

Total Cost of Ownership Modelling and Procurement Intelligence: AI-Driven Approaches to Retail Supply Chain Cost Optimisation

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1. Introduction to Retail Supply Chain Optimization with AI

Retail supply chain processes require substantial investment to maintain their competitive edge, including expenditure on transportation, warehousing, information technology, and other functions. To stay ahead of the competition in resource allocation, more and more researchers take advantage of artificial intelligence methods to optimize retail supply chain operations from multiple perspectives, such as satisfying customer demands, improving operational efficiency, and reducing operational costs. The ability to leverage data-based insights to optimize operations is a competitive advantage for businesses. With rapid advancements in big data and artificial intelligence techniques, as well as the decreasing cost of data storage and computation, the data-driven framework has been recognized as a promising tool for supply chain optimization and a vehicle for reducing operational costs in retail and other sectors.

The primary goal of a supply chain is to satisfy customers, often by providing low-cost products. To do so, the firm needs to optimize all supply chain activities to reduce costs, such as transportation, production, inventory, facilities, waste, packaging, and energy. The optimization of any two or more of these components is called multitier optimization. This is a typical research topic in the field of production and operations research. When AI technology has been involved in the research, retail multi-objective optimization algorithms can also be used to study such issues. AI is a systematic method for creating human-like thought processes in the development of computer software. AI focuses on creating both expert systems and intelligent agents. AI targets extracting information from available data. In the traditional supply chain management paradigm, two initializing processes are regarded as the fundamental activities: demand

forecasting and replenishment policy. In today's consumer-driven market, companies need to reorganize—not replace—these practices. The rise of AI reflects this fundamental business shift.

1.1. Overview of Retail Supply Chain Costs

Globalization and the proliferation of consumer choice have driven the demand for reducing the cost of supply chains. The expenditures that are typically incurred while fulfilling supply chain operations can be classified into either direct or indirect expenses. Direct costs include the expenses for procurement, manufacturing, warehousing, handling, logistics, distribution, inventory, and customer service. Indirect costs cover the spending for sales loss due to stock-outs and profit loss because of excess inventory discounted sale, logistics, and damage due to handling. Moreover, distribution management and inventory holding costs contribute about 50 percent of total operating expenses and are the focal point of the supply chain. Reducing supply chain costs results in low product pricing, which largely affects revenue. In enterprises, supply chain management significantly improves overall profitability.

Moreover, competition in supply chain management can be in terms of low inventories, high service levels, fast replenishment, and price discounts. The reasons for which supply chain costs increase include time, excess labor, obsolescence, fluctuating demand, market dynamics, and expensive transportation. Higher demand for fresh goods than dry goods increases transportation costs as well as inventory holding costs. Robustness implies insensitivity to exogenous drivers such as changes in the product lifecycle of technology and consumer attitudes to certain product categories. Likewise, external improvement shows progress in influencing the supply chain by educating an external actor to regulate the system. It is, therefore, in the best interest of the retail sector to optimize inventory management systematically and use advanced methods to minimize supply chain costs.

2. Machine Learning Techniques in Retail Supply Chain Optimization

Machine learning (ML) employs various techniques to discretely solve problems in the retail supply chain, such as inventory management, and to offer accurate demand forecasting, targeted logistics, and supply stability for sound decision-making. ML uses algorithms and develops mathematical models that improve computing performance with a basic theoretical framework, finally suggesting possible solutions. Automated

and cognitive computing models detect root causes, patterns, and solutions while using real-time data analysis. The performance of ML techniques depends on the concept, and the quality and quantity of data are important attributes for more accurate and reliable results in model prediction. Data engineering, feature engineering, and model-optimized quality and data quantity significantly enhance ML solution operations to solve contextual retail challenges. The data is collected in a managed analytical pipeline, analyzed, and used to generate insights, and machine learning algorithms are then designed to power real and practical applications. The retail industry and the operational supply chain are constantly evolving, and new models and decision techniques are being developed to eliminate an inefficient supply chain. There are several practical examples of supervised and unsupervised machine learning applications in the retail sector to solve business problems and to improve operational supply chain efficiency. An executed prediction model using the predictive analytics approach to improve future sales is a hybrid model that uses the combination of a recurrent neural network and a long short-term memory on various architectures, activation functions, and an optimizer. Predictive analytics can convert supply and demand predictions, warehouses, and help make informed decisions based on a new selling strategy, time-series data of warehouse consumption during ordinary days, and holiday or promotion days. The predictability of all potential data that have serial characteristics in the warehouse provides a model with comprehensive capabilities to deal with realistic scenarios.

2.1. Supervised Learning for Demand Forecasting

Demand forecasting in retail supply chains is one of the most important challenges in yield management. Predicting patterns of customer demands is a fundamental approach for optimizing retail supply chain costs. Retailers benefit from demand predictions in instances where the primary concern is mastering seasonal variations to ensure appropriate levels of inventory in order to maintain a high level of customer service. Supervised learning has typically been applied to gain insights from the historical sales data of products of interest. Several models have been developed using various supervised learning algorithms such as linear regression, support vector machines, decision trees, and random forests to predict the demand patterns of a variety of products with different characteristics.

Linear regression is used to understand the relationships between input features and outputs, while decision trees and random forests are mostly predictive models that recursively split feature spaces into homogeneous leaves. These models have been previously used as a baseline solution in demand optimization problems. The input for training the supervised learning-based model is past sales data of a retail chain. In other words, a regression model is trained to predict future sales demands using the available sales data, whose labels are assumed to be the sales values of the products at the corresponding future dates. Feature preprocessing, data cleaning, and the preprocessing of raw data are essential steps to train the demand forecasting model. In addition, feature selection is a critical part of building an effective predictive model. The key to successful demand predictions is to determine the most important, relevant features or attributes that are associated with the sales of a product. Data preprocessing is a sensitive issue for demand forecasting using real retail sales. The data is expected to be affected by factors such as seasonality, time of the year, discounts, and other periodic promotions of the retail chain. Removing or not considering these factors might greatly affect the prediction accuracy of the model. Despite using real historical sales records as the training input, supervised learning-based models are affected by the rapidly changing market behaviors and trends. A direct application of this model to real sales might result in a lack of accuracy since the market behaviors might dramatically change and vary compared to the data of the past. As a result, the usage of supervised learning models might lead to lower demand forecasting in terms of classification accuracy or root mean square errors. Tailoring existing learning techniques to market conditions is one of the major issues that need to be addressed with this approach. Some recent works have exploited these models for solving demand forecasting problems. Real data examples in a retail chain with approximately 9,000 branches have demonstrated that supervised learning models could provide valuable insights for estimating potential sales strategies and their resulting effects prior to their practical application. It has been shown that the feature selection phase highly impacts prediction RMSE. Some different algorithms and parameterizations of the selection of randomly parameterized versions of greedy search, simulated annealing algorithms, and scatter search algorithms were compared with respect to prediction accuracy. Results on three different retail store products on a daily, monthly, and weekly basis have shown a comparative improvement when adopting the scatter search algorithm.

3. Case Studies and Best Practices in AI-Driven Retail Supply Chain Optimization

This section collects a series of engaging case studies embracing AI to optimize the retail supply chain, focusing on successfully achieved cost efficiencies. Each case study describes a different strategy embraced by a leading retailer, also providing best practices and key success metrics. It reflects on the importance of corporate culture embracing AI solutions. Each case study also reflects on the challenges with AI, their potential solutions, or workarounds, and their recommendations for retailers. In the subsequent analysis of the cases, best practices are extracted for two different, plausible retail approaches: Firstly, in the case of Fox, the company follows an omnichannel approach and highlights lessons learned for this scenario. Championing convenience as well as the delivery experience for the last mile, recommendations are deduced for retailers who share this focus. Comparably, the Charles Vögele and Plaza Brands case studies leverage concessions in other stores and, on that basis, derive best practice recommendations for retailers. Against the backdrop of retail as well as the supply chain, this section showcases AI feasibility and emphasizes the potential for cost savings. Metrics prominently include lead times, delivery and stock optimization as well as increased operational efficiency, yet it is acknowledged that efficiency gains in establishments can be challenging to measure. The importance of organizational culture is noted early, with the follow-up case study identifying this as a significant barrier – alongside those often posed by the data available. The practical segment of each case gives a flavor of how the specific project was realized. For example, Fox's AI implementation embraced a platform solution including demand forecasting, replenishment, stock optimization and allocation optimization; the Charles Vögele project encompassed a lot-size optimization to group multiple orders in one container. Overarching challenges with AI include the potential for increased spreads if connected with aggressive AI bots, product returns are complex with the risk of cancellations, and wildcards or 'nudges' are products which don't fit a consumer's usual profile. Transforming an industry, dozens of AI-based applications and platforms are currently emerging to help retailers reimagine and optimize their supply chain processes. The central value proposition of these solutions is to boost efficiency across a range of operations and reduce associated costs. In these case studies, AI's potential to optimize the retail supply chain is the focus. The applications of AI-centric solutions described here are expected, before significant scale, to have a positive effect on the supply chain

and/or business results. Although measurable ROI is emphasized in the strategic as well as technical assessments section, the improvement generated by technological advancement can have a positive effect on corporate strategy, either immediately or over a while. Thus, the case studies' purposes, scopes as well as methods employed are outlined, specifically emphasizing a focus for commercial applications.

3.1. Success Stories from Leading Retailers

Retail: Australia's largest regional retailer implemented advanced analytics and a machine learning solution to provide real-time insights into stock replenishment. The solution provided both recommended orders and a forecast that the retailer was able to use in negotiations with suppliers. The retailer intended to replace its tactical processes currently configured in its order management solution, backed up by manual and labor-intensive allocation tasks. The retailer is also looking at the potential to use AI to categorize store sizes, another manual and time-consuming task currently. The solution is expected to generate an annualized benefit of AU\$15m-20m. **Pharmacy:** A top US drugstore retailer implemented machine learning to assist in price optimization. The retailer in question has the most store locations of any drugstore in the US, leading it to be ranked number one in its sector. The retailer's large network of stores, covering diverse demographics, and the highly competitive retail market in which they operate, make for a complex environment in which to price its products. AI was chosen by the retailer as the most appropriate technology to use because of its ability to handle the complexity. Machine learning enables the retailer to move away from a rules-based approach to pricing that had been in place. The new ecosystem has the ability to connect promotions with prices and enable real-time pricing. Using machine learning will reduce end-of-life date products and increase incremental sales. The system will enable them to be accurate to six decimal places. The value of the deal was not disclosed. The retailer did not respond to our requests for comment.

4. Challenges and Ethical Considerations in Implementing AI in Retail Supply Chains

Supply chain management challenges are common and complex within the retail sector. AI technologies appear to offer potential as tools to tackle some of the supply chain management challenges within retail, including optimizing costs. Adopting AI technologies often comes with new challenges. Data integration and quality are among

the key technical obstacles. Further barriers in adopting AI are organizational in nature, stemming from resistance to change and a lack of skilled workforce. The organizational and technical challenges highlight the importance of working internally to ensure successful implementations of new AI-driven solutions. In addition to technical and organizational challenges, the proliferation of AI within retail operations raises numerous ethical considerations, particularly in relation to surveillance and consumer privacy.

Two central areas of ethical concern for retail are discussed here. First, the deployment of AI technologies may lead to some consumers feeling continuously watched by a range of actors. This may lead to reduced trust between these parties, increased adversarial attacks on the systems that surveil, and on other parties as a result of increased animosity. The risk of privacy invasion is intensified by cost-optimizing technologies that aid in the scale of surveillance processes. Second, there are systems that add a cost-reducing capability to perform price discrimination based on class, race, gender, religious belief, and ad targeting according to personal characteristics. In relation to targeting and discrimination, there is a need for transparency and accountability to control for misuse or bias that can enter these systems. Grocery retailers have a responsibility to ensure these processes are conducted ethically. Therefore, it is prudent to build in tools to ensure accountability and transparency either at a technical or organizational level. In practice, however, a lack of transparency has raised concerns about machine learning methods. Many systems are being used in a way that is not transparent, with potentially significant impacts on the lives of many people. Machine learning systems used in retail operations have the potential to automate decision-making processes and, importantly, hold the ability to reduce or exacerbate discrimination, depending on the transparency of the inner algorithmic workings. AI technologies may encode biases present in the training sets into the final system. Therefore, retailers who implement these technologies within their supply chain must mitigate these harmful biases. Retailers can thus use AI to optimize costs in differing segments without compromising ethical principles. To reduce these risks, grocery retailers should set out clear ethical guidelines and processes when incorporating AI algorithms from suppliers in optimizing costs of inventory solutions.

4.1. Data Privacy and Security Concerns

AI may access a variety of data sources, including data on the retail environment, such as relevant weather, traffic, events or holidays, as well as previous sales data and external economic or business performance data. While not as revealing as video footage, data such as heat maps of shopper smartphone activity in-store may also be used to analyze customer types and behaviors. Loyalty cards and other customer data collection techniques may help retailers tailor products, pricing, and sales tactics to individual customers. While this may improve the shopping experience for customers, the granular data collected raises privacy concerns. Access to personal data is sensitive, so legal obligations attached to its processing are more stringent. Whatever the initial legitimate processing purpose is, any further analysis and processing resulting in the use of this data as personal data incurs all the obligations of personal data processing (e.g., respecting data subjects' rights; processing under a legal basis; ensuring that personal data are made accessible to authorized personnel only and ensuring that all commitments towards data subjects are fulfilled). In this context, legal frameworks establish principles for bringing together not just fragmented markets but fragmented data privacy principles. Many businesses have had to rethink their processing activities, and those that use AI or machine learning must also comply with these rules. The winds of change are therefore sweeping through the retail world. The poorly managed use of AI, as well as the data harvested through our connected world, can result in damage to individuals, society, or environmental interests. While data used in retail may not be expressly sensitive, some people are happy to share their data as part of the shopping experience. Moreover, negative experiences can have a serious knock-on effect across the market. Thus, retailers must rely on their customers' trust to build a successful and lasting business. It is necessary to sieve and select personal data held securely and only for as long as needed. Any third party handling personal data should do the same. Retailers must implement firewalls, encryption, and malware protection as part of a robust security strategy to minimize the risks of cyberattacks. Furthermore, choosing suppliers that can demonstrate conformity to legislation and industry standards to protect against cybersecurity threats is important. Measures also include penetration testing and privacy impact assessments of the services retailers use to ascertain if there are risks to subject rights. A degree of anonymity can be helpful, either by ensuring data is not sufficiently detailed as to be re-identified or by using secure servers when using

external algorithms. In the case of shoppers' personal data and anonymization, extreme caution is needed given the value of well-processed personal data and the risks in incorrectly anonymizing. Moreover, data loss, data degeneracy, and access to certain connective data can lead to re-identification, thus rendering a trade-off between optimization benefits and data privacy. Retailers may attempt to reconcile personalized shopping, based on granular customer data, with protecting customer privacy to avoid reputational or legal damage.

5. Future Trends and Opportunities in AI-Driven Retail Supply Chain Optimization

Emerging Trends and Opportunities The retail landscape is going through significant transformation. Technological advancements are reshaping the way retailers work in the market across the globe. As a result, several retailers are counting on advanced data analytics. Retailers are also focusing on the integration of robotics and related automation technologies. This integration is intended to assist in streamlining the supply chain, optimizing processes, and improving speed and efficiency. Besides this, the use of artificial intelligence and machine learning can provide better predictive analytics as well as help retailers in decision-making with reduced lead time.

One potential opportunity in the AI-driven retail environment is predictive retail using advanced and real-time demand signals from multiple data sources that can make the supply chain industry more agile in capturing demand. Additionally, AI can help retailers model consumer choices for different scenarios more effectively based on real-time data and recent trends that can significantly reduce the bullwhip effect in the retail supply chain. AI can play an important role in the emerging field of 'Retech' supply chain, which is a combination of 'remote & technology.' It is a supply chain that forges a strong passion for human service with technological capabilities to deliver superior customer experience and integrate the alignment of the workforce with real-time demand to optimize speed and efficiency.

Overall Trend/Future Outlook In the retail industry, AI-driven solutions are increasingly becoming practical. There is a big opportunity for winning applications for AI in the supply chain, and a significant percentage of supply chain experts believe that predictive and prescriptive analytics are areas they should invest in. The average company is not likely to have the ability to develop major technology investments on its own. For this reason, it is important to be proactive in collaborating with a major

provider. Staying agile and being involved early is also important because the best supply chain models are benchmarked with increasing frequency. The Refinery of Future Process is a scenario for a retail supply chain when demand is highly variable. It will be required to update the supply chain model frequently to predict and track market dynamics. Supply chain modeling and optimizations need to be carried out more and more often today without becoming a major operational matter. In a high manner, avoiding inefficiencies. The Refinery of Future Retail Supply Chain encourages being agile throughout this perspective.

5.1. Integration of IoT and AI Technologies

IoT is a new technology framework that enables the transfer of data from sensors, devices, and machines in real time. In the retail supply chain, IoT technologies offer early visibility of potential issues and increase connectivity among different business partners. This real-time data is then aggregated and analyzed by AI innovations to make the most reliable predictions. The data from this framework will allow forecasters to be much more accurate in their predictions, which can increase supply chain efficiency and drive down costs while improving customer service. Specifically, IoT devices could be used in a variety of ways to reduce additional retail supply chain costs, such as in-store for smart shelves that automatically charge customers for any items they remove from it, or at the door for improved security that would reduce shrinkage due to organized theft. IoT technologies could also be used in the backend to automatically manage inventory.

The primary advantage of IoT is real-time capabilities, which means that companies could automatically manage their inventories in real time, further reducing costs while improving efficiency. The largest challenge faced by the retail sector in adopting these technologies and incorporating them into the supply chain is that the platform may not be compatible with other future platforms. As hardware and software are constantly changing and innovating, it remains a top priority to ensure these devices are ready to adapt to future startup initiatives. Adoption of technologies like this is still growing, and as startups seek ways to overcome current software compatibility for new solutions and the hardware supporting them, one emerging trend is the expansive solutions that can cover all the technology aspects of retail. Although this is still in the works, the enthusiasm around solving these issues and advancing AI and enhancing visibility through analysis is evidence enough that IoT and AI technologies and their integration

into the supply chain will be the major growing innovation. We believe that this fusion of AI and IoT will continue to grow and advance into the 2020s. Many retailers have been using IoT to maximize operational effectiveness in their warehouses and stores, but a new initiative has the potential to take things to the next level. Given how important the supply chain is for the retail industry, we can see this initiative quickly expanding into much of the industry.

6. Conclusion

The cost of operating a retail supply chain is at times greater than the cost of goods, squeezing profits to be reinvested in innovation and expansion. Yet, some retailers are using AI technologies to create structures that reduce these costs significantly. They do so by reformulating traditional supply chains, to employ innovative and largely efficient semi-automated solutions that optimize for cost and time performance throughout. In this essay, we have described the state of the art AI-driven retail supply chain solutions. Notably, we have discussed the benefits and challenges of employing AI for retail supply chain optimization, emphasizing the ethical considerations that sellers and developers looking to optimize supply chain costs must delve into.

Going forward, an open question is, how can the research and retail sectors foster the ongoing growth and responsible dissemination of AI-driven retail supply chain optimization technologies? We speculate that retailers would benefit from an eagerness to adapt AI-driven retail supply chain optimization, or face fierce competition in the race to implement highly efficient supply chain solutions. The next five years may very well reinvent the concept of a retail supply chain, and those who survive in the long term will have adapted to the omnipresence of AI technologies reshaping all sectors, including supply chain management.

Indeed, artificially intelligent supply chains become so good, products move from factories to homes faster at a lower cost than ever, perhaps the most significant investment hack of the century. It is, however, worth mentioning, that a comprehensive lifestyle AI retail supply chain management technique or method is yet not known. Supplementing this is limited research on AI lifestyle retail supply chain management, evident through the papers that are related to this topic in this literature study.