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Supply Chain Management in Apparel Industry

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ABSTRACT

Worries about insufficient data have given way to worries about an excess of data in the realm of supply chain management (SCM) in today's intricate and constantly evolving world. The substantial increase in data generated throughout the apparel supply chain has transformed the landscape of SCM analysis. The effectiveness and efficiency of earlier processes have dwindled with the surge in data volume. Due to the constraints of current methodologies in handling and deciphering extensive datasets, researchers have devised novel approaches capable of analyzing and interpreting vast amounts of data. Consequently, the main objective of this study is to explore the applications of machine learning (ML) within the Apparel Supply Chain, recognized as one of the prominent artificial intelligences (AI) methodologies.

Keywords: Supply Chain, Artificial Intelligence, Machine Learning, Apparel Industry

1. INTRODUCTION

The future success of an apparel company will hinge on its ability to embrace enhanced serviceability when designing its optimal supply chain framework. Traditionally, the apparel supply chain is segmented into three variations to accommodate the entirety of the business environment. Prioritizing effective supply chain management, characterized by prompt responsiveness to market demands while ensuring optimal inventory levels, surpasses the benefits of merely efficient supply chain management, which focuses solely on inventory minimization without swift adaptation to consumer needs.

Numerous industries are contending with the challenges of supply chain management as businesses recognize the importance of fostering integrated relationships with both suppliers and consumers. Supply chain management now serves as a mechanism for enhancing competitiveness through risk mitigation and elevating customer service standards. This article delves into various challenges encountered in supply chain management, aiming to enhance comprehension of key ideas and concepts within the field. It emphasizes the importance of planning and coordination in intricate integrated systems, alongside the utilization of information technology. A framework is outlined to synchronize the supply chain, establishing the necessary structure and implementing effective controls across the enterprise and other chain components.

2. ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING

A machine learning algorithm refers to a computational process that leverages input data to achieve a specific goal without relying on hardcoded instructions. These algorithms are designed to autonomously adjust or refine their approach through iterative experiences, ultimately enhancing their proficiency in accomplishing the target objective. The process of adaptation is termed training, which entails supplying samples of input data alongside their corresponding desired outputs. The algorithm iteratively refines its configuration to produce the desired outcome when presented with the training inputs and extends its

capabilities to achieve the desired result with new, previously unseen data. This training phase encapsulates the "learning" aspect of machine learning.

Training in machine learning isn't restricted to a single adaptation process within a specific timeframe. A robust algorithm, akin to human learning, continues to refine its capabilities over time by analyzing new data and learning from past failures. The algorithm can evolve in multiple ways in response to training. It has the flexibility to select and manipulate input data to yield more definitive conclusions. Additionally, it may employ a network of potential computational pathways to optimize results. Furthermore, it can utilize the provided data to generate probability distributions and employ them for outcome predictions. (2)

Since the inception of the term Machine Learning in the late 1960s, its meaning and definition have continuously evolved. While the initial concepts of Machine Learning emerged from endeavors in Artificial Intelligence, the field has transitioned its focus from attaining AI to addressing real-world challenges and solving practical problems.

The period between 1980 and 1990 marked a crucial phase for Machine Learning as it underwent a reorganization, emerging as a distinct field in its own right. This transition was primarily driven by the growing prominence of expert systems and a decreasing reliance on statistics. Machine Learning operates by acquiring knowledge and making observations to learn and predict outcomes without directly influencing the outcome process. In contrast, Artificial Intelligence engages with the environment, interacting to learn and undertake actions aimed at achieving its objectives effectively. (1)

3. SUPPLY CHAIN IN THE APPAREL INDUSTRY

3.1 Introduction

In recent years, businesses have undergone significant transformations owing to shifts in global political, economic, social, and technological landscapes. Concurrently, consumers' preferences, demands, and needs have undergone drastic changes, intensifying competition among companies.

Supply chain management (SCM) has risen in prominence both in practical implementation and academic discourse over the past decade, garnering increasing attention and recognition. Presently, the textile and garment sectors make substantial contributions to numerous national economies, particularly in emerging countries. The textile-apparel chain is inherently complex, encompassing various activities such as yarn manufacturing, fabric production, garment assembly, and distribution. Additionally, intermediary steps and numerous auxiliary components further compound the intricacy of the chain. Companies within this sector adopt diverse operational models, each fulfilling distinct roles in the textile-apparel chain. (3)

3.2 Implementing Supply Chain Management Strategies in Apparel Industry where there is scope for improvement

A primary objective of integrating efficient supply chain practices within the apparel industry is to alleviate congestion points where bottlenecks commonly occur in the flow of raw materials and finished goods. To accomplish this goal, companies that have effectively enhanced their existing supply chain systems concentrate on specific critical areas with substantial potential for improvement.

3.2.1 Management of Inventory Investment

Vendor-managed inventory (VMI) is witnessing a growing trend as each involved party seeks to shift

inventory responsibilities onto the other. This system enables vendors to manage inventory, thereby reducing investment and risk for other chain participants. With the apparel industry experiencing shorter product life cycles, the demand for decreased inventory investment has intensified. The primary driver behind cycle time reduction is the adoption of quick response inventory systems, enhancing customer service by providing the right products in the right quantities, at the right time and place. (4)

3.2.2 Establishing Supplier Relationships

A common denominator among all successful supply chain endeavors is the cultivation of strategic partnerships with suppliers. Vendor review initiatives have prompted corporations to streamline their supplier base, prioritizing those with favorable customer feedback. Suppliers who maintain strong relationships with their customers are typically more cooperative and easier to collaborate with. As the demand for robust supplier relationships grows, manufacturers require insights into their suppliers' financial performance and business strategies. Such relationships may incentivize firms to establish compatible forecasting and information technology systems. Similarly, suppliers also benefit from access to customer data, enabling them to efficiently manage shipping details and production schedules. (4)

3.2.3 Increase Customer Responsiveness

Enhancing customer service levels is essential for fostering stronger relationships between customers and suppliers. This can be achieved by offering superior services such as shorter delivery times, thereby building a closer and more intimate connection with customers. By consistently improving supply chain efforts, firms can earn the trust of their customers and solidify these crucial relationships. (4)

3.2.4 Building Competitive Advantage

Sustaining a competitive edge over rivals is a challenging endeavor, yet it's crucial not only for attracting more customers but also for ensuring the efficiency of firm practices. Companies equipped with the resources to implement an effective supply chain management system enjoy a competitive advantage. These firms are frequently regarded as industry frontrunners, enabling them to cultivate a strong reputation and garner popularity. However, achieving this status is no easy feat, as it demands meticulous efforts to minimize costs and wastage wherever feasible. Numerous companies endeavor to enhance the competitive efficiency of their entire supply chain by implementing strategies aimed at reducing labor costs and employing other cost-cutting measures. Additionally, there's a growing emphasis on targeting the retail market, particularly as major retail giants exert considerable influence over how they conduct business with their suppliers. This shift provides the added benefit of accessing point-of-sale data and improving distribution efficiency. (4)

3.2.5 Enabling Information Technology

A robust information technology system has the potential to bolster an enterprise's communication capabilities significantly. While there may be challenges related to compatibility among trading partners, the implementation of a user-friendly IT system that facilitates access to real-time data can markedly enhance the efficiency of the existing communication infrastructure.

3.3 The need for an efficient Supply Chain Management system in the Apparel Industry:

While supply chain management (SCM) plays a crucial role in virtually every industry, its significance in the apparel sector is particularly pronounced. This is primarily due to the constant evolution of fast fashion trends and micro-seasons, which exert a profound impact on the entire industry. The rapid rate at which customer preferences shift necessitates fashion retailers to maintain an extensive array of products to cater to their demands. Consequently, the product lifecycle within the industry becomes exceedingly brief. Even before new merchandise hits the shelves, the fashion industry is already initiating production on new styles, ensuring that they remain ahead of the curve as current stock trends out of fashion. Moreover, preceding the engagement of wholesalers and retailers, the intricate supply chain of the apparel industry commences with manufacturers crafting fibers, textiles, and finished garments. This underscores the necessity for a well-structured logistics management system within the industry to consistently propel new products through the supply chain and effectively oversee inventory flow throughout operations. (5)

The fashion industry grapples with numerous challenges in demand forecasting. With short product lifecycles and rapidly shifting trends, each new season's products lack sales history. This absence of data, such as last year's sales numbers, makes it challenging for retailers to gauge product performance. Trends are influenced by various factors including media, individual influencers, weather, and economic conditions, which are often unpredictable. Predicting whether a popular trend from the previous year will persist or fade from the market is no easy feat. Moreover, consumer preferences are constantly evolving, further complicating the forecasting process. (5)

In the apparel industry, it's imperative for companies to navigate between shortages and overstocking, particularly given the condensed fashion seasons. Shortages at critical moments can profoundly affect seasonal sales, while excess inventory can erode profitability and waste valuable retail space. Effective supply chain management is key to maintaining a steady flow of products, arriving just in time to meet current demands. Without a robust SCM structure, apparel brands and retailers risk falling short of consumer expectations.

4. IMPLEMENTATION OF MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE IN SUPPLY CHAIN:

AI holds the potential to enable organizations to achieve a more automated supply chain paradigm. Depending on specific requirements, automation levels can vary from semi-automated to fully automated, or a blend of both. AI solutions play a pivotal role in automating various supply chain functions, including demand forecasting, production planning, and predictive maintenance, leveraging self-learning capabilities and natural language processing. In supply chain applications, AI seeks to replicate human decision-making processes, aiming to enhance delivery and service efficiency by identifying optimal routes and optimizing deliveries through AI algorithms.

AI presents significant advantages in terms of productivity, innovation, and global economic expansion. As per McKinsey & Company, the adoption of AI "has the potential to generate additional global economic activity of nearly $13 trillion by 2030, representing approximately 16 percent higher cumulative GDP than today." This translates to an annual GDP increase of 1.2 percent. PwC provides a more substantial estimate, exceeding $15 trillion. (7)

4.1 Areas of Supply Chain where ML and AI could be implemented:

Machine learning and AI concepts can be applied across various components of the supply chain to enhance outcomes significantly. These areas can be broadly categorized into several components: Inventory Management, Quality & Safety, Resource Management, and Supplier Relationship Management.

4.1.1 Inventory Management

The primary goal of inventory management is to address unforeseen shortages while preventing excess stock. It involves finding the right timing for purchasing orders to maintain operational efficiency and strike a balance.

4.1.2 Quality and Safety

With the ongoing demand to meet deadlines and maintain production flow, maintaining quality and addressing safety risks poses a significant challenge. A robust quality management system necessitates in-depth analysis of manufacturing processes, raw material handling, and worker procedures. Given that many manufacturers rely on manual labor, human errors are inevitable. Moreover, mishandling of products and machinery can lead to injuries, further complicating the situation. Machine learning and artificial intelligence possess the capability to analyze existing data and provide precise predictions regarding areas where product quality falls short or which operations are prone to frequent workplace accidents. By integrating ML and AI concepts into existing quality management and safety control systems, tools can enhance accuracy and efficiency, thereby improving overall performance.

4.1.3 Resource Management

The shortage of resources can significantly affect the supply chain of manufacturing companies. Despite significant technological advancements in overcoming resource constraints, there is a growing apprehension that technological substitutes may not entirely avert a major resource crisis. Faced with dwindling resources, companies must adopt a systematic approach to mitigate the associated risk of disruption and devise more resource-efficient supply chain strategies. To accomplish this, it's crucial to pinpoint dependencies and risks and then apply pertinent supply chain strategies. Utilizing tools based on machine learning and AI principles can facilitate this process. These tools not only possess the capability to forecast potential outcomes of implemented strategies but also aid in identifying the underlying causes of issues stemming from resource scarcity. (8)

4.1.4 Supplier Relationship Management

For a business to thrive, adopting a well-informed approach is crucial and demands meticulous attention. While some companies may perceive Supplier Relationship Management (SRM) as an unnecessary expense and a time-intensive endeavor, neglecting it can lead to complications within the supply chain, resulting in various adverse effects. However, implementing SRM practices can be intricate, especially within multinational supply chains with a vast network comprising thousands of suppliers. The application of machine learning and AI concepts can streamline and enhance the implementation of a robust SRM system, simplifying the process while boosting efficiency. Consequently, companies can cultivate more fruitful supplier relationships, fostering their ability to thrive, expand, and bolster profitability. Moreover, this approach equips companies with a deeper comprehension of their supply

chain dynamics, enabling them to make informed strategic decisions and anticipate, as well as mitigate, potential disruptions or complications. (9)

4.2 Ways by which ML and AI can benefit Supply Chain:

4.2.1 Predictive Analytics

Precision demand forecasting offers numerous benefits in supply chain management, such as reduced holding costs and optimized inventory levels. Leveraging machine learning models enables companies to harness the power of predictive analytics for demand forecasting. These models excel at uncovering latent trends within historical demand data. Additionally, supply chain machine learning can proactively identify potential issues before they escalate into significant business disruptions. An effective supply chain forecasting system ensures that the organization possesses the resources and insights necessary to tackle emerging challenges and threats. Moreover, the timeliness of the response is directly linked to the company's capability to promptly address issues. (10)

4.2.2 Automated Quality Inspections for Robust Management

Logistics hubs often employ manual quality checks to examine containers or items for potential damage during transit. The application of artificial intelligence and machine learning has broadened the capabilities of automation in supply chain quality inspection. Machine learning-enabled methodologies enable automated inspection of faults in industrial equipment and image recognition-based damage detection. The advantage of employing these advanced automated quality inspections is the reduction in the risk of delivering defective or damaged goods to clients. (10)

4.2.3 Real-time visibility to improve customer experience

According to a Statista analysis, visibility remains a persistent challenge for supply chain organizations. A successful supply chain company prioritizes visibility and tracking, continually exploring new technologies that can aid in this regard. Machine learning solutions, incorporating deep analytics, IoT, and real-time monitoring, offer businesses the opportunity to significantly enhance supply chain visibility, elevate customer experiences, and expedite delivery timelines. Achieved through machine learning models and algorithms, these solutions analyze historical data from diverse sources to identify correlations across operations throughout the supplier value chain. Amazon serves as an exemplary illustration of this concept, utilizing machine learning techniques to deliver outstanding customer service. (10)

4.2.4 Streamlining production planning

Machine learning can streamline production schedules by identifying inefficiencies and waste through sophisticated algorithms trained on existing production data. Integrating machine learning into the supply chain is crucial for establishing a more adaptable ecosystem capable of effectively managing various disruptions. (10)

4.2.5 Reducing costs and response times

An expanding array of B2C enterprises are leveraging machine learning techniques to initiate automated responses and rectify demand-supply imbalances, thereby reducing costs and improving customer experiences. Machine learning algorithms' ability to analyze real-time data and historical delivery

records aids supply chain managers in optimizing routes for their vehicle fleets, leading to reduced travel times, cost savings, and enhanced productivity. Moreover, by improving communication with diverse logistics service providers and integrating freight and warehouse procedures, administrative and operational costs within the supply chain can be reduced. (10)

4.2.6 Warehouse management

Efficient supply chain planning is often linked to warehouse and inventory management. Machine learning facilitates ongoing enhancement in a company's endeavors to achieve the desired level of customer service quality at the lowest cost, utilizing the latest demand and supply information. Machine learning in the supply chain, with its models, methodologies, and forecasting capabilities, has the potential to address both under and overstocking issues and revolutionize warehouse management practices. Additionally, companies can harness AI and machine learning to analyze vast datasets and significantly mitigate common human errors. (10)

4.2.7 Reduction in forecast errors

Machine Learning serves as a potent analytical tool that can aid supply chain firms in handling vast volumes of data. In the supply chain, machine learning entails processing massive amounts of data characterized by significant variety and unpredictability, stemming from telematics, IoT devices, intelligent transportation systems, and other robust technologies. This capability enables supply chain organizations to garner deeper insights and make more precise projections. According to a McKinsey analysis, AI and machine learning-based supply chain solutions have the potential to reduce forecast errors by 50%. (10)

4.2.8 Advanced last-mile tracking

Last-mile delivery plays a pivotal role in the supply chain, with its ramifications directly influencing various verticals such as customer experience and product quality. Data indicates that last-mile delivery constitutes 28% of total delivery expenses within the supply chain. Machine learning in the supply chain can yield substantial advantages by integrating data points such as address entry patterns and overall delivery time to specific locations. Moreover, ML can aid in streamlining processes and providing customers with more accurate shipping status updates. (10)

4.2.9 Fraud prevention

By automating inspections and auditing procedures and conducting real-time data analysis to detect anomalies or deviations from typical patterns, machine learning algorithms can enhance product quality and mitigate the risk of fraud. Additionally, machine learning techniques can help prevent privileged credential abuse, a prevalent cause of breaches across the global supply chain. (10)

5. CURRENT USES OF ML AND AI TOOLS BY COMPANIES TO IMPROVE SUPPLY CHAIN MANAGEMENT:

In the e-commerce sector, Amazon, a prominent leader in the supply chain market, utilizes cutting-edge and innovative systems, including automated warehousing powered by artificial intelligence and machine learning. Amazon's highly efficient supply chain system manages various facets such as

packaging, order processing, delivery, customer support, and reverse logistics, leveraging intelligent software systems alongside advanced transportation and warehousing infrastructure.

Likewise, the supply chain ecosystem of tech behemoth Microsoft relies heavily on predictive insights derived from machine learning and business intelligence. Operating at a massive scale, Microsoft offers products and services that generate vast amounts of data, necessitating integration for predictive analysis and operational optimization. Leveraging machine learning techniques, the company has developed a seamlessly integrated supply chain system that enables real-time data acquisition and analysis. Additionally, Microsoft's robust supply chain incorporates proactive and early warning systems, aiding in risk mitigation and swift issue resolution.

Likewise, Alphabet Inc. relies on a flexible and responsive supply chain that seamlessly collaborates across multiple regions. Alphabet's supply chain incorporates machine learning, AI, and robotics to automate its operations.

Consumer goods leader P&G boasts one of the most intricate supply chains, featuring a vast product range. The company effectively employs machine learning techniques, including advanced analytics and data application, to manage end-to-end product flow seamlessly.

Automobile companies such as Rolls Royce, in collaboration with Google, have integrated machine learning and artificial intelligence technologies to develop autonomous ships, effectively replacing entire crew roles. The company's existing ships utilize algorithms to precisely detect surrounding objects in the water and classify them based on the potential threat to the ship. Furthermore, ML and AI algorithms are employed to monitor ship engine performance, oversee security measures, and facilitate cargo loading and unloading operations. (10)

6. CHALLENGES & BARRIERS WHILE IMPLEMENTING AI AND ML IN SUPPLY CHAIN:

While the adoption of ML and AI concepts and tools appears to offer a promising solution for many key supply chain activities, several challenges hinder their implementation. Despite technological advancements over recent decades, the transition from theory to real-world application poses significant hurdles. ML and AI face various issues that must be addressed, including:

6.1 Lack of big, clean data

AI, akin to other computational processes, relies heavily on high-quality data. Machine learning (ML), in particular, demands vast amounts of precise data to train algorithms and construct predictive models effectively. Nevertheless, many companies encounter challenges related to data quality and acquisition capabilities.

Companies can enhance their data quality by implementing robust master data management practices and integrating real-time data into their processes and systems whenever possible. Real-time, multi-party digital business networks play a crucial role in this effort by continuously synchronizing external systems, ensuring a "single version of the truth" and enabling businesses to operate with the most up-to-date information.

Consideration should also be given to solutions featuring pre-trained, ML-based algorithms, which leverage extensive data from similar scenarios and corporations. Digital business networks have the capability to rapidly refine well-trained algorithms and intelligent agents, which new network members can leverage owing to the large volumes of transactions they facilitate. (7)

6.2 Compartmentalized AI is unintelligent AI

Supply chains are inherently cross-functional and cross-enterprise, with the necessary information dispersed across internal and external partners. Companies that attempt to integrate AI in fragments, disregarding the overall picture, risk experiencing suboptimal results. Without access to all relevant data, algorithms may have blind spots and overlook opportunities for optimization and execution.

To enhance data accuracy, context, and completeness, companies should strive to incorporate as many relevant systems, operations, and trading partners as possible. The objective should be to link the entire supply chain to a real-time network from the source to the end customer. Only a comprehensive supply chain solution that monitors both demand and supply can fully optimize critical activities such as inventory levels and logistics management. (7)

6.3 Black box versus explainable AI

When researchers found that the algorithm exhibited a significant bias towards recruiting men, Amazon's experiment to use AI for talent acquisition went awry. This occurred because the algorithms were predominantly trained on data from male candidates. Consequently, the AI downgraded applicants from two women's colleges and made other inaccurate gender-based assessments.

AI inputs, processes, and decisions must be transparent. Companies need to comprehend the workings of algorithms, their decision-making processes, and how they generate and deliver value, at least in broad terms. Ideally, the system should explicitly articulate the rationale behind decisions, enabling users to scrutinize, approve, and override autonomous agent decisions. Companies should have the ability to customize algorithms to align with their specific requirements. (7)

6.4 Short-sighted optimization

Every procedure and modification carries a cost. When these costs are not factored into decision-making, the outcome can be worse than if no action was taken at all. It's easy to overlook the long-term consequences of actions in complex supply chains with multiple partners and systems. Many solutions make the mistake of overhauling the entire supply chain, leading to unnecessary changes and expenses, when a small or localized adjustment would suffice.

To address this challenge, optimizations should be continuous rather than one-off, and they should involve the smallest number of entities possible to minimize network disruption. These incremental adjustments can yield significant gains without causing disruptions across the entire supply chain. (7)

6.5 Over-enthusiastic AI vendors

Many companies have embraced AI, which is understandable given the ambiguity of its definition and its broad and expansive scope. "Machine learning" is a more well-defined term often used interchangeably with "artificial intelligence."

However, when employing terms such as "artificial intelligence," "machine learning," "neural networks," "deep learning," and similar, providers need to clarify their meanings. Most importantly, companies must illustrate how their AI surpasses standard heuristic algorithms in terms of business value. How does it operate? Does it encompass all systems and businesses to cover the entire network? Is it limited to specific functions or domains? Who is utilizing it, and what have the results been? (7)

6.6 The AI skills gap

The rapid advancement and growing feasibility of AI have caught many businesses off guard. This is due to AI requiring modern capabilities such as new languages, frameworks, and thinking methodologies. Few businesses are adequately prepared to adapt to this shift.

As the market gradually addresses the skills gap, businesses should proactively assess their requirements and potential new hires. To facilitate the transition to ML and AI technology, they should explore options such as training existing staff and providing incentives and opportunities for new career paths.

Another option is to partner with a technology company possessing the resources and expertise to develop and manage an AI-powered platform. This enables businesses to swiftly establish operations and begin observing tangible results. (7)

7. FEASIBILITY

Companies have recognized that to capitalize on the advantages of AI, they must cultivate an agile, flexible data culture grounded in ongoing learning and enhancement. Any AI implementation proposal must offer a clear and quantifiable business value to be considered optimal. Additionally, it must be practical, considering both ease of implementation and data availability as distinct aspects of feasibility. (11)

Companies should initiate their AI endeavors on a small scale, prioritizing the research and trial phase with Proof of AI development. These tests should be gradually and meticulously scaled up, ensuring that each advancement brings the project and the organization closer to AI adoption with assured and precise business value. To achieve scalability, they need to accelerate the AI prototype by leveraging real-time data from the production environment. Once the enhanced model, validated with real data, has been implemented, the AI system can be deployed across various branches or factories. Companies must continually monitor and optimize the created value, output quality, and reliability to attain maturity in this realm. (11)

8. CONCLUSION

Enhancing supply chain efficiency is pivotal for any enterprise. Given the challenging profit margins within which businesses operate, even minor process improvements can significantly impact the bottom line profit.

Innovative technologies such as machine learning facilitate the management of challenges related to volatility and accurate demand forecasting in global supply chains. According to Gartner, it is predicted that by 2023, at least 50% of global companies engaged in supply chain operations will be utilizing AI and ML-related transformational technologies. This trend underscores the increasing popularity and adoption of machine learning in the supply chain industry.

However, to fully leverage the benefits of machine learning, businesses must plan ahead and begin investing in machine learning and related technologies today. This proactive approach will enable them to realize increased profitability, enhanced efficiency, and improved resource availability in the supply chain industry. (10)

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