

Advanced Computing in Supply Chain Management

Shence Yang^{1,a,*}

¹Computer Science department, University of Toronto, Toronto, M1C 1A4, Canada

a. shence.yang@mail.utoronnto.ca

*corresponding author

Abstract: With the emergence of new, powerful modern computing technologies in recent years, there is a growing interest in revolutionizing traditional supply chain management through digital transformation, aiming for greater efficiency and profitability. This paper evaluates the possible integration of modern technologies with the supply chain system through literature reviews. It introduces the evolution and drawbacks of traditional supply chain management, highlighting the significant benefits that modern technologies can bring. By investigating real-life cases and their application in various industries, this research offers an all-inclusive assessment that portrays how such methods can ameliorate effectiveness, transparency, and decision-making at different stages of supply chain management but at the same time, also pose challenges for the business. Therefore, this paper aims to raise awareness among readers and enrich their understanding of the various issues related to this subject matter.

Keywords: Supply chain management (SCM), Advanced computing technologies, Blockchain.

1. Introduction

Supply chain management (SCM) ensures that goods and services flow smoothly from manufacturers to consumers. It strategically coordinates business functions across different enterprises to enhance efficiency and customer satisfaction. The process combines procurement, logistics, and manufacturing to reduce costs and enhance competitive advantage [1]. The effectiveness of supply chains directly influences a corporation's competitiveness, customer satisfaction, and profitability. Currently, with the dramatic advancements in technology, there is an unprecedented opportunity for transformation in SCM. Nonetheless, integrating new systems into already established ones can be challenging. This study seeks to demonstrate how revolutionary computing technologies can be used in managing supply chains through literature reviews and it will examine different applications and case studies to show where precisely these technologies can help address some common weaknesses in the traditional supply chain.

This research hopes to help the audience appreciate the transformative impact of these technologies on the industry. It remains crucial, however, to thoroughly understand and evaluate each feature of these new technologies before implementing them in practice.

2. History and Current Status of Supply Chain Management

Supply chain management (SCM) has changed dramatically over the last few years. Originally defined in 1993 as a network of facilities that procures resources for intermediate and completed goods and delivers final products to clients, SCM's focus has expanded beyond logistics [2]. By 2012, SCM incorporated a strategic dimension, creating a competitive advantage for goods and services [3]. This development has made SCM more resilient, flexible, and competitive. In today's world, e-procurement and other electronic systems have been integrated into modern SCMs. SCM is now seen as a comprehensive management approach that includes logistics, procurement, sustainability, risk management, and customer service [4]. Generally speaking, SCM has changed from being focused on the storage and shipment of products to a broad conception that includes decision-making, sustainability, and integration with modern technologies. This evolution reflects the increasing complexity and importance of supply chains in the global economy.

However, traditional supply chains are reactive, based on historical transaction rules and often consisting of independent systems with minimal data sharing. As a result, there are numerous issues with traditional SCM that could have a detrimental effect on the business. Firstly, traditional SCM involves many manual tasks, including—but not limited to—processing orders, tracking stock, and documenting shipments. However, the system's heavy reliance on human labor can compromise data security and integrity. For instance, manual data entry can result in typographical errors, delays in updates, and lost paperwork, leading to inefficiencies and vulnerabilities. These issues can open the door for unauthorized access or alterations of private information, jeopardizing its integrity. Additionally, the manual procedure slows down the entire supply chain and makes it less responsive to changes.

Secondly, the lack of traceability will raise challenges in maintaining product safety and quality, inadequate inventory monitoring and control, and escalating supply chain costs [5]. Traditional supply chains prioritize production and provision over addressing customer needs. They lack optimization and the "intelligence" to quickly identify issues along the value chain. Even when problems are detected, predicting their impacts and finding solutions can be time-consuming and labour-intensive. It can lead to delays in production, mistakes and longer time-to-market, which ultimately affects customer satisfaction and corporate profits. For instance, a food business may struggle to track the source of raw materials due to inadequate record-keeping. This lack of traceability can cause delays and increase costs when identifying the source of contamination during a foodborne illness outbreak. Inadequate inventory monitoring can result in stockouts or overstock, leading to lost sales or extra storage costs. Maintaining consistent product quality is also challenging due to the inconsistency at different supply chain stages, ultimately affecting customer satisfaction and harming the brand's reputation.

Furthermore, traditional SCM also faces limited visibility and lack of real-time data, which results in complicated performance analysis and ability to identify gaps, reduces accountability, slows down and reduces the quality of decision-making, and even more Impacts ROI [6].

These drawbacks underscore the critical need for modernizing supply chain management with advanced computing technologies. This section will explore how modern advanced computing technologies can mitigate the limitations of traditional SCM and transform it into digital supply chains.

3. Application of Advanced Computing Technology in Digital Supply Chain

3.1. Block Chain

The application of blockchain technology in supply chains and supply networks is relatively new in scientific research. The first academic papers on this topic appeared in the Web of Science and Scopus databases in 2016. Blockchain technology, originally developed for Bitcoin, is a secure, distributed ledger system that facilitates trusted, transparent, and authenticated data exchange without intermediaries, thus ensuring data integrity and security [7]. It possesses two main characteristics crucial for effectively implementing logistics and supply chains. First, it facilitates the secure, verified, and trustworthy exchange of information in real time, making data accessible to all supply network members or designated parties, depending on the type of blockchain used [8]. Second, it provides smart contract-based automated transaction execution and verification. According to Christidis and Devetsikiotis, these smart contracts are blockchain-based applications that automatically enforce the terms of an agreement when certain conditions are met [9].

The article “Applications of Blockchain in the Supply Chain” indicates that blockchain technology dramatically enhances visibility and traceability in supply chain management by providing a secure, trustworthy and transparent way of monitoring products from their origin to the end consumer. This capacity solves significant problems in logistics such as verifying product source, route and authenticity. The blockchain records detailed information about where products come from, including place, time, and responsible parties, and then tracks the entire path from origin to final consumer. This holistic visibility, enabled by blockchain technology, provides a competitive edge to buyers. It enables them to trace the product’s origins, identify its producers, and understand its transportation process. Therefore, it not only builds trust among organizations but also gives them a significant competitive advantage in the market [8].

Usually, RFID (Radio Frequency Identification) tags, which can carry various data like origins, timestamps, responsible entities, mode of production and transportation details, are used alongside blockchains. RFID technology allows for the quick transfer of information without contact and allows computers to read the information of many products at once. When combined with blockchain, RFID tags can store sensitive product information, while blockchain provides a secure, shared channel to safely manage this information, ensuring that only authenticated supply chain members can access or modify it [9].

Blockchain technology is already making a significant impact on supply chains. For example, Walmart and IBM have partnered to create standards and solutions for safer food across the supply chain. They have experimented with tracking and tracing products such as pork and mangoes from China to the United States. According to Walmart, implementing blockchain has cut down the time it takes to trace a package of mangoes from farm to store from days or weeks to just two seconds. Furthermore, Provenance offers blockchain-based software solutions for product traceability [10], while Cargill lets consumers use blockchain to trace their Thanksgiving turkey back to its farm of origin [8]. These are just some instances where this technology has been applied in practice. However, there is much more potential to boost traceability and visibility and improve planning, synchronization, and operational efficiency.

A survey of 42 supply chain management experts has revealed its major hurdle: a need for more knowledge about blockchain. According to the poll, 80% of respondents already knew how valuable blockchains could be when integrating with the supply chain [8]. However, more education is still needed to ensure individuals possess the expertise required to use it effectively.

3.2. Internet of Things (IoT)

The Internet of Things (IoT) links millions of devices, such as sensors, to the web so that they can rapidly exchange data with each other without human intervention. IoT is a great asset in terms of data processing since it automates daily operations and business processes. Nonetheless, there are some issues that come with it like managing many connected devices and dealing with massive volumes of their generated data [11].

Integrating IoT into SCM offers several benefits. One such benefit is the significant increase in visibility at this level through continuous monitoring, which is enabled by the strategic placement of sensors throughout the supply chain. IoT sensors continuously record and share data such as asset locations, shipment status updates, and environmental conditions. This real-time monitoring enables organizations to address issues promptly and make informed decisions, rather than remaining unaware of potential problems [12].

Additionally, IoT increases efficiency in operations while cutting costs by automating tasks and maximizing output. For instance, factories can embed sensors in key positions to predict machine maintenance. Also, IoT-driven fleet management systems can optimize transportation routes, thereby reducing fuel usage and logistics expenses. Moreover, inventory management supported by IoT ensures product availability while minimizing costs incurred due to carrying excess stock [12]. IoT devices also play a crucial role in improving customer satisfaction by enabling accurate order tracking, allowing customers to know the precise location of their packages at any given time [12].

Furthermore, IoT advocates sustainability through waste reduction. Sensors tracking energy consumption and water usage in real-time can prompt necessary actions to correct them. Also, as mentioned before, predictive maintenance can extend the longevity of the machine being used and contribute to less material wastage. Route optimization also lowers fuel consumption, thereby cutting down on greenhouse gas emissions, which supports sustainability goals while saving funds [12].

However, implementing IoT in SCM faces many challenges. Data security and privacy are significant barriers, as these devices collect sensitive information, making them attractive targets for hackers seeking unauthorized access. Hence, organizations must use robust encryption methods when transmitting or storing data and ensure safe communication channels while exchanging between different points within the network. Another area for improvement is interoperability, where the lack of universal standards and protocols makes it hard for devices produced by different vendors to communicate with each other smoothly. Additionally, scalability becomes a problem since companies must handle vast volumes of traffic from many connected things, especially those associated with big data analytics that require huge processing power. Furthermore, the high initial investment required for setting up IoT systems, including purchasing new hardware like sensors, upgrading existing networks, and continuous maintenance activities, could prevent small businesses from adopting these technologies successfully. Besides, dealing with international data protection regulations and laws adds complexity, particularly if legal requirements frequently change without prior notice from relevant authorities. Hence, careful planning followed by implementing best practices and monitoring compliance levels over a long-term period is recommended [12].

3.3. Artificial Intelligence

Using AI in SCM offers significant benefits. One major application is in inventory control and planning, where AI techniques like expert systems enable better management of inventory levels and reduce errors by predicting demand and optimizing order quantities based on real-time data [13]. For instance, the Inventory Management Assistant (IMA) improved the effectiveness of inventory management by reducing errors and optimizing safety stocks. These AI systems are more flexible and

accurate than traditional mathematical models, especially when dealing with unexpected changes in demand and supply.

In transportation, traditional supply chains struggle to adapt to real-time changes, leading to inefficiencies like increased fuel consumption, longer delivery times, and higher operational costs. Manual planning is also time-consuming and prone to human error. However, when it comes to AI, it can solve complex routing and scheduling problems using genetic algorithms (GAs) and ant colony optimization [13]. GAs mimic the process of natural selection, where the best solutions evolve over generations. They start with possible solutions and use operations like selection, crossover, and mutation to create new solutions, gradually improving them. Ant colony optimization, inspired by ants finding the shortest path to food, uses artificial “ants” to simulate this behavior and identify optimal routes. AI also helps in purchasing and supply management by automating decisions and evaluating supplier performance through agent-based systems and machine learning. By analyzing large datasets and learning from historical data, AI enhances supply chain operations' overall efficiency and effectiveness.

4. Conclusion

This paper uses a literature review to explore the potential applications of advanced computing technologies, such as blockchain, IoT, and AI in SCM. The integration of these technologies holds the promise of creating a more efficient, transparent, and waste-reduction supply chain management system. Blockchain, when coupled with RFID tags, enhances traceability and visibility by securely storing different information. IoT technology brings operational efficiency and real-time monitoring capabilities through sensors and connected devices. AI, with its genetic algorithms and ant colony optimization, offers a faster solution to complex routing and scheduling problems than traditional methods.

However, the adoption of advanced computing technologies in SCM is not without challenges. Significant obstacles include data security and privacy concerns, interoperability between different systems, high initial costs, and regulatory compliance requirements. These challenges must be navigated carefully, as failure to address them could result in legal penalties and other serious consequences.

It is important to note that this study has some limitations, such as a lack of detailed analysis of the application in different environments. Future research could explore the effectiveness of such a method in real-life companies of different sizes and types, providing a more comprehensive view of the improvements. Additionally, future work could delve deeper into optimizing the cost-profit ratio of implementing such technologies in real-life scenarios.

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