, long-term contracts with stringent technical standards. Businesses must dynamically adjust inventory structures and procurement plans to navigate these distinct market environments effectively.

3.2. Current Challenges in Automotive Parts Inventory Management

Despite advancements in inventory management, several persistent challenges hinder efficiency and operational effectiveness [1]:

(1) Slow Work-in-Progress (WIP) Turnover

The complexity of manufacturing processes and the diversification of customer demands contribute to extended production cycles. Empirical data indicate an average WIP turnover period of approximately 15 days—significantly exceeding theoretical processing times. This prolonged turnover delays production completion and inventory replenishment.

(2) Extended Storage Due to Outsourced Processing

Many automotive parts manufacturers rely on outsourced processing for specialized tasks such as surface treatment and mold fabrication. While outsourcing enhances specialization and efficiency, it also disrupts production flow, prolonging lead times and increasing storage durations.

(3) Long Procurement Lead Times and High Safety Stock Levels

Certain components require extended procurement lead times due to supplier constraints or procurement uncertainties, necessitating higher safety stock levels. However, excessive safety stock ties up capital, elevates inventory holding costs, and increases the risk of obsolescence.

To address the challenges in automotive parts inventory management and enhance its efficiency and accuracy, thereby optimizing enterprise operations and strengthening competitiveness, a multi-faceted approach is required. First, refining production planning and improving supply chain coordination can facilitate precise alignment between inventory levels and fluctuating demand, thereby minimizing work-in-progress inventory and reducing excess stock accumulation.

Additionally, adopting a zero-inventory strategy—where production is initiated immediately upon order confirmation—enables a demand-driven supply model, effectively lowering safety stock levels, reducing unnecessary inventory holding, and alleviating financial constraints. Furthermore, the integration of advanced information systems and digital technologies can enable real-time inventory monitoring and tracking, allowing dynamic adjustments in production and procurement plans. This digital transformation enhances responsiveness to market fluctuations, mitigating the risks of both overstocking and stock shortages, and ultimately fostering a more resilient and agile supply chain.

4. CURRENT RESEARCH ON INVENTORY CLASSIFICATION MANAGEMENT

The classification and organization of automotive parts directly impact manufacturers' operational efficiency and cost management. In an effective inventory management system, parts are accurately categorized, stored, and tracked to ensure timely availability and utilization. Different inventory classification methods influence supply chain management, production planning, and cost control. By adopting optimized classification strategies, automotive manufacturers can enhance inventory efficiency, reduce costs, and improve service quality.

Extensive research has been conducted on inventory classification methodologies, with the ABC classification method being the most widely applied. Rooted in the Pareto 80/20 principle, ABC analysis classifies inventory based on value contribution but suffers from overly simplistic criteria. The Analytic Hierarchy Process (AHP) addresses this limitation by incorporating multi-criteria decision-making, though it is highly sensitive to subjective biases. To mitigate these biases, information entropy has been introduced as a refinement.

Bao et al. [2] proposed an AHP-entropy hybrid model to improve traditional ABC classification, demonstrating its effectiveness in manufacturing companies. Li et al. [3] validated the effectiveness of ABC classification in an automotive repair enterprise and proposed tailored management strategies for different part categories. Zowid et al. [4] introduced a Gaussian Mixture Model (GMM) to address multi-criteria classification in ABC inventory management, achieving superior performance in balancing cost, service level, and inventory efficiency.

Cheng et al. [5] explored inventory management in assemble-to-order (ATO) production, establishing predictive models and control strategies to mitigate demand volatility. Chen et al. [6] developed a Canopy-FCM fuzzy clustering approach for classifying aftermarket service parts, overcoming the rigidity of traditional ABC analysis. May et al. [7] proposed a modified weighted nonlinear optimization (WNO) technique, which demonstrated superior performance in prioritizing inventory compared to ABC analysis and other classification methods.

Svoboda et al. [8] introduced a multi-dimensional cost-based inventory classification model, segmenting products based on replenishment strategies to enhance inventory efficiency. Their method leveraged machine learning classifiers and genetic algorithms to construct intuitive and practical decision trees for optimized inventory management. Hou et al. [9] developed a combined weighting-based spare parts classification model, integrating AHP and entropy weighting to minimize subjective bias. Using the TOPSIS method for comprehensive evaluation, their approach was successfully applied in a natural gas pipeline enterprise, showcasing its practical value.

These advancements highlight the evolving landscape of inventory classification research, where traditional methods are continuously refined through the integration of advanced statistical, optimization, and machine learning techniques to improve inventory accuracy, responsiveness, and decision-making in complex supply chain environments.

5. SUPPLY CHAIN INVENTORY MANAGEMENT UNDER SUPPLY AND DEMAND UNCERTAINTY

Uncertainty in supply chains primarily arises from three sources: supply uncertainty, demand uncertainty, and simultaneous supply-demand uncertainty. Supply uncertainty refers to unpredictable supplier lead times, which may result from raw material shortages, disruptions in production processes, or logistical constraints. Demand uncertainty stems from market fluctuations, influenced by factors such as seasonality, competitive dynamics, and new product introductions [10]. These uncertainties significantly impact inventory levels and complicate inventory management. A key objective of supply chain management is to minimize inventory levels while ensuring demand fulfillment, thereby reducing holding costs and mitigating risks. To enhance the efficiency and flexibility of inventory management under uncertainty, scholars have conducted extensive research on optimizing inventory strategies.

In addressing supply uncertainty, Zhang et al. [11] investigated inventory optimization under uncertain order cycles using the widely accepted min-max robust optimization theory. Their model incorporated risk management principles to assess the dual impact of decision-makers' risk preferences and market uncertainty on inventory performance. Similarly, Zhang and Jian et al. [12] examined a multi-period inventory game under supply uncertainty, proving the existence of an equilibrium inventory strategy and characterizing its properties. Their findings highlighted the influence of supply uncertainty and product substitution rates on retailers' inventory decisions.

For demand uncertainty, Li et al. [13] developed a dynamic inventory system model, validated using control theory, and conducted simulation experiments across four stochastic demand models. The study assessed optimal inventory strategies under varying lead times and demand scenarios, incorporating inventory cost and service level metrics. Yang et al. [14] highlighted the challenges posed by highly uncertain demand for automotive parts, demonstrating that traditional inventory models struggle to accommodate market and consumer demand variability. They proposed a fuzzy-set-based inventory model, wherein demand is represented as a fuzzy set, and defuzzification techniques were applied to determine optimal order quantities, reducing inventory management costs.

Saputro et al. [15] proposed an integrated inventory and inbound logistics model, addressing additional costs arising from stochastic demand and supplier quality uncertainty. Using simulation-optimization techniques, the study employed genetic algorithms for supplier selection and discrete-event simulation for performance evaluation, dynamically adjusting lead times. Alkahtani et al. [16] introduced a nonlinear supply chain management model with adjustable production rates, optimizing total production costs while ensuring adaptability to demand variability. Their model allowed manufacturers to balance economic efficiency with production flexibility under uncertain demand conditions.

To explore inventory strategies under simultaneous supply and demand uncertainty, Ding et al. [17] investigated a two-stage supply chain with periodic production and inventory replenishment. Their findings demonstrated that as production capacity variability increases, both the optimal base inventory level and inventory costs rise. Moreover, a faster increase in production capacity variability leads to a steeper rise in inventory levels and costs. To enhance coordination between supply chain stakeholders, the study proposed an inventory subsidy contract, effectively aligning upstream and downstream inventory decisions while reducing overall inventory costs.

These studies underscore the critical need for adaptive, data-driven inventory management strategies to navigate the complexities of supply and demand uncertainty. The integration of robust optimization, fuzzy logic, simulation-optimization, and incentive-based coordination mechanisms represents a significant advancement in modern inventory management, enhancing resilience and efficiency in automotive supply chains.

6. INVENTORY MANAGEMENT MODELS

Navarro et al. [18] developed a two-stage economic production inventory model that considers work-in-progress (WIP) inventory and probabilistic demand. The demand rate follows an exponential probability density function, with retail demand influenced by the proactiveness of the sales team. Mitrovic et al. [19] utilized Arena simulation software to optimize inventory management by identifying the optimal inventory levels that minimize total ordering costs. However, in practical operations, received orders may contain non-conforming (NC) products, complicating inventory planning. To address this issue, Nakhaeinejad et al. [20] proposed a novel inventory model integrated with an inspection strategy, wherein buyers inspect received shipments to ensure product quality before acceptance.

Focusing on automotive maintenance spare parts, Li [21] introduced a distributed multi-echelon spare parts inventory algorithm based on centralized control, effectively improving inventory management performance by addressing low service levels and inadequate inventory control in after-sales maintenance. Ramos et al. [22] conducted a case study on demand forecasting and inventory control, demonstrating that their optimization approach reduced procurement frequency, increased order volumes, and boosted sales by 22.49%.

Mehdizadeh et al. [23] investigated key factors linking automobile sales and mileage with spare parts demand, aiding retailers in determining optimal order timing. Their approach combined ABC analysis and rough set theory to extract patterns, predict future demand, and enhance key performance indicators for an Iranian dealership. Fang et al. [24] proposed an integrated vendor-managed inventory (VMI) system for the electronics manufacturing industry, implementing two distinct VMI models to enhance inventory management, reduce costs and lead times, shorten customer response times, and improve overall system efficiency.

To address demand uncertainty and mitigate stockout risks in manufacturing, Ma [25] developed multi-period stochastic inventory models for both discrete and continuous demand scenarios. These models effectively optimized inventory levels, reduced total costs, and minimized the impact of shortages. Chen et al. [26] focused on order cancellation scenarios, leveraging linear regression models to predict cancellation volumes and constructing an optimized raw material inventory model for manufacturers, minimizing total inventory costs.

Jiang et al. [27] explored cloud-based inventory control strategies, demonstrating that cloud services facilitate multi-directional inventory data aggregation and networked resource management. They proposed a joint decision-making model for demand forecasting and inventory allocation, optimizing inventory levels while minimizing total costs and forecasting errors.

These studies highlight the evolution of inventory management models from traditional economic order quantity (EOQ) approaches to intelligent, data-driven, and cloud-integrated inventory systems. By incorporating stochastic modeling, predictive analytics, simulation techniques, and AI-driven forecasting, modern inventory models significantly enhance operational efficiency and supply chain resilience.

7. COMPREHENSIVE REVIEW AND FUTURE DIRECTIONS

Despite significant advancements in automotive supply chain management, several unresolved challenges persist, particularly in inventory classification management.

7.1. Inventory Classification Management

Traditional inventory control methods, such as the ABC classification method and Economic Order Quantity (EOQ) models, lack real-time adaptability, multidimensional considerations, and operational flexibility. These limitations make them inadequate for modern manufacturing environments characterized by a diverse range of parts, small-batch production, and dynamic demand fluctuations. Consequently, developing scientifically robust and efficient inventory classification strategies is critical for enhancing the operational performance of automotive parts manufacturers and suppliers.Existing research on inventory classification has explored various methodologies, including hybrid models combining Analytic Hierarchy Process (AHP) and information entropy, as well as fuzzy clustering-based approaches. Additionally, studies have focused on improving classification efficiency and accuracy through multi-dimensional classification models and Gaussian Mixture Models (GMM). These contributions have provided valuable theoretical and practical insights for refining inventory classification processes.

However, several research gaps remain. Current studies often overlook critical material characteristics and key classification factors, resulting in overly generalized classification schemes. Furthermore, existing classification frameworks often lack the granularity needed to accommodate the complexity of modern supply chains. Future research should focus on integrating multiple classification models, leveraging machine learning, big data analytics, and real-time decision-making systems to enhance the accuracy, efficiency, and cost-effectiveness of inventory management. Such advancements would reduce inventory holding costs, streamline procurement strategies, and alleviate the operational burden on enterprises, ultimately fostering greater supply chain resilience and competitiveness.

7.2. Supply Chain Inventory Management Under Supply and Demand Uncertainty

Existing research has extensively examined uncertainty in supply chains, particularly its impact on inventory management. Both supply and demand uncertainties significantly influence inventory levels and complicate inventory control. To address these challenges, numerous studies have sought to enhance the efficiency and adaptability of inventory management strategies. However, current research primarily focuses on demand uncertainty, while studies addressing simultaneous supply and demand uncertainty remain limited.

Research on supply uncertainty is also relatively scarce, particularly concerning strategies for mitigating supply disruptions. Given the increasing risks associated with globalized supply chains, centralized production, and supply chain compression, supply disruptions have become a pressing challenge. However, there is a notable lack of comprehensive frameworks for effectively managing such disruptions. Additionally, research on demand uncertainty often relies on simplistic assumptions, such as modeling demand as a linear function of price or a random variable following a predefined distribution. These approaches fail to capture the complex characteristics of real-world demand fluctuations, limiting the development of robust uncertainty management strategies.

Future research should prioritize the development of integrated response strategies for simultaneous supply and demand uncertainties, resilient supply disruption mitigation frameworks, and a deeper exploration of demand uncertainty driven by dynamic market characteristics. By addressing these gaps, scholars can significantly improve the adaptability, resilience, and efficiency of inventory management in automotive supply chains.

8. CONCLUSION

This study systematically reviews existing inventory classification methods and provides a comprehensive analysis of inventory management challenges under various conditions. The review highlights critical gaps in inventory classification strategies and integrated response mechanisms for supply and demand uncertainties, underscoring the need for further research in these areas. By addressing these limitations, this study contributes to the theoretical foundation for enhancing inventory management efficiency and improving supply chain resilience. These insights serve to drive advancements in both research and practical applications, fostering more adaptive and intelligent inventory management strategies in the face of increasing supply chain uncertainties.

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