(RESEARCH ARTICLE)

Technology as a solution to the supply chain problems in the United States: What more can be done?

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Abstract

The study examined the critical role of technology in addressing supply chain challenges in the United States, with a focus on identifying gaps and exploring opportunities for improvement. Through a comprehensive analysis of existing literature and empirical studies, the research uncovered key supply chain challenges faced by firms in the U.S., including issues related to counterfeit goods, logistics inefficiencies, environmental concerns, inaccurate demand forecasting, and cyber-security threats. Also, the study examined the role of emerging technologies such as blockchain, artificial intelligence, Internet of Things, big data analytics, and machine learning in enhancing supply chain resilience and agility. This study highlighted the contributions of these technologies in promoting transparency, traceability, sustainability, and efficiency across various aspects of supply chain management. By synthesizing insights from diverse sources and datasets, the study provided valuable recommendations and strategies for leveraging technology to address supply chain challenges effectively. These recommendations covers areas such as investment in advanced technologies, collaborative data sharing platforms, integration of sustainability metrics, predictive analytics for risk management, and supply chain resilience planning.

Keywords: Supply Chain; Blockchain Technology; Internet of Things; Big Data Analytics; Machine Learning

1. Introduction

Supply chain (SC) issues have become increasingly important, especially considering recent global events that have highlighted vulnerabilities in the system [1, 4, 7]. In recent years, the intricate web of global supply chains has faced unprecedented challenges, exacerbated by the COVID-19 pandemic, natural disasters, geopolitical tensions, and evolving consumer demands [13, 6, 17, 27]. Various supply chain disruptions have occurred over the years, ranging from historical events like the fire at the Philips microchip plant in Albuquerque, New Mexico, in 2000, Hurricane Katrina in 2006, and the tsunami in Japan in 2011, to more recent incidents such as the explosion at the BASF plant in Germany in 2016 and a fire at the Meridian Magnesium Products of America factory in Eaton Rapids, Michigan, in May 2018 [17, 27, 21]. These catastrophes led to significant disruptions in supply chains, resulting in prolonged delivery delays, decreased revenues and sales, and production suspensions that impacted workforce utilization [21, 16].

These disruptions have underscored the critical need for resilient and adaptive supply chain systems. The United States, as a major player in the global economy, has been particularly impacted by these disruptions, experiencing shortages of essential goods, delays in product delivery, and increased costs of production and distribution [26]. In response to

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these challenges, businesses and policy makers have turned to technology as a solution to enhance the efficiency, transparency, and agility of supply chains. Leveraging innovations such as blockchain, artificial intelligence, Internet of Things (IoT), and advanced analytics, technology offers promising avenues for optimizing supply chain processes, mitigating risks, and ensuring the seamless flow of goods from point of origin to the end consumer [27, 26, 12]. However, despite the advancements made thus far, there remains ample room for improvement and innovation. This study aims to explores the role of technology in addressing supply chain challenges in the United States and identifies opportunities for further enhancement to build a more resilient and sustainable supply chain ecosystem. The following objectives serve as guide to accomplish the study aim.

- Identify the supply chain challenges being faced by firms in the United States.
- Assess the role of emerging technologies, such as blockchain, artificial intelligence, big data analytics and IoT, in enhancing supply chain resilience and agility.
- Propose recommendations and strategies for optimizing the use of technology to address supply chain challenges and foster a more resilient and sustainable supply chain network in the United States

These objectives are essential for advancing the field of supply chain management and addressing critical challenges within the United States' supply chain ecosystem. By identifying gaps and areas for improvement in existing technological applications, weaknesses and inefficiencies can be identified, which can then form the basis upon which mitigating strategies are formulated. This can allow stakeholders to identify successful strategies and areas for refinement, informing decision-making processes to optimize resilience efforts.

2. Materials and Methods

In this section, the research methodology is tailored to investigate the role of technology in addressing supply chain challenges in the United States. Structured upon the research onion framework by Saunders, Lewis, and Thornhill [25], this methodology unfolds through layers which include the philosophical underpinnings of the study, as well as the specific data collection techniques. The research philosophy embraces interpretivism, facilitating an in-depth exploration of stakeholders' perspectives on technology's efficacy in resolving supply chain issues. Also, the study employs a deductive approach, which aim to test the formulated hypotheses through empirical data analysis of existing relevant literature.

Techniques for data collection and analysis encompass a comprehensive literature review, qualitative coding, and narrative content analysis. This involves a systematic review of pertinent literature and scholarly works pertaining to the adoption of technology in supply chain management. The chosen choice of data collection method and analysis is justified because it harmonizes with the study research philosophy and strategy, enabling a nuanced understanding of technology's impact on the U.S. supply chain. In addition, the study time horizon spans the past decade, aligning with the aim of the study which is to examine recent developments in technology's integration within the U.S. supply chain environment.

Furthermore, ethical considerations are paramount, emphasizing research integrity and adherence to ethical guidelines throughout the study. The researcher ensures that all materials used in this study are duly cited and appropriately referenced. This methodological framework equips the researcher towards the exploration of how technology can further optimize the U.S. supply chain, aligning with the overarching aim of our research.

2.1. Description of Secondary Resources

In this study, data collection was meticulously undertaken through the review of 40 carefully selected publications across multiple reputable journals as displayed on google scholar database, spanning the period from 2019 to April 2024. The initial stage in the data collection process involved the identification of 24 abstracts relevant to the study's focus within this specified time frame. From these abstracts, a rigorous selection process led to the identification of five articles deemed particularly pertinent to the research objectives. These articles were chosen based on their perceived significance and impact within the research community, as evidenced by factors such as citation counts and widespread recognition. The selected empirical studies are considered to offer valuable insights and perspectives crucial for addressing the research questions effectively

The selected articles represent a diverse array of topics within the realm of supply chain management, each contributing unique perspectives and findings to the broader discourse. The following list presents the datasets chosen for thematic analysis based on the above criteria, alongside the names of the authors and the specific topics covered in each article:

- **Dataset No. 1:** Ejairu et al.[27], "Blockchain in global supply chains: A comparative review of USA and African practices".
- **Dataset No. 2:** Okoye et al. [28], "Sustainable Supply Chain Practices: A review of Innovations in the USA And Africa".
- **Dataset No. 3:** Atadoga et al. [29], "AI in supply chain optimization: A comparative review of USA and African Trends".
- **Dataset No. 4:** Lorriane and Fathia [26], "Streamlining Supply Chains Through Automation: A Comparative Analysis of US and Bangladesh Manufacturing Industries".
- **Dataset No. 5:** Oriekhoe et al. [30], Review of Technological Advancements in Food Supply Chain Management: A Comparative Study between the U.S. and Africa".

These selected articles are expected to enrich the study by providing empirical evidence, theoretical insights, and practical implications relevant to the research objectives. Through thorough examination and analysis, they are anticipated to contribute significantly to the depth and comprehensiveness of the study's findings and conclusions.

3. Results and Discussion

This study aims to explores the role of technology in addressing supply chain challenges in the United States and identifies opportunities for further enhancement to build a more resilient and sustainable supply chain ecosystem. The analysis carried out in this section are structured under three headings, each of which corresponds to each of the three research objective.

3.1. Analysis and Discussion of Findings on Research Objective One

The first research objective aims to identify the supply chain challenges being faced by firms in the United States. Base on the five articles under review, the themes with respect to the identified challenges are shown in table 1.

Table 1 Supply chain challenges being faced by firms in the United States

Authors	Major Themes Identified
Ejairu et al. [27]	Counterfeit goods Fraud Inefficiencies in logistics
Okoye et al. [28]	Environmental concern Ethical issues
Atadoga et al. [29]	Inaccurate demand predictions Higher lead times, Increase in operational costs, Delivery inefficiency.
Lorriane and Fathia [26]	workforce skill gaps Cyber-security threats Global supply chain disruptions
Oriekhoe et al. [30]	Demand volatility, Perishability concerns The need for efficient and sustainable practices

Data Extracted from the Selected Dataset with respect to Research One

The information in table 1 shows the key themes with respect to the supply chain challenges being witnessed in the United States, as identified by the respective authors of each of the selected dataset.

3.1.1. Counterfeit Goods Challenge to Supply Chain in the USA

Counterfeit goods pose a multifaceted challenge to the supply chain in the United States, and not only do they jeopardize consumer safety and trust, but they also have significant economic implications [30]. Counterfeit products often infringe on intellectual property rights, resulting in revenue losses for legitimate businesses and governments. Moreover, counterfeit goods may not meet regulatory standards, leading to potential health and safety hazards for consumers [27, 30]. Addressing this challenge requires a comprehensive approach, including the implementation of robust authentication and traceability solutions throughout the supply chain [4, 15]. Technologies such as blockchain offer promising solutions by providing immutable records of product provenance and enabling real-time visibility into supply chain transactions [15]. Partnership among stakeholders, including manufacturers, retailers, government agencies, and technology providers, is essential to effectively combat the proliferation of counterfeit goods and safeguard supply chain integrity [27].

3.1.2. Logistics Inefficiency as a Challenge to Supply Chain in the USA

Logistics inefficiencies also present significant challenges to supply chain operations in the United States. These inefficiencies can manifest in various forms, including delays in transportation, inaccurate inventory management, and disruptions in the flow of goods [27]. Poorly optimized logistics processes not only result in increased costs but also impact customer satisfaction and competitiveness. To address this challenge, firms need to invest in advanced logistics technologies and adopt best practices for supply chain management [27, 29]. Automation, data analytics, and real-time monitoring systems can help streamline logistics operations, improve resource utilization, and enhance overall efficiency [14]. Additionally, collaboration among supply chain partners and the adoption of interoperable systems are critical for achieving seamless integration and visibility across the supply chain network [30].

3.1.3. Environmental and Ethical Challenge to Supply Chain in the USA

Environmental sustainability and ethical considerations are becoming increasingly important in supply chain management in the United States [28]. Firms are facing growing pressure from consumers, regulators, and stakeholders to adopt environmentally responsible practices and ensure ethical sourcing and manufacturing processes. Failure to address these concerns not only risks reputational damage but also exposes firms to legal and regulatory risks. In order to mitigate these challenges, organizations need to integrate sustainability principles into their supply chain strategies and operations [7, 30]. This includes reducing carbon emissions, minimizing waste generation, and promoting fair labor practices throughout the supply chain [4].

3.1.4. Inaccurate Demand Forecast and Timely Delivery Challenge to Supply Chain in the USA

Inaccurate demand forecasting and challenges in timely delivery pose significant hurdles to supply chain efficiency in the United States [4, 29]. Fluctuations in consumer demand, coupled with longer lead times and operational inefficiencies, can result in stock-outs, excess inventory, and missed sales opportunities. To address these challenges, organizations need to leverage advanced analytics and predictive modeling techniques to improve demand forecasting accuracy [29]. Real-time data analytics and supply chain visibility tools can enable proactive decision-making and optimize inventory levels [17]. Additionally, investments in transportation infrastructure and last-mile delivery capabilities are essential for ensuring timely and reliable delivery of goods to customers [29]. Collaborative partnerships with logistics providers and technology vendors can further enhance supply chain agility and responsiveness to changing market dynamics [26].

3.1.5. Cyber-security Threats as a Challenge to Supply Chain in the USA

Cyber-security threats represent a growing concern for supply chain operations in the United States [26]. With the increasing digitization of supply chain processes and the proliferation of interconnected systems, supply chain networks are becoming increasingly vulnerable to cyber-attacks. These threats can range from data breaches and ransomware attacks to supply chain disruptions and intellectual property theft. To mitigate cyber-security risks, organizations need to implement robust cyber-defense measures and adopt a proactive approach to cybersecurity [9]. Also, there is the need for collaboration with cybersecurity experts, government agencies, and industry partners is essential for sharing threat intelligence and implementing best practices for cyber-resilience across the supply chain ecosystem [26]. The cyber-defense from this partnership may includes implementing multi-layered security controls, conducting regular risk assessments, and investing in employee training and awareness programs [26].

3.2. Analysis and Discussion of Findings on Research Objective Two

The second research objective aims to assess the role of emerging technologies, such as blockchain, artificial intelligence, big data analytics and IoT, in enhancing supply chain resilience and agility. The identified themes with

respect to the most adopted technologies in the enhancement and management of supply chain in the United States are as shown in table 2.

Table 2 Emerging technologies adopted by firms in the United States

Authors	Major Technologies Themes Identified	Contributions
Ejairu et al. [27]	Blockchain Technology	Transparency Traceability Accountability
Okoye et al. [28]	Internet of Things (IoT) Blockchain	Transparency Traceability Adoption of eco-friendly logistics strategies, such as the use of renewable energy in transportation and distribution networks.
Atadoga et al. [29]	Blockchain Internet of Things (IoT) Artificial Intelligence Predictive big data analytics, Machine learning, and advanced automation technologies.	Enhancement in demand forecasting, Optimize inventory management Streamline logistics processes. Overall efficiency and competitiveness in global markets.
Lorriane and Fathia [26]	IoT (Internet of Things) Data analytics, Artificial intelligence	Cost savings Productivity gains Competitiveness in global markets
Oriekhoe et al. [30]	Blockchain Internet of Things (IoT) Artificial intelligence	Transparency Traceability Efficiency

Data Extracted from the Selected Dataset with respect to Research One

The frequency distribution of the identified themes in table 2 with respect to the key technologies adopted by firms in the United States to enhance the management of their supply chain is as shown in table 3.

Table 3 Major Technologies Adopted as Solutions to Supply Chain Problems in the USA

S/N	Major Technologies Adopted	Frequency
1.	Blockchain	4
2.	Internet of Things	4
3.	Artificial intelligence	3
4.	Big data analytics	2
5.	Machine Learning	1

Frequency distribution of the majorly adopted technologies mentioned in the reviewed articles

The information in table 3 presents the concise and graphical view of the major technologies adopted as solutions to supply chain problems in the USA. The information in both table 3 shows that both blockchain technology and internet of things are the most adopted technologies used in providing solutions to most of the supply chain challenges identified in table 1. The next most adopted technologies include artificial intelligence, big data analytics and machine learning.

3.2.1. Blockchain as a Solution to Supply Chain Challenges in the USA

Blockchain technology has emerged as a transformative solution to address supply chain challenges in the USA. Its foundational principles of transparency, traceability, and accountability revolutionize traditional supply chain practices. By leveraging blockchain, stakeholders across the supply chain can access a decentralized and immutable ledger that records every transaction or event in real-time [2, 27, 28, 5]. This transparency ensures that all parties have visibility into the movement of goods, from raw material sourcing to final delivery, thereby reducing the risk of fraud, counterfeiting, and unauthorized alterations. For instance, in the food industry, blockchain enables end-to-end traceability, allowing consumers to verify the origin and journey of products, thereby enhancing food safety and quality assurance.

Moreover, blockchain facilitates secure and efficient collaboration among supply chain partners, eliminating the need for intermediaries and reducing transaction costs. Smart contracts, self-executing contracts with predefined terms written directly into code, automate contract enforcement and streamline processes such as payment settlements and customs clearance [4, 7, 24]. Additionally, blockchain promotes the adoption of sustainable practices by enabling the tracking of environmental and social impact metrics throughout the supply chain [28, 4].

3.2.2. Internet of Things as a Solution to Supply Chain Challenges in the USA

Internet of Things (IoT) plays a pivotal role in enhancing supply chain visibility, efficiency, and resilience in the USA. IoT devices, equipped with sensors and connectivity capabilities, enable the monitoring and tracking of assets, inventory, and environmental conditions in real-time [28, 26]. For instance, RFID tags and GPS trackers provide granular insights into the location and condition of goods throughout the supply chain, facilitating accurate inventory management and demand forecasting. Moreover, IoT sensors embedded in manufacturing equipment and transportation vehicles enable predictive maintenance, minimizing downtime and optimizing resource utilization.

Furthermore, IoT-driven data analytics empower organizations to derive actionable insights from the vast amounts of data generated by connected devices. Advanced analytics algorithms identify patterns, anomalies, and optimization opportunities, enabling proactive decision-making and continuous process improvement [29, 26]. For example, in the retail sector, IoT-enabled smart shelves monitor inventory levels and customer preferences, triggering automatic replenishment and personalized marketing campaigns. Overall, IoT fosters agility and responsiveness in supply chain operations, enabling firms to adapt to changing market dynamics and customer demands effectively.

3.2.3. Artificial Intelligence as a Solution to Supply Chain Challenges in the USA

Artificial intelligence (AI) technologies offer immense potential to optimize supply chain management in the USA. AI-powered algorithms and machine learning models analyze large volumes of data to uncover valuable insights, trends, and correlations [9, 29, [30]. For instance, AI-driven demand forecasting models leverage historical sales data, market trends, and external factors to predict future demand with higher accuracy, reducing stock outs and excess inventory. Additionally, AI algorithms optimize routing and scheduling decisions, minimizing transportation costs and lead times.

Moreover, AI enhances decision-making capabilities by providing real-time insights and actionable recommendations to supply chain managers [30, 10]. For example, AI-driven predictive analytics identify potential supply chain disruptions, such as natural disasters or supplier delays, enabling proactive risk mitigation strategies. Furthermore, AI-powered predictive maintenance algorithms detect equipment failures before they occur, reducing downtime and maintenance costs [18]. Overall, AI empowers organizations to make data-driven decisions, enhance operational efficiency, and improve customer satisfaction [16].

3.2.4. Big Data Analytics as a Solution to Supply Chain Challenges in the USA

Big data analytics serves as a cornerstone for unlocking actionable insights from the vast amount of data generated across the supply chain ecosystem [30]. By leveraging advanced analytics techniques such as machine learning and predictive modeling, organizations can extract valuable insights to optimize various aspects of supply chain operations [12]. For instance, predictive analytics algorithms analyze historical data patterns to anticipate future demand fluctuations, enabling more accurate inventory management and production planning.

Furthermore, big data analytics enables real-time monitoring and analysis of supply chain performance metrics, allowing organizations to identify inefficiencies and bottlenecks promptly [14]. For example, real-time dashboards provide visibility into key performance indicators (KPIs) such as order fulfillment rates, transportation costs, and supplier lead times. This real-time insight empowers supply chain managers to make timely decisions and take corrective actions to improve operational efficiency and customer service levels.

Additionally, big data analytics facilitates the identification of patterns and correlations across disparate data sources, enabling organizations to uncover hidden opportunities for process optimization and cost reduction [11]. For example, analyzing customer purchase patterns and market trends can inform targeted marketing strategies and product development initiatives. Moreover, big data analytics enables supply chain stakeholders to proactively identify and mitigate risks, such as supplier disruptions or quality issues, thereby enhancing supply chain resilience and agility. Overall, big data analytics serves as a powerful tool for driving continuous improvement and innovation in supply chain management in the USA.

3.2.5. Machine Learning as a Solution to Supply Chain Challenges in the USA

Machine learning (ML) is emerging as a potent solution to tackle supply chain challenges in the USA. ML algorithms can sift through vast datasets, identifying patterns and trends that human analysts might miss. By leveraging historical data and real-time inputs, ML models can make accurate predictions and recommendations to optimize various aspects of the supply chain [19, 14].

One prominent application of ML in supply chain management is demand forecasting. ML algorithms can analyze past sales data, market trends, weather patterns, and other variables to predict future demand more accurately [17, 9, 13]. This enables companies to optimize inventory levels, reduce stock-outs, and minimize excess inventory holding costs. Additionally, ML algorithms can adapt dynamically to changing market conditions, improving the accuracy of demand forecasts over time.

Another area where ML shines is in inventory optimization. By analyzing historical demand patterns and lead times, ML models can determine the optimal reorder points and order quantities for each product SKU [9, 14]. This helps companies minimize carrying costs while ensuring product availability to meet customer demand. ML algorithms can also identify slow-moving or obsolete inventory items, enabling companies to liquidate excess inventory before it becomes a financial burden.

ML-powered predictive maintenance is another valuable application in supply chain management. By analyzing sensor data from manufacturing equipment and transportation vehicles, ML models can predict equipment failures before they occur [23]. This enables proactive maintenance interventions, minimizing downtime and reducing maintenance costs. Predictive maintenance also extends the lifespan of critical assets, improving overall operational efficiency.

Furthermore, ML algorithms can optimize routing and logistics operations, improving delivery performance and reducing transportation costs [22]. By analyzing factors such as traffic patterns, weather conditions, and delivery schedules, ML models can generate optimal delivery routes in real-time. This helps companies minimize fuel consumption, reduce carbon emissions, and improve customer satisfaction by ensuring on-time deliveries.

3.3. Analysis and Discussion of Findings on Research Objective Three

The third research objectives focus on proposing recommendations and strategies for optimizing the use of technology to address supply chain challenges and foster a more resilient and sustainable supply chain network in the United States. To optimize the use of technology and foster a more resilient and sustainable supply chain network in the United States, several recommendations and strategies can be proposed:

Investment in Advanced Technologies: companies should consider investing in advanced technologies such as blockchain, artificial intelligence (AI), Internet of Things (IoT), big data analytics, and machine learning (ML) to enhance supply chain visibility, efficiency, and resilience [1]. Government incentives and funding programs can facilitate technology adoption among small and medium-sized enterprises (SMEs) to level the playing field and drive innovation across the supply chain.

Collaborative Data Sharing Platforms: the relevant authorities should consider establishing collaborative data sharing platforms or consortiums where supply chain stakeholders can securely share data and insights [8, 12]. Blockchain technology can facilitate transparent and tamper-proof data sharing, enabling real-time visibility into inventory levels, production schedules, and transportation logistics [2]. By fostering greater transparency and collaboration, these platforms can improve supply chain efficiency and responsiveness to disruptions.

Integration of Sustainability Metrics: Both the government and firms should integrate sustainability metrics into supply chain management practices to promote environmental responsibility and ethical sourcing [4]. This can be done by utilizing IoT sensors and blockchain technology to track and verify sustainable practices, such as carbon emissions, fair

labor practices, and responsible sourcing of raw materials [28, 26]. Implementing green logistics strategies, such as route optimization and mode switching, can reduce carbon footprint and mitigate environmental impact.

Predictive Analytics for Risk Management: Firms need to harness the power of predictive analytics and AI to proactively identify and mitigate supply chain risks [14, 11]. Develop predictive models that leverage historical data, market trends, and external factors to anticipate potential disruptions, such as natural disasters, geopolitical events, and supplier bankruptcies. By identifying vulnerabilities and developing contingency plans in advance, companies can minimize the impact of disruptions on their supply chain operations.

Supply Chain Resilience Planning: Develop robust supply chain resilience plans that prioritize flexibility, redundancy, and agility [21, 3, 6]. Also, there is a need to implement agile manufacturing and distribution practices that enable rapid adaptation to changing market conditions and demand fluctuations [20].

4. Conclusion

The study examines the relationship between technology and supply chain management within the United States. Through a meticulous examination of existing literature and empirical studies, the research highlights a myriad of challenges confronting U.S. supply chains, ranging from counterfeit goods and logistical inefficiencies to environmental concerns and cybersecurity threats. Drawing upon the insights gleaned from the analysis, the study arrives at a conclusive assertion: for U.S. firms aspiring to fortify their supply chain resilience and adaptability within the contemporary business environment of the 21st century, strategic investment in cutting-edge technologies is imperative. Specifically, embracing innovations such as blockchain, artificial intelligence, Internet of Things, big data analytics, and machine learning emerges as a pivotal imperative. These technological advancements not only enhance operational efficiency but also equip organizations with the agility and foresight necessary to navigate the complexities and uncertainties inherent in today's globalized marketplace. Thus, by leveraging these transformative technologies, U.S. firms can position themselves at the forefront of supply chain innovation, fostering resilience and competitive advantage in an ever-evolving business.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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