

Cross-Functional Data Integration and Process Automation: AI-Driven Frameworks for Retail Supply Chain Efficiency Enhancement

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1. Introduction

Understanding consumer behavior is key to achieving efficiency in the modern retail supply chain. Shopping is integral to contemporary routines, and demands across this sphere have diversified across countless mediums, locations, and markets. On subsequent levels, the largest industries in the supply chain are faced with increasingly complex business offerings and operations. The convergence of economic, social, and technological factors has shifted the role of retail supply chain management from a largely passive process to one that embodies proactivity and makes normative decisions. As such, while the industry has thrived, it has also faced a new set of hurdles and problems. Fierce competition between economies and corporations within the global context means it is imperative for supply chain systems to be handled and managed as efficiently as possible. Essentially, the need for cost-effective supply chain solutions is basic. But the challenges are unique to the industry.

In recent history, the traditional linear route to market has been mitigated as retail has become a digital and omnichannel hybrid, a mix of online and offline supply strategies. The current pandemic and subsequent public health concerns regarding shopping in person have only compounded this, solidifying e-commerce as an essential component of contemporary retail. Combined, these companies are required to operate against a bigger, more complex array of operational nodes, meaning the potential for complications and disruptions is significantly expanded. Part of the solution to efficacy in the modern supply chain lies in the power of AI to streamline and automate processes. Today's retail supply chain operations have been positively infiltrated by innovative technologies; most prominently, artificial intelligence. This essay serves as an

exploration of the integration of AI in the retail supply chain management sphere. Gone are the days when a retailer could operate based on passive supply chain management to still keep up. The discussion posits that the integration of AI is bound to significantly enhance the efficiency of the supply chain industry.

1.1. Background and Significance

Retail supply chains have long been crucial to downstream retail performance as they change and evolve to meet changing global conditions and corporate priorities. The clearest trend in recent years for retail supply chains has been an increasing emphasis on efficiency and operational performance. Retail supply chain management is an increasingly important source of competitive advantage due to the fragmentation of the marketplace and other pressures. Consumer behavior and a changing market environment have increased the need for supply chain management innovation. Profit margins and the frequency of promotional sales in both retail stores and online are placing an increasing emphasis on supply chain management practices that increase efficiency and reduce costs. The expansion of technology solutions and the growth of digital merchandise continue to increase their importance in retail. Retailers are scrambling to keep pace with these innovations and give consumers new purchase options. Manufacturers and suppliers play important roles in this rapidly changing landscape, and retail success largely depends on their ability to adjust to new expectations. The scope of undertaking this pioneering work involves designing and adapting generic supply chain and logistics processes, as well as implementing retail-specific execution strategies. Different consumer preferences and the desire to reduce costs and contribute to core margins through operational efficiency are driving retailers to modify their supply chains in complex ways. The relationship between AI and retail supply chain efficiency is introduced, and opportunities for improvement are highlighted.

1.2. Research Objectives

The primary objectives of this research are to investigate how artificial intelligence (AI) can facilitate the efficient shift of goods through a retail supply chain and, concomitantly, enhance twelve dimensions of supply chain performance, including flexibility, agility, reactivity, innovation, collaboration, visibility, resilience, eco-sustainability, servitization, circularity, reverse logistics, and postponement. To achieve

our primary research objective, we initially aim to identify the specific ways and levels in the supply chain (strategic, operational, and tactical) through which AI can revolutionize the operations management of the retail sector. Subsequently, within the objectives of a more descriptive analysis, we seek to outline the main processes and activities within a retail supply chain that can enhance their performance by means of AI. Additionally, we aim to target the mainstream of the existing state-of-the-art to ensure that it draws realistic strategic implications. We also want to address the in-depth application of descriptive objectives, exploring the competitive strategy issues underpinning the current adoption of AI by retail firms and the potential evolutionary paths that AI can plan in the retail sector.

Finally, we shall detail the principal barriers that currently hinder AI's adoption and what pathways can unlock them. Ultimately, we provide relevant managerial implications drawn from research coverage. Broadly, AI can generate benefits for low-touch and high-touch areas of the supply chain. It can smooth the shift from bulk replenishment to demand-driven replenishment by revisiting the essential supply chain alignment pillars that are "visibility," "vocabulary," and "vectors." The objectives of the research are driven by the desire to make a significant contribution to the existing knowledge regarding the potentially valuable role that AI can play in retail supply chains. Although various barriers exist to its adoption, AI prevails as strategically advantageous. The paper provides clear insights for improving the operational management of a retail chain in detail, at three different decision levels, as a response to real-world retail chains' operational strategies.

2. Retail Supply Chain Overview

The retail supply chain and how it functions form the backbone of modern retail operations. The operations involved in these processes occur at a global level where goods such as clothing are produced in various countries and then sold to consumers at retail outlets. The retail supply chain is a network composed of several interconnected entities designed to efficiently and cost-effectively move products from manufacturers to consumers. Each entity in the network contributes to the overall operations, requiring effective communication and coordination to achieve strategic and performance measures.

The basic structure of any supply chain consists of a "supply" chain and a "demand" chain. These two chains are operated in unison to effectively flow goods and services from the manufacturers of goods to the consumers who use them. The supply chain primarily consists of four components that directly impact system efficiency: suppliers, manufacturers, logistics, and operations. When incorporating a retail MCS into the retail supply chain operational processes, utilizing information efficiently and effectively will be necessary. Logistics and operations are two of the most significant components of a retail supply chain system; the dates and service levels provided from operational systems are a key component to achieving supply chain performance measures. The concept of understanding the entire supply chain and focusing on the needs of the consumer is a critical aspect of supply chain partnerships among a network of suppliers, distributors, and retailers. Initial research has revealed that every chain participant is important to overall system efficiency. Every function in the given organization serves its own purpose to promote greater overall organizational efficiency when each is operating optimally. Technology and analytics may be utilized to plan and optimize the processes in these two functions as well.

2.1. Key Components of Retail Supply Chain

The retail supply chain is composed of vital components that directly impact the extended time it takes to get a product from the original source to the final consumer. A number of crucial interactions and activities occur that reflect on an organization's ability to combine and balance the trade-offs necessary to accelerate the flow of supply and meet the demands of consumers. These components form the underlying processes of the retail supply chain. This includes sourcing, procurement, logistics, and inventory management. Actual demand affects not only how much is ordered, but also how orders are arranged.

This leading edge of the supply chain is also supported by additional elements such as supplier relationship management, merchandising, and store management. Of noteworthy significance are the collaborative links found in these components. Collaboration is another fundamental aspect of supply chains in the retail industry that stems from the deeply interconnected activities of those operating within the system. On a fundamental level, the procurement, logistics, and inventory management components must interact harmoniously. This makes sense when one realizes that each step relies

and interacts with the movements and/or data transfer provided by entities from upstream and downstream stages. Finally, it should be noted that many components in the retail supply chain are heavily data-laden. It is evident that a stipulative approach to the actual management of data is involved in both logistics and inventory management. Technology and current data management systems support all activities in the supply chain.

3. AI and Machine Learning in Retail Supply Chain

Transformative AI and Machine Learning Capabilities AI and machine learning are quickly advancing decision-support systems and operations within the retail supply chain. These technologies can actively ingest, analyze, and learn from data across various sources to make decisions that optimize performance. Implementing AI in the retail supply chain enhances various activities such as execution, collaborative applications with suppliers and partners, and information flows. This enables practitioners to streamline the integration of supply chain functions and processes. AI also provides advanced capabilities in other areas of the retail supply chain, such as predictive analytics. The technology has strong capabilities to enhance performance in areas where predictive analytic applications are essential, such as demand forecasting, stock management, and multi-tier visibility. **Real-Time Adaptive Management** As retailers develop AI models for predictive analytics, enhanced logistics, and supplier insights, they should look to develop machine learning-enabled techniques that gain capabilities to ingest and analyze large volumes of streaming data in real time and to predict events before they happen, such as stock-outs at retail locations. The process of AI and robots gathering data and analyzing the data in real time makes the real-time part of real-time and adaptive management a reality. One can re-innovate, model, measure, and synchronize real-time events more often and faster, but still in line with demand signals and value chain participants than any other available technology today. This capability then enables retailers who create a culture of enabling and innovating using AI technology to also gather data and take action in real time based on changes in the marketplace and unforeseen disruptions. Rather, AI will enhance existing real-time technologies and advance them to other uses and applications, or to new levels of connectivity, accuracy, and speed, thereby enhancing capabilities for today's existing supply chain technologies.

3.1. Applications in Procurement

In retail supply chain management, AI and other smart procurement technologies are also used to select suppliers, initially contact them, and negotiate contracts, as well as to place an order. By applying AI technologies, procurement can benefit from better data access, flexibility, and strategic business insights. AI, combined with real-time data analytics, can provide easily accessible and intuitive supplier performance knowledge as well as market trends to both users and managers. Predictive analytics are used to foresee future procurement needs, enabling an organization to identify and manage trade-offs and risks in critical procurement decisions. Enterprise AI helps sourcing and procurement teams minimize inefficiencies and devise consistent sourcing strategies through the integration of various AI applications, including strategic sourcing, supplier selection, contract management, and ERP integration. Sourcing services are offered to support the client's strategic requirements in preparing and conferring purchase agreements and are provided to satisfy the prime purchasing of goods that can be requested on a purchase order or invoice.

AI can monitor sourcing needs and manage the RFP and other related communication requests of suppliers. In the procurement phase, our solutions, developed using AI techniques, concentrate mainly on tender or negotiation management, supplier selection, and workflow management for procurement, contract, and post-contract creation. Although tender management in competitive procurement has been the main target of existing research, we concentrate in particular on the AI methods used in this process, which are different from those reported earlier by analyzing the practical settings used for retail sector solutions. Using AI applications across sourcing and procurement, answer strategic questions to take procurement operations to the next level. Integrated AI capabilities can help procurement teams find savings opportunities. Predictive analytics also help procurement teams understand their future needs and support these strategic conversations, like tracking events that could disrupt supplier networks and negotiation risks when procurement should be in a rush. From the interaction values that suppliers seek to pay in the long term, normal or exceed, to details from customer service calls, organizations have the tools to identify trends and patterns to help them negotiate.

3.2. Applications in Distribution

AI also offers the opportunity to revolutionize distribution, a part of the retail supply chain. On the most tactical end, AI can help retailers and manufacturers optimize the routing and scheduling of their delivery fleet. By combining predictive and real-time data and using advanced optimization algorithms, it is possible to produce dynamic schedules that mitigate unexpected traffic or weather-related issues to reduce transit times, creating a win-win for the logistics service provider, retailer, and end customer. Further up the line, AI can improve the degree of accuracy to which demand can be forecast. In so doing, the likelihood of demand for products being underestimated by the retailer and stock unavailability for customers can be reduced. It is also feasible to have a similar benefit in terms of ensuring overstocking is minimized, thus reducing the level of de-stocking that may be required. There are AI tools available today that can be used within the supply chain, giving full visibility of all goods from overseas suppliers, through all partners, and on to the retailer's distribution center and store network as needed. At a futuristic level, understanding the end-to-end supply chain status at any point for every unit is crucial. More on the operational side, the use of AI can improve the planning and control of warehouses. From a process perspective, it is possible to further explore the opportunities for using automation and robotics in areas within the distribution network to provide very interesting benefits not only to an operation's competitive position by directly impacting service delivery but also by the ability to command the whole supply chain by flexing the use of central, as well as local, distribution centers dependent on the retailers' strategic requirements. Consumers expect the inviolability of service, and in some cases, they do not buy a product if the delivery times are not rapid. The potential of AI can optimize the service and, at the same time, reduce the costs of shipping. The savings are not only related to the individual purchase, which in any case has its logistic cost, but to the whole supply chain management.

3.3. Applications in Inventory Management

In retail, inventory management is a delicate and complex process. Retailers require just enough stock on-site to meet customer demand and minimize stock carrying costs like depreciation or loss of consumer interest. This requires active stock level monitoring to ensure stores carry the stock levels they need. AI and machine learning can aid retailers in stock level monitoring. Manually checking stock levels is both labor-intensive and

time-consuming, making it difficult to ensure optimal stock levels. AI can be used to integrate a stock level monitoring system in a store's existing inventory management software. Using external factors such as holidays, events, and weather data, retailers can have a good idea of how much stock they will need and when. This is due to the system using machine learning to adjust stock levels and forecasting based on external factors. AI not only helps businesses forecast levels more accurately but also in planning for future eventualities.

For a growing business, predictive analysis via AI can give insight into more unpredictable events. For example, AI algorithms can analyze purchase and returns history to determine patterns in purchasers and how they buy items or what influences them. This may include consumers of a certain gender, age, or geographical location. This data will further allow retailers to better stock plan to avoid holding excess stock for prolonged periods of time and reducing the likelihood of a stock-out due to factors such as returns or warranty periods. It is the accurate analysis of the data and sales, however, that can provide true insight, which may previously have only been available with retrospective analysis. Tools can take information from various systems and consolidate it into actionable intelligence. The stock ordering can become automated collaboration between AI and trend forecasting that places more emphasis on speedy replenishment rather than deep storage, as stock is ordered with the assumption that it will be sold within a period of time. In addition, suppliers can provide a more direct-to-shelf approach, reducing the need for back rooms, which cover retail space, thus increasing potential earnings and reducing warehousing fees. Automated systems not only save time, labor, and expense but have been shown to achieve cost savings. AI-driven inventory optimization can also offer businesses more lean and agile inventory control, leading to reduced stock holdings and positively impacting cash flow. A retailer integrating AI into their inventory processes is a collaborative relationship between warehouse management and AI that builds a robust stock output model that contributes to a resilient omnichannel retail strategy. The idea of an AI system to reduce out-of-stock has long been suggested. However, while demand for AI is high among retailers, with a significant percentage believing AI can solve their out-of-stock issues, retailers are slow to adopt, citing potential difficulty and reluctance to change their working practices. In this regard, the key is to integrate AI with systems that are already firmly in place, meaning that AI is a collaboration, enhancing what is already being achieved. Overall,

the potential of AI in inventory management and reordering is enormous, which would lead to a leaner, more cost-effective inventory management process overall.

4. Case Studies

ZYMERGEN

Background - Zymergen has an AI-powered supply chain optimization solution to predict better lead times and suggest potential substitution ingredients for their novel biochemicals. Integrating these capabilities into existing systems helps strategically position Zym and doubles down on their lowered cost of production. Outcomes Measured - An average initial decrease in product costs of 37% for the first steps in up to 16 products. The company also experienced supply chain security, reducing the odds of supply disruption by sourcing from regions with greater political stability. What They Say - AI is expected to increase sales revenue by 40% and improve operational efficiency by over 70%. Zym is intentionally designed from the ground up to seamlessly integrate into existing enterprise supply chain systems and can integrate with other ERP systems. Companies can start enjoying 80% of the ROI in as little as 1-2 weeks following the setup of data access and system interfacing.

DMAXOS

Background - DMAX developed a deep learning-based chatbot and automation platform to work through ERP systems to automate many of the tasks that cause lost time, such as matching orders, invoices, and payments. Further capabilities exist to automatically reconcile incoming product quality issues, possible substitutions, and shortages directly with a company's customers. Outcomes Measured - People who spend 22 hours a week reconciling are now actively working 22 hours a week driving transformation at their companies as a DMAX bot does their old job at least 50% better than or as well as they did. "This means we have now recouped the time it takes to download our partner platform, integrate with our buyers, and pay for our platform with the sustainment solution," says the DMAX president.

4.1. Successful Implementations of AI in Retail Supply Chain

There is no shortage of successful examples around the globe of AI applied to solve retail supply chain management challenges. These cases span from food retail focused on improving their in-store operations to fashion e-tailers searching for the best

matching supplier. Some players are advancing with basic process automation, such as registration and approval of a new supplier, and others are on the edge of connecting strategic decisions with full operations at the point of sale. After auditing these cases, some common factors can be pinpointed. Many retailers enjoy new possibilities by integrating basic changing technologies into their network of processes. There is a strategic vision in place that drives retail companies to search for competitive advantages. Results are becoming measurable and the value of new strategic liabilities, like data and a well-designed digital infrastructure, is now private but clear.

In Poland, Alma Market has been refining its assortment with a big data real-time analysis using big data tools. This initiative touched upon all operations in the organization and delivered positive results after only 11 months, including improvement of internal processes' efficiency, better usage of space in stores, year-to-year improvements in assortment, and reduced out-of-stock inventory since the pilot phase. Calendar Club, a franchising chain focused on gifts and entertainment segments, benefited from advanced analytics to choose the holiday products to sell. They claim an increase in consumer satisfaction and an increase in operational speed, which the product transport provider confirmed. KM Warehouse offers clients the integration of five of its warehouses to cut labor-related costs in supply chain operations. The software that links all warehouses based on machine learning and big data reduces the total number of customer claims for assembly kits yearly.

5. Challenges and Future Directions

The cost of investment and implementation, data privacy issues, and lack of qualified human personnel are among the main challenges in the adoption of AI in retail supply chains. Discussion of these challenges is pivotal to acknowledge why AI's potential is often not fully realized and thus underscore the importance of addressing these hurdles. However, overlooking these challenges may misguide retailers about the true operational reality and the efforts needed to effectively integrate AI technologies into supply chain functions. To assess the context and direction of AI, the trends along which AI is evolving might serve as valuable indicators of future growth and innovation opportunities. Firstly, an increasing number of AI technologies are maturing to meet the rigor of retail operations and thus are becoming ever more available to facilitate the adoption of retail AI in practice. Secondly, the supply chains are expected to serve now

and in the future are changing due to evolving consumer expectations and shopping behaviors. Recommendations that mostly stem from the review of existing studies and practices emphasize the need for proactive AI integration strategies based on innovation, investment, and action. The increasing involvement of AI in retail supply chain processes can enhance their efficiency and attractiveness, but only if persistent challenges and future trends are adequately addressed. Retailers should act proactively to embrace the future being realized today.

5.1. Current Challenges in AI Adoption in Retail Supply Chain

Certain features of the retail industry and the current market scenario have turned the adoption of AI in retail supply chain into a challenging task. For example, employees tend to exhibit resistance to new changes in the organization, which is among the primary reasons for project failure. Furthermore, legacy systems present in the organization pose a huge hurdle in the process of IT environment upgrades and AI-based technology interfacing. All of these inefficiencies in the structured process can limit the results that can be achieved through AI worth millions of dollars. The data generated in the retail supply chain is often unstructured. There are no standards for data formats, units of measurement, abbreviations, masters, etc., available in the supply chain domain for processing and analysis. Moreover, data quality concerns have long been a bottleneck in the supply chains of retailers.

AI in retail supply chains requires a change in the existing culture of the organization. Without dominant cultural behavior in the organization that supports innovation, experimentation, and decoupling from "this is the way we have always done things," an AI journey is bound to be difficult. Apart from employees, various stakeholders exist across the landscape of AI in retail supply chain whose support is needed to make these systems sustainable. In practice, engagement and collaboration are the keys to successful AI adoption in retail companies. The ROI associated with AI adoption provides another major challenge. The process of implementing AI can be costly, taking several months—if not years—to derive benefits from it. Organizations struggle to justify this investment, and this can be a roadblock.

5.2. Future Trends and Opportunities

The landscape in this area is changing rapidly, and recent technological advancements mean that existing research and practice will date quickly. As such, it is useful to

consider what future trends and opportunities are likely to exist. For supply chain management generally, the increasing proliferation of technology means that much more product and process data can be exchanged in the supply chain. In turn, this will support the market shift towards a more direct-to-consumer model. At the same time, while there are barriers to adoption with such new technologies, the potential to support new supply chain innovations includes automating the replenishment of stock on retail shelves and real-time demand shaping. The intelligent application of AI will be one of several key enablers of this transformation.

In the case of IoT, it is reported that IoT will be the second most relevant technology to support omni-channel management, while similarly, blockchain could disrupt the retail value chain. Furthermore, the fusion of 5G communications with AI can support retailer innovations in personalization by optimizing data transmitted to smart home and IoT devices in real-time. It is predicted that 5G will result in future retail storefronts resembling a high-tech interactive gaming environment. It is suggested that combining big data, IoT, AI, and blockchain could offer a completely new experience to customers by delivering personalized content in an ethical manner. Finally, consumer interest in sustainability in retail is growing, with increasing numbers of consumers indicating that environmental values will shape purchasing decisions. Both consumers and AI are likely to drive more sustainable practices through the value chain, which includes exploitation, manufacture, transportation, and purchase. Indeed, it is suggested that 2020 will be the year that supply chain sustainability analysis breaks through and becomes more desirable than contracting solutions, such as auditing supplied product flows for authenticity, assurance of working conditions, and transparency of the path to sustainability through smart contracts.

Fundamentally, the value of integration hinges on the extent to which it leverages AI to create new and expanded possibilities for the retailer. It is noted that companies who do not respond as fast as their IoT competitors are getting left behind. This sentiment is supported by research showing that mature retailers are integrating blockchain and AI at three times the rate of immature retailers. Smart automation and real-time data analytics and interpretation utilizing AI is a contentious edge that offers a glimpse of the future, including the application of AI in the response to COVID-19. Furthermore, AI provides a means of directing the consumption of capacity according to market demand

more effectively than any of the process initiatives of the past. There is significant potential to also further develop predictive and micro-prediction expertise within the supply chain through ongoing research. Developing supply chain AI that continues to learn and adapt to live market conditions is an effective measure. AI can help plan and execute costs while it is learning profit potential and cash optimization and considering the whole cost choices around use. These are the market demands in 2021 that will allow retailers to hold onto and grow market share in a time of unprecedented change. It is a time of great opportunity, and one that competitive retailers are embracing to their advantage.

6. Conclusion

In conclusion, AI technologies help retail companies innovate their current supply chain performance. More powerful AI systems will change the way the supply chain parts operate, integrating rather than merely coordinating them. Beyond determining commodity resources, the technologies can match production capabilities to potential consumer demands and build adaptable and flexible systems to overcome volatility. Not surprisingly, retail companies have recognized the value AI provides in various parts of a supply chain, starting with procurement optimization and progressing through warehouse and transportation management to inventory control and management of finished goods. They progressively implement AI approaches and continue to see benefits, including better forecast consistency and more aligned procurement responsibilities with stock levels. Nonetheless, several considerations and restrictions on AI in the supply chain need to be addressed, given that broader implementation of AI supply chain products will be strengthened in the long term.

The appropriate goals and performance measures, as well as the costs and advantages of technological and functional operations, have always culminated. Given rapid adjustments in consumer attitudes and expectations and continuously growing competitive stakeholders, most firms are evaluating how best to enhance the performance of their present retail supply chain strategies, tactics, and enterprise technology business solutions. This feature suggests that the retail environment of today is in a state of flux. With all the continuous improvements, the supply chain of the retailers is bound to evolve. While not all of these innovations may be implemented on a broad basis or, in any situation, satisfy their aspirations, these modifications tend to be

widely defined. In reality, in the years to come, the retail sector will supply chain trends and help evaluate the opportunities better. The current supply chain situation might be enhanced further by the changes noted. Recognizing that AI has made the greatest impact on retailers is critical for business.