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A Comprehensive Review of Machine Learning Techniques for Retail Supply Chain Optimizations

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ABSTRACT: The rapid growth of digital retail platforms, changing customer preferences, and increasing market uncertainty have created significant challenges in managing modern retail supply chains. Supply chain performance optimisation, real-time decision-making, effective inventory management, and accurate demand forecasting are crucial for staying competitive. By facilitating data-driven prediction, pattern recognition, and automated decision support across a variety of supply chain processes, machine learning (ML) approaches provide encouraging possibilities. With an emphasis on optimisation of logistics, supplier selection, demand forecasting, inventory management, warehouse automation, risk management, and ML, this article offers a thorough examination of machine learning's uses in retail supply chain optimisation. Existing ML approaches, including supervised learning, ensemble methods, deep learning models, and hybrid optimization techniques, are analyzed based on their capabilities, benefits, and limitations. The review highlights that ML-driven solutions improve forecasting accuracy, reduce operational costs, enhance resource utilization, and increase supply chain resilience. There are still major obstacles, though, and they have to do with data quality, the interpretability of models, scalability, deployment in real-time, and interface with current systems. Intelligent, explicable, and scalable ML frameworks are necessary to enable decision-making throughout the retail supply chain, according to a comprehensive review of current studies that found research gaps. The findings of this review provide insights into current advancements and future research directions for developing adaptive and transparent machine learning-based retail supply chain optimization systems.

KEYWORDS: Retail Supply Chain Management, Supply Chain Optimization, Demand Forecasting, Inventory Optimization, Artificial Intelligence, Predictive Analytics.

1. Introduction

In today's competitive and always-changing retail world, it's important to be able to accurately predict demand and keep track of inventory. Distributors confront increasing difficulties in matching supply and demand due to the proliferation of sales channels, the proliferation of products, and the rising unpredictability of customer behaviour [1]. Management of the processes involved in the creation and distribution of goods to consumers is known as supply chain management. Demand forecasting and planning is a foundational aspect of supply chain management because it allows for the correct prediction and preparation of future product needs, which is crucial for efficient inventory and production management [2]. Modern supply chains are so complicated and unpredictable that old ways of planning and forecasting don't work anymore [3]. Data analysis and ML methods are essential for effective process management. Companies can quickly adjust to changes in demand by utilising ML methodologies. This is especially crucial in a market that is always changing.

ML algorithms allow organisations to analyse fresh data in real-time, allowing them to maximise productivity while minimising expenses [4]. Better inventory management, fewer shortages, and happier customers are all possible outcomes of demand forecasting and planning that makes use of data analysis and ML. Companies are able to better plan production and manage resources thanks to these technologies, which allow for more precise identification and forecast of consumer demands. The term "artificial intelligence" (AI) describes a collection of tools that allow us to program computers to think and act like humans. The branch of artificial intelligence known as ML enables computers to learn automatically from data and experiences without human instruction. SCM is synonymous with the integration of the supplier base, which evolved from traditional purchasing and materials duties [5][6]. SCM is all about reducing inventory, both

internally and externally, from the standpoint of transportation and logistics management. It's all about integrated logistics systems.

A. Structure of paper

This paper is organized into six sections. Section II presents the fundamentals of retail supply chain management, including its key elements, performance metrics, activities, and importance. The optimisation of retail supply chains and the use of AI and ML in improving operational efficiency are covered in Section III. The primary uses of ML in supply chain management, as discussed in Section IV, are demand forecasting, partner selection, and logistics optimisation. A review of the most current literature is conducted in Section V, which also summarises the present research. Section VI concludes the article by summarizing its key results.

2. Fundamentals of Retail Supply Chain Management

Supply chain management is the most important part of running a successful retail business. It helps get things from producers to wholesalers, then to retailers, and finally to customers. Back in the day, inadequate transportation infrastructure, bad roads, and a lack of warehouses made it difficult for manufacturers to get their products to merchants in India. As a result, shipping items from suppliers to small merchants, vendors, and shopkeepers was a major hassle. All parties involved in the supply chain, from producers to buyers, are feeling the effects of the awful chain management [7]. Which causes economic and market issues such as product shortages, price increases, inflation, and black market trading? In this way, the following goals may be effectively achieved by efficient supply chain management.

- The timely, accurate, and correct distribution of items to their intended recipients is essential.

- The constant supply of high-quality items depends on the free flow of information among all parties involved in the retail supply chain, including input from customers.

- Streamlined inventory management, efficient procurement, and secure warehousing to prevent shortages across the supply chain.

The timely, accurate, and undamaged delivery of products is the hallmark of a well-oiled retail supply chain. The store can better serve its consumers and attract new ones while keeping the ones they already have. As a result, retail SCM is crucial to organised retailing and the store's overall operation [8]. Retailers must reevaluate their supply chain systems and come up with novel tactics if they want to keep up with the rapid rise of organised retails marketplaces in India. Figure 1 summarises the specifics of the supply chain process circle.

Fig. 1. Retail supply chain process circle

Each stage is a comprehensive process that begins with the manufacturing of the product and is crucial to the supply chain management process. After the product reaches retailers and ultimately consumers, every firm that adheres to the supply chain management process. A well-organised store meets customer expectations by following the steps in the supply chain cycle. The issue arises when small businesses and unorganised conventional shops fail to properly follow the supply chain process, which leads to fluctuations in product demand and supply.

A. Retail Supply Chain Performance

Retail SCP is assessed based on measurable values or KPIs that allow the evaluation of the efficiency of business activities in achieving the brand's strategic goals[9]. These KPIs provide a systematic framework for evaluating in-market outcomes, customer engagement, and operational effectiveness [10][11]. Retail supply chain performance into three main dimensions:

- **Reliability**: This dimension measures how consistent and accurate the supply chain is in delivering on promises to customers. Metrics used in this dimension include on-time delivery rate and perfect order fulfillment. Reliability is often associated with internal process stability.

- **Responsiveness**: This dimension measures the speed and adaptability of the supply chain in response to changing market demands. An example of a key metric is ordering fulfillment cycle time. Responsiveness is essential in a retail environment where speed to market can be a competitive advantage.

- **Cost**: A financial dimension that measures the efficiency of operational expenses. Commonly used metrics include logistics costs per unit and COGS.

B. Elements of supply chain management

SCMs main goal is to track and connect the product's

lifecycle from start to finish, including manufacturing, packaging, and shipping. This is doable for companies who keep a close eye on their own stock, manufacturing, shipping, sales, and development processes. The core of supply chain management is the integration of both demand and supply. Utilising a wide range of strategies, it takes a holistic perspective of the chain and performs admirably at each link [12][13]. Achieving cost savings, helping businesses improve their long-term performance, and satisfying stakeholders and clients should be the goals of all parties involved. Rates can be reduced by the elimination of unnecessary expenses, handling, and transportation using this technique. The following is an explanation of the key components of SCM, with a graphic representation in Figure 2:

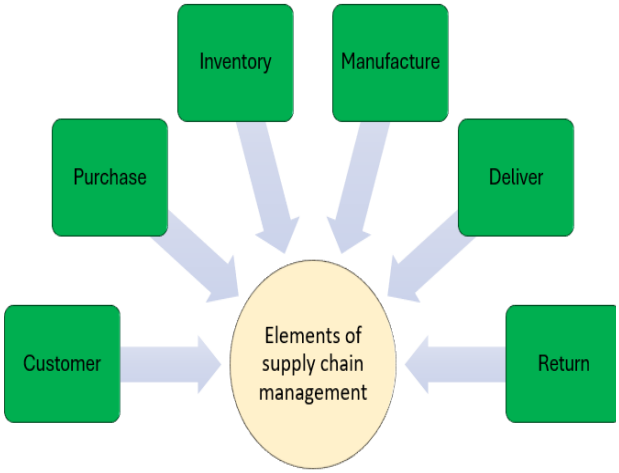

Fig. 2. Elements of Supply Chain Management

1) Customer

The chain reaction starts when a consumer chooses to purchase a product that a vendor has listed for sale. The consumer contacts the company's sales department and requests a certain amount to be delivered by a specific date in the form of a sales order [14]. A requirement that the factory must meet that is written into the sales order if the product needs to be made.

2) Purchase

The manufacturing department receives a catalogue from the buying department detailing all the items and services needed to complete customer requests. The procurement team notifies approved vendors through purchase orders so that manufacturing may begin on schedule with the raw ingredients.

3) Inventory

The raw materials are brought into the warehouse once they have been acquired from the vendors and checked for accuracy and quality. The business receives an invoice from the vendor subsequent to the delivery of the products. The raw materials are kept in storage until they are required by the production department.

4) Manufacture

Producing items that consumers have requested is the next stage in the process of SCM. During this phase, tasks such as product design, manufacture, testing, packing, and delivery synchronization occur. The role of the SCM in this scenario is to oversee the processes of production, quality assurance, packaging, and shipment readiness.

5) Deliver

Here, the supplier shows up at the agreed upon location with the products for delivery. Here, at what is effectively the logistics stage, take client orders and arrange for their products to be delivered. A number of processes come together during the delivery phase, also known as logistics, including the collection of customer orders, the creation of a warehousing system, the selection of carriers, and the establishment of an invoicing system.

6) Return

The final and most significant phase of SCM is the return. Finally, the customer sends back any faulty or damaged items to the seller. In this area, companies need to handle consumer enquiries, complaints, comments, etc. At this point in the supply chain, many companies have difficulties. For supply chain planners, the challenge is to establish a flexible system that can accept customers' damaged, defective, or extra products for return and speed up the return process when consumers have issues with their given goods.

C. Importance of Supply Chain Management

The importance of SCM is clear when thinks about the costs of supply chain tactics that don't work and the benefits that businesses that do use them get. What matters most to businesses is the level of integration in their supply chain. Due of its ability to:

- Minimise stockpiles along the supply chain.
- Improve the quality of information shared between partners.
- Instead than working alone, plan with others.

D. Activities of Supply Chain Management

Figure 3 displays the three tiers of supply chain management tasks performed by various departments inside an organization:

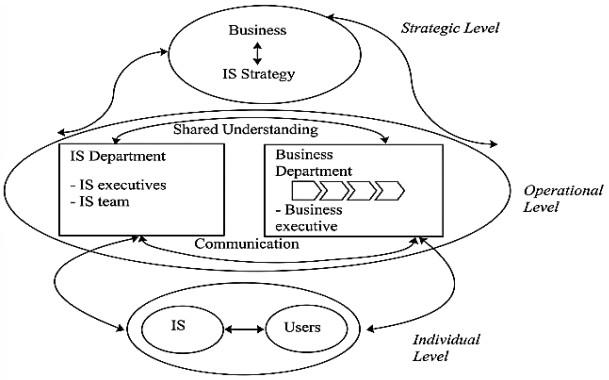

Fig. 3. Supply chain management activities

1) Strategic

The organization-wide strategic choices such production site size and location, supplier alliances, product development, and sales market penetration are made at this level. A company's future is significantly impacted by such choices. Products, their designs, internal vs. outsourced manufacturing, supplier selection, strategic alliance formation, and material flow management are all part of this process.

2) Tactical

The primary objective of tactical decisions is to implement strategies that result in cost savings. Establishing a purchasing strategy with preferred suppliers, working with logistics companies to create cost-effective transportation, and developing warehouse strategies to reduce inventory storage costs are all examples of possible strategies. The frequency of updates to such judgements usually ranges from quarterly to annually. These encompass decisions on manufacturing and purchasing, inventory rules, transportation tactics (including the frequency of customer visits), and more.

3) Operational

The items' progress through the supply chain is impacted by decisions made at this level. Modifying production schedules, negotiating purchase agreements with suppliers, processing client orders, and rearranging inventory are all examples of operational choices. Schedules, lead time quotes, routing, and truck loading are all examples of the kinds of day-to-day decisions that fall under this category.

3. Overview of Retail Supply Chain Optimization

The goal of optimising the retail supply chain is to increase efficiency and happiness among customers through better inventory management, transportation, warehousing, and distribution [15]. With the use of cutting-edge tech like AI, ML, the IoT, and big data analytics, logistics planning, inventory optimisation, and demand forecasting can all be done with pinpoint accuracy. These innovations facilitate quicker, more data-driven decisions while decreasing operating expenses and strengthening supply chain resilience.

1) Supply Chain Planning and Optimization

ML may improve production scheduling, inventory management, and demand forecasting. By analysing past data, current patterns, and external factors, AI systems can improve prediction accuracy, maximise inventory levels, and determine optimal production methods.

2) Warehouse Automation

Automatic picking, sorting, and inventory management are just a few of the warehouse duties that can be taken care of by robots powered by artificial intelligence. In the end, this enhances efficiency, accuracy, and simplifies processes while cutting labour expenses.

3) Risk Management and Resilience

AI has the potential to improve supply chain risk management by analysing and predicting the occurrence and severity of risks based on data from many sources. With its help, companies can build resilience and proactively deal with shocks.

4) Customer Service and Personalization

Virtual assistants and AI chatbots can improve customer service by responding to questions, keeping tabs on purchases, and offering customised support. AI may also sift through customer data to deliver tailored product recommendations and specialised advertising approaches.

5) Continuous Improvement and Optimization

AI can analyse data, find inefficiencies, and suggest process changes to help supply chain operations continuously improve. It could help a firm improve its supply chain performance and react to changing market conditions [16]. These examples of AI in SCM show how the technology may enhance decision-making, streamline processes, and boost efficiency. Organisations may improve their operational efficiency, acquire a competitive advantage, and increase customer happiness by utilising AI technology.

B. Integrated supply chain management

Supply chains that reduce inventory holding costs and respond rapidly to consumer demand have become more important to companies in recent years as a result of declining profitability and fiercer market rivalry. Strategic agreements are a way for companies in different industries to work together to get long-term benefits and the best supply line for the world [17]. Businesses must work together by creating partnership policies if they

want to triumph over the enterprise's overall cost. This is because, in practice, the goals of the group as a whole might differ from those of any one individual member. When every link in the supply chain has their opinion heard, only then can global optimisation be achieved. The different policies are derived to attain the lowest total integrated cost through cooperation of these members. Cooperation with other businesses in the supply chain is one approach to integration. A second is for all parties involved in the supply chain to constantly update one another. Present the primary processes involved in integrating the supply chain in Figure 1.1.

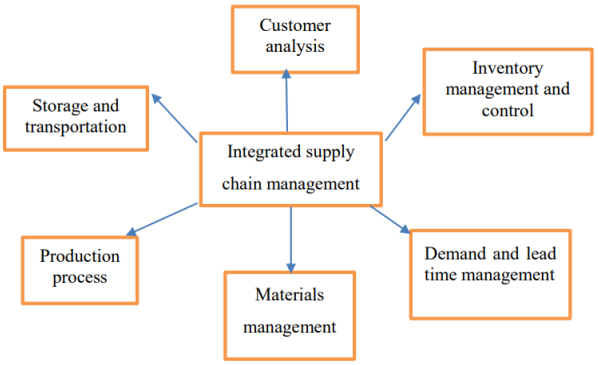

Fig. 4. Integrated supply chain management

Integrated SCM is now seen as one of the best ways to compete in a market where prices are high. This is because they can get goods and services to customers faster and cheaper than their rivals. Supply chain management's overarching objective is to maximise overall system cost optimisation via maintaining collaboration amongst various supply chain participants, which in turn reduces the integrated total cost of the supply chain and therefore boosts their profits.

4. Machine Learning Application Areas in Supply Chain Management

ML can be used in real life, as shown by three examples. The purpose of these examples is to show the reader how ML may be applied in real-world scenarios; each case demonstrates one of the three main purposes of the SCM Model. The three apps were chosen because they all offer a clear overview of ML in action, have simple structures, and provide easy-to-understand explanations.

1) Selecting Supply Chain Partners

One of the biggest obstacles in SCD is identifying the right people to work with as clients or vendors in order to take advantage of new prospects. In light of globalisation and the exponential growth of technology, this is more true than ever before.

2) Demand forecast for DM

ML algorithms are used by dm, a top German pharmaceutical company, to predict customer demand. The dm drugstore company maintains six distribution facilities to guarantee the availability of goods, serving 3,350 outlets globally. Distribution centers are responsible for arranging incoming items from industry partners for individual retailers in a manner that prevents product shortage and maintains high customer satisfaction. Despite manufacturers' generally extensive delivery schedules, retailers sometimes need items within a short time frame. The distribution facilities continue to face this as their primary obstacle.

3) Detecting False-Positive RFID Tag Reads in Transport Management

The distribution center shipping is a critical operation for SC. Several aspects, including the selecting procedure and the assignment of pallets to the allocated vehicle, contribute to an error-free transportation. The METRO Group Cash & Carry has installed RFID gateways to track the pallets that are being sent out in order to implement a control system. Its Unna, Germany distribution hub has RFID portals installed on loading ramps so that warehousing products may be immediately detected when they leave the facility [18]. A transponder is carried by it for the purpose of pallet detection.

5. Literature Review

Research conducted recently shows that ML may greatly improve the optimisation of retail supply chains in several ways, including the prediction of demand, optimisation of inventory, planning of routes, and management of suppliers.

Omer, Hassan and Aziz (2025) offers a comparison of ML methods with more conventional forecasting models for predicting demand in supply chains. The study delves into important methodologies such as supervised and unsupervised learning algorithms, statistical time-series models, ensemble methods, and DL architectures. The retail, manufacturing, healthcare, and food industries have provided empirical evidence that shows how well they work and how practical they are. New developments in explainable AI, hybrid modelling, and real-time adaptation are discussed, as are issues with data quality and model interpretability and system integration [19].

Vlachos and Reddy (2025) presents five ideas for future study. A research agenda focused on the 4Vs of ML—Volume, Variety, Variation, and Visibility—is established with the emergence of Generalised AI and LLMs. For the purpose of guiding future studies, this study agenda might be useful. Along with considerations of the social, commercial, and technological implications of ML for supply chain practitioners, this comprehensive literature review includes 107 publications published between 2019 and 2023 that focus on supply chain

management and ML. Important ML topics and challenges in the SC setting were examined using descriptive analysis (geographic, chronological, ML algorithm, publishing) and theme analysis (iterative theme identification) [20].

Zhao et al. (2025) utilises blockchain and artificial intelligence to improve the level of smart SCM and greatly raises the level of data security and reliability. The study's findings point to the potential of blockchain and AI as a combined technology to improve the efficiency and openness of supply chain data, opening up new avenues for supply chain management solutions [21].

Mupparaju et al. (2024) offered a fresh optimisation and DL approach for managing the supply chain for food production and upkeep. Using a DAE model, first describe how to utilise greenhouses to produce food, including how to forecast plant growth and yield, and then go on to show how to use refrigerators to sell food. After that, the AWP algorithm is used to optimise the supply chain. This system checks the expiration date and uses optical recognition to guarantee that people's health and food safety are not compromised. Conventional methods can't compare to the suggested work performance [22].

Tungare and Jha (2023) details the process that went into creating Retail Mitra, a mobile app that promotes retail stores. This app lets the owner of a brand get information about each product in each store by entering daily stock levels, receipts, expiration dates, and sales through a cloud-based app. Because of this, the promoter's performance is rather disciplined, and the area managers are able to remotely comprehend and handle concerns at different stores with the retailer. The development platforms utilised R programming language, while MySQL was used for data collection and storage. Dashboards were created and made available to the brand owners so they could compare performance by outlet. This helped boost sales by 30% and cut losses by 24% in only two months [23].

Madhushan and Kavirathna (2022) creates a model for SCND in the face of interruptions by taking into account the distribution network's direct shipment from suppliers to retailers and the varying degrees of disruptions that have happened at DC. Python optimisation models are constructed using linear programming techniques. The model's output reveals the best distribution networks to employ in the event of various disruption scenarios, including partial DC interruptions and complete DC outages, with a focus on minimising costs associated with direct shipping. As a whole, direct shipping may be used to optimise SCND in general and under interruptions specifically by identifying marginal values in various aspects. By prioritizing the expenses associated with DC failures, this strategy may be utilised to strengthen DC resilience [24].

TABLE I. SUMMARY OF RECENT STUDY ON MACHINE LEARNING FOR RETAIL SUPPLY CHAIN OPTIMIZATION

Author(s)	Focus Area	Techniques	Challenges	Future Work
Omer, Hassan & Aziz (2025)	Demand forecasting in supply chains	Statistical forecasting, supervised & unsupervised ML, ensemble learning, deep learning	Data quality, model interpretability, and integration with existing supply chain systems	Develop real-time adaptive forecasting, hybrid ML models, and Explainable AI (XAI)-based decision support.
Vlachos & Reddy (2025)	Machine learning applications in supply chain management	Systematic Literature Review (107 studies), thematic analysis, 4Vs framework	Limited visibility, data variety, scalability, and adoption of ML in practical supply chain environments	Explore Generalized AI, Large Language Models (LLMs), and advanced ML frameworks for intelligent supply chains.
Zhao et al. (2025)	Intelligent and secure supply chain management	Blockchain and Artificial Intelligence integration	Data security, interoperability, implementation complexity, and scalability	Develop scalable AI-blockchain platforms with enhanced privacy, automation, and cross-organizational collaboration.
Mupparaju et al. (2024)	Food production and supply chain optimization	Deep Autoencoder (DAE), Adaptive Waterwheel Plant (AWP) optimization algorithm	Food quality monitoring, expiry verification, refrigeration management, and supply chain optimization	Extend the framework to large-scale food logistics with IoT-enabled real-time monitoring and predictive analytics.
Tungare & Jha (2023)	Retail inventory and sales management	R Programming, MySQL, cloud-based	Manual inventory tracking, poor outlet	Integrate advanced machine learning for demand prediction,

		Retail Mitra application, dashboards	visibility, and delayed decision-making	inventory optimization, and automated decision support.
Madhushan & Kavirathna (2022)	Supply chain network design under disruptions	Linear Programming implemented in Python	Distribution center disruptions, increased logistics cost, and network resilience	Incorporate machine learning for disruption prediction and dynamic optimization under uncertain environments.

Research Gaps: ML has shown promise in optimising retail supply chains in recent studies, however there are still significant knowledge gaps in this area. Existing research primarily focuses on individual tasks such as demand forecasting, inventory monitoring, supply chain network optimization, or blockchain-based security, while limited attention has been given to developing a unified framework that integrates multiple retail supply chain functions. Furthermore, many studies rely on traditional ML or mathematical optimization techniques without leveraging advanced ensemble learning and XAI to improve both predictive accuracy and decision transparency. Challenges related to real-time data integration, model scalability, dynamic supply chain disruptions, and seamless deployment in practical retail environments also remain insufficiently addressed. Table I summarises these limitations and shows how they underscore the need for a smart, scalable, and interpretable ML framework to help optimise the retail supply chain from beginning to end by providing data-driven decisions, better inventory management, and more accurate forecasts.

6. Conclusion and Future Work

The use of ML has been a game-changer in the retail industry, particularly in the areas of demand forecasting, inventory management, logistics planning, and decision-making. This review highlights that ML-based approaches, including ensemble learning, DL, and hybrid models, enable retailers to analyze complex data patterns, reduce operational costs, minimize supply disruptions, and enhance customer satisfaction. The lack of broad acceptance is due, in large part, to problems with data quality, model interpretability, scalability, and real-time deployment. Existing studies mainly focus on individual supply chain functions, creating a need for integrated frameworks that support end-to-end optimization. The IoT, cloud computing, big data analytics, and XAI are all examples of new technologies that might be part of the answer for intelligent, scalable ML in the future. Transparent and adaptive supply chain systems that can react to changing market conditions and boost retail performance as a whole are within reach, thanks to these innovations.

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