The Application of Artificial Intelligence in the Collaborative Optimization of Digital Supply Chains within E-Commerce

Kai Wang *

College of International Studies, Southwest University, Chongqing, China

* Corresponding Author Email: wkai18055@gmail.com

Abstract. The thriving development of artificial intelligence in recent years has promoted revolutionary transformation in every industry. The great potential of AI attracts every industry to integrate Artificial Intelligence (AI) into their operating systems, and supply chain is one of them. With the help of many advanced technologies, supply chain management has been improved significantly and the integration with AI has further propelled the progress. The author intends to generalize the practical application scenarios of AI in e-commerce supply chain optimization through a case analysis and finds out potential challenges to consider solutions. This paper selects JD.com, one of the Chinese top e-commerce companies that operates its own supply chain as a research example. Then, this paper generalizes four aspects of application scenarios in supply chain optimization with AI, including demand forecasting, procurement, inventory and warehousing, and logistics and delivery. Moreover, there are still some challenges for supply chain optimization with AI such as capital pressure and privacy safety. Through the generalization of application scenarios of AI in supply chain optimization and analysis of potential challenges, the author wishes to explore further possibilities for using AI to optimize supply chain.

Keywords: AI, Supply Chain Optimization, E-Commerce.

1. Introduction

Over several decades, many technologies have continually been driving the development of supply chain. While supply chain has been improved much with these technologies, it still has some limitations, such as autonomy. In recent years, the advent of AI revolutionized supply chain. This paper selects the supply chain of e-commerce as research target, focusing on making clear how AI optimizes supply chain in demand forecasting, procurement, inventory and warehousing, and logistics and delivery. The author compares conventional supply chain with AI optimized supply chain, and lists limitations of traditional methods, proving AI's revolutionary role in optimization. Then, this paper takes JD.com as typical case to analyze e-commerce enterprise to demonstrate the optimization process. In the end, the paper lists several challenges for applicating AI to supply chain optimization and solutions.

2. Scenarios of AI in the Collaborative Optimization of E-commerce Digital Supply Chains

There is no doubt that the advent of e-commerce is a milestone of the twenty-first century. Today, it profoundly influences every aspect of people's lives. One of the core elements that underpins the smooth operation of e-commerce is supply chain. Therefore, the supply chain also needs to continuously integrate advanced technologies to achieve iterative upgrades in order to meet functional requirements across different periods. The focus for the next decade will be AI and AI is actively integrated into every aspect of e-commerce.

2.1. Demand Forecasting Optimization with AI

Actually, demand prediction models have been the cornerstone of the operational efficiency for many industries who have complicated supply chains, especially for retail and e-commerce. With accurate demand forecasting, business can rationally plan inventory level and manage production

schedule, thereby enhancing the efficiency of entire supply chain [1]. Therefore, companies start to research from various perspectives, striving to achieve the most accurate forecasting. Meanwhile, the increasingly mature AI technology provides an opportunity for substantial optimization of supply chain. In the past, supply chain management usually focused on procurement, production, inventory and logistics, which mainly served to ensure continuity in production and sales. However, with the increasingly complex market environment, enterprises start to realize the importance of precise prediction. They used to use statistical methods to predict demand through historical sales data and sales experience. Unfortunately, the results often deviated significantly from expectations with the limitation of volume of data and models. Thanks to the development of cloud computing, big data, and artificial intelligence, the present demand forecasting is much more precise and detailed. As one of the subsets of artificial intelligence, machine learning makes a great contribution to accurate forecasting. It takes advantage of various algorithms and techniques to support computers to learn from data, thereby making predictions and decisions without being explicitly programmed. When it is applied to demand prediction, machine learning can figure out a series of models, correlations and trends that can be used to predict future demand and optimize inventory level according to historical sales data, customer demographics, market trends and other relevant factors [2]. The greatest reliance on machine learning for demand forecasting lies in its capacity to process vast quantities of data. Generally, machine learning techniques empower supply chains the capability to deal with large volumes of data and analyze a variety of complex factors while making decisions and predicting demands. At the same time, it also ensures the accuracy of the forecast.

2.2. Procurement and Supplier Optimization with AI

As one of cornerstones of supply chain, procurement largely determines the operation of supply chain, therefore, companies always strive to optimize procurement as much as possible. In the past, companies usually adopted traditional procuring strategies. They distributed their procurement orders to several suppliers, thereby achieving economies of scale and lower purchase prices. This strategy certainly reduced costs but it also caused centralized risks and complex purchase management. When time comes to AI era, AI revolutionizes the procurement process. Enterprises start to use techniques like machine learning, natural language processing to automate tasks, optimize decision making and provide insights. The system that is integrated with AI can use algorithms to help companies make reasonable selection while choosing suppliers and optimize procurement process through demand forecasting [3]. It also enables organizations make decisions on the basis of a large volume of datasets, enhance operation efficiency and establish firm relationships with supplier partners. With AI techniques, the complexities of modern supply chain will not be difficult for procurement teams because they can use AI to develop innovative strategies as soon as possible. Actually, each procurement decision is heavily dependent on the accuracy of demand prediction. As mentioned earlier, machine learning has much improved the accuracy of demand forecasting. These enhanced predictions allow procurement team to make reasonable purchase decisions, avoid excess inventory and reduce spending on carrying costs and warehousing. Moreover, AI automates the process that companies use to evaluate and select suppliers through analyzing their financial stability, delivery performance, compliance records and market reputation. Another AI technology frequently used in procurement is natural language processing. It is usually employed to automatically analyze complex contracts with legal jargon and intricate terms. Natural Language Processing (NLP) algorithm can extract critical information, reducing time spent on contract revies and minimizing the risks of human errors [4].

2.3. Inventory and Warehousing Optimization with AI

How to manage inventory level and warehousing consistently pose challenges for business. Before the advent of AI and other advanced technology, organizations usually managed inventory levels according to operational experience and historical sales. In order to avoid stockouts, they usually take the measure of increasing safety stock. The common methods used in inventory are economic order

quantity and reorder point. Although these two approaches can maintain a certain operational standard, they still suffer from inaccuracies in forecasting, making them prone to issues such as excess inventory and stock shortages. As to the management of warehousing, businesses usually rely on manual operation and paper documentation, including material receipt, stocktaking, picking and dispatch. Moreover, unreasonable warehousing layout and outdated handling methods all lead to low operation efficiency. Organizations have to pay a large amount of money for unnecessary expenditure each year. Therefore, it is urgent for businesses to improve the efficiency of inventory and warehousing management, cutting unnecessary costs. It is also one of the foremost challenges for them to maintain a perfect balance among inventory levels in order to limit the damage effects of both stockouts and overstocking. AI technology makes things easy. Dynamical demand forecasting powered by AI systems much improves accuracy, allowing business to advance plan their inventory demands. AI also can integrate external variables like transportation delays, production capabilities, market trends, weather and supplier lead time within their predictions to forecast the time of a likely stockouts or overstocking situation and offer warnings [5]. What's more, AI technology revolutionizes warehousing management. AI analyses item outbound frequency and dynamically adjusts storage layout, positioning 'high-frequency goods' near dispatch points to minimize picking routes. Now, it is common to see automatic transport robots working in warehouses. Organizations integrate AI and visual recognition technology to achieve automated goods receiving, dispatch and sorting, which much improves operational efficiency and reduces risks of human errors.

2.4. Logistics and Distribution Optimization with AI

User experience has always been the top priority in services. In the context of supply chain, business is striving to optimize their logistics and delivery as much as possible to create convenience for each customer [6]. Logistics and distribution constitute the critical final stage of the supply chain. Traditional logistics and distribution primarily rely on the experience of drivers or dispatchers to plan fixed routes. However, this approach is ill-equipped to handle external disturbance like weather, traffic and order changes, making delay commonplace. Moreover, inefficient manual allocation of vehicles to orders makes it difficult to respond to order changes. Furthermore, poor coordination between warehouse picking and transport operations leads to prolonged waiting times. To ensure delivery rates, companies typically increase redundant transport capacity, resulting in excessive costs. AI technology developed a dynamic approach for route optimization with its ability to analyze large volumes of data in real-time. This approach can adjust delivery paths on the basis of external factors, like traffic conditions, weather, and vehicle performance. With this approach, AI will help reduce energy consumption, decrease delivery time, and enhance overall cost-effectiveness [7]. In the optimization of logistics routes, AI systems are able to continually adjust according to up-to-date information, enhancing flexibility and efficiency. The origin of data that is used to dynamic route optimization comes from traffic sensors, GPS devices, weather reports, and accident databases. Consequently, business can make quick respond when facing unforeseen events, such as traffic congestion, road closures, or adverse weather, avoiding disrupting scheduled deliveries [8]. In the delivery part, autonomous delivery systems are changing the game. These systems integrate advanced technology, like machine learning and robots with self-driving vehicles, including autonomous trucks and drones. With advanced technologies helping navigate, optimize, and carry out delivery operations, autonomous delivery systems can distribute items without the need for direct human intervention. Generally, drones are used for small parcels, and autonomous trucks for bulky items or long-distance freight.

3. Case Analysis

JD.com, one of the largest e-commerce enterprises in China, provides an illustrative example of how AI reshapes traditional supply chain management. At first, JD.com relied on third-party logistics providers but this resulted in suboptimal delivery efficiency and poor customer experience. Therefore,

JD.com determined to establish their own supply chain system. Historically, companies including JD relied on conventional approaches in procurement, inventory, and logistics, which often resulted in inefficiencies and rigid operations. Before the introduction of AI, JD likewise operates their supply chain through manual forecasting and reactive decision-making. During the process, they used algorithms to improve accuracy as much as possible, the results still suffer from low efficiency and limited granularity. Rigid structures of traditional supply chain make it difficult to proactively anticipate risks like supplier delays and structural market shifts because it usually relies on historical data or human instinct to work. Therefore, operation team always fails to deploy strategies when it meets disruption. Moreover, the connection among departments and upstream or downstream is not close, resulting in poor communication and misunderstanding [9]. Evidently, even for a major corporation like JD.com, operating a supply chain under constrained technological conditions is subject to the same inherent drawbacks. In the context of procurement, JD has a powerful procurement team who always can get a lower from suppliers, enabling JD.com to serve customers at lower prices while maintaining product quality. Although JD.com can secure lower prices through economies of scale during procurement, the difficulty in accurately forecasting market demand often leads to overstocking. With AI technology such as machine learning and algorithmic models, JD is able to score and screen supplier on the basis of historical performance, credit records, and delivery capabilities, thereby achieving a more favorable balance between cost and risk. The formidable computational power of AI technology enables it to process vast quantities of data to provide more precise forecasting. In the context of inventory management, compared to using historical sales data and static models to manage inventory and manual labor and paper-based documentation to operate warehousing, JD applies dynamic demand forecasting models that incorporate external factors such as seasonal changes, logistics delays, and regional demand variations with AI implantation. In warehousing, JD intelligent warehouse system (storage-rack mobile robot scheduling algorithm) employs real-time scheduling strategies to enhance task matching efficiency between robots, shelving units and workstations, thereby boosting overall warehouse operational efficiency [10]. According to public report, at Yiwu's "Asia No.1" logistics hub, JD implements "goods-to-person" picking model with AGV robots, QR codes and inertial navigation technology. This approach achieves approximately threefold efficiency gains over traditional 'person-to-goods' methods, with peak picking speeds reaching 86,000 items per hour. In the context of logistics and delivery, JD has abandoned the traditional logistics model reliant on dispatchers' experience and fixed route planning. After the integration with AI, JD's logistics system employs real-time data from GPS, traffic sensors, and weather databases to dynamically plan delivery routes. Moreover, JD has pioneered the use of autonomous delivery technologies, including drones for rural areas and unmanned delivery vehicles for last-mile distribution in cities. This case demonstrates that AI enables enterprises not only to achieve operational efficiency and cost reduction, but also to build a more flexible, data-driven, and customer-oriented supply chain ecosystem.

4. Challenges and Countermeasures in AI Application

There is no doubt that AI has been revolutionizing supply chain from various aspects. Many cases also have proved the successful application of AI to supply chain. However, the present AI is not mature enough and there still is a long way for AI to further develop. Therefore, it is necessary to make clear these challenges and find out methods to overcome them.

4.1. Challenges in AI Application

AI does indeed offer advantages in supply chain optimization, including more accurate forecasting, lower costs and greater efficiency. However, in practical implementation, enterprises will also face a series of challenges. One of the largest challenges is the hefty investment. To integrate AI with supply chain, businesses need to purchase or develop big data analytics platforms, AI decision support systems, and predictive modelling tools. Moreover, AI needs the support of cloud computing and

edge computing while dealing with vast volumes of data because AI places extremely high demands on computational power and storage capacity. To establish smart logistics hubs, businesses should invest much in hardware infrastructure, including Internet of Things (IoT) sensors, automated warehouse robots, and automated delivery system [11]. The pressures from substantial capital investment, long payback period, and uncertainty of Return on Investment (ROI) are difficult for small and middle-sized enterprises to bear. Another challenge is the rising ethical considerations as the application of AI technology. Establishing smart supply chain with AI technology, enterprises usually need to share part of their sensitive information with one another. In order to better serve customers, businesses need to collect and store their private information. Therefore, how to store and protect information becomes crucial to address concerns related to bias and discrimination.

4.2. Countermeasures in AI Application

Actually, for many large enterprises, capital investment is not the issue. However, to play it safe, they can first conduct a pilot in a specific area sector such as demand forecasting or warehouse management, gradually accumulating experience and data before expanding to other areas. This approach reduces one-off capital expenditure, shortens the ROI cycle, and increases the project's success rate. For Small and Medium-sized Enterprises (SMEs), the best approach is to find companies who provide intelligent supply chain and smart warehousing services to establish deep cooperation with them. To address privacy protection, governments must enact legislation to strengthen oversight, while businesses must exercise self-restraint and adhere to ethical standards.

5. Conclusion

This paper has discussed the application of Artificial Intelligence in optimizing supply chain management, with a particular focus on procurement and supplier selection, inventory and warehousing, and logistics and distribution. By comparing traditional approaches with AI-driven methods, it is clear that AI significantly improves demand forecasting accuracy, reduces procurement risks, enhances warehouse efficiency, and enables dynamic route optimization in logistics. The case analysis of JD.com illustrates how an e-commerce enterprise integrates AI with its supply chain and proves the success of AI application to supply chain optimization. However, there still are challenges for AI application to supply chain optimization. The measures provided by this paper still are limited and it is necessary to find better ones with the development of technology and further research. Overall, AI is revolutionizing and reshaping supply chain management and will continue to serve as a key driver for digital transformation in the e-commerce industry. While AI current practices already demonstrate remarkable benefits, the potential of AI has yet to be fully unlocked. Future research should explore how emerging technologies can be integrated with AI to build smarter, more resilient, and sustainable supply chains.

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