



(REVIEW ARTICLE)



## Leveraging advanced technologies in Supply Chain Risk Management (SCRM) to mitigate healthcare disruptions: A comprehensive review

Uchechukwu Christopher Anozie <sup>1,\*</sup>, Gbenga Adewumi <sup>2</sup>, Oyinlola Esther Obafunsho <sup>3</sup>, Adekunle Stephen Toromade <sup>4</sup> and Oladapo Sola Olaluwoye <sup>5</sup>

<sup>1</sup> College of Business, Auburn University, USA.

<sup>2</sup> Whitman school of Management, Syracuse University, USA.

<sup>3</sup> School of professional studies, Saint Louis University, USA.

<sup>4</sup> School of Biosciences, University of Nottingham, UK.

<sup>5</sup> Faculty of Management Sciences, Accounting, Osun State University, Nigeria

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### Abstract

The Healthcare sector is undeniably one of the most critical sectors in any given economy and disruptions in this industry have dire consequences that affect patient care, the efficiency of healthcare systems and by far public health. This publication seeks to analyze and discuss the vital role of supply chain risk management in addressing disruptions, becoming resilient and ensuring that healthcare services function effectively. The pandemic (COVID-19) brought to fore just how critical it is to have a robust and agile system for supply chain risk management in healthcare, the sudden and unprecedented surge in demand for essential medical equipment like personal protective equipment (PPE) left millions of people at risk thereby jeopardizing their safety and health. This crisis echoed the urgent need for efficient and effective supply chain risk management strategies to mitigate such risks and ensure the availability of vital medical supplies. This review paper will be sharing different strategies and actionable tips to develop contingency plans, identify, reduce potential disruptions and recommended practices for risk management in the healthcare supply chain. This will highlight key areas such as inventory management and stockpiling, which focuses on maintaining safety stock levels to buffer against sudden disruptions, using advanced analytics to forecast demand and manage inventory levels. It will also examine risk assessment and identification by pinpointing potential attacks, threats, and vulnerabilities within the healthcare supply chain through thorough risk assessments. Additionally, it will cover supplier base diversification, emphasizing the importance of engaging multiple suppliers to reduce dependency on a single source and enhance supply chain resilience by balancing global and local suppliers to mitigate geographic disruption risks. Furthermore, it will explore the integration of technology, leveraging innovative solutions like blockchain for enhanced transparency, security, and traceability of supply chain transactions.

**Keywords:** Supply chain; Risk management; Inventory management; Healthcare; Blockchain technology; Sustainability

### 1. Introduction

The vulnerabilities within the healthcare supply chain were identified and laid out during the COVID-19 pandemic, the healthcare industry experienced shortages of essential medical supplies like ventilators, PPE and other medical devices. [1] Clearly the pandemic exposed the over dependency on a few key manufacturing hubs (geographically), notably in China for essential medical supplies and when travel restrictions were put in place this disrupted production. Furthermore, beyond the economic implications of the pandemic, shortages of PPE jeopardized the lives of healthcare

\* Corresponding author: Uchechukwu Christopher Anozie

workers, while the limited access to medical devices like ventilators led to deaths of patients that could be avoided. Lockdowns in key manufacturing countries disrupted the flow of essential materials thus impacting the production of medications. Another outcome of the pandemic in the healthcare sector revealed the disparity in accessing medical supplies between developing and developed countries, [2] where the former competed for scarce supplies thus leading to more avoidable deaths and risks to healthcare providers.

The effect of these shortages came with increased costs and risks that could bring the healthcare systems to its knees. [3] The sudden surge in demand for PPE and medical equipment became overwhelming and could not meet production capacity, this led to price gouging created by a seller's market. Hence the importance of this publication which aims to share a detailed view on the importance of supply chain risk management in fostering resilience, agility and adaptability in the healthcare system.

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## 2. Risks in Healthcare supply chain

Similar to many other sectors of the economy, the healthcare sector's supply chain has faced significant and complex disruptions globally, particularly in the United States. Let's examine some of these disruptions.

**Pandemic:** At the top of the list is the COVID-19 pandemic, which starkly revealed the significant inefficiencies in the supply chains of various industries, particularly in the healthcare sector.[4] Like a flash, the world experienced increased demand for medical supplies- ventilators, sanitizers, mask, gloves to combat the virus and save lives, however the healthcare supply chain was not prepared as hospitals and clinics experienced shortages of these essentials.[5] As a result, businesses and individuals started charging excessively high prices for supplies. This made it very difficult for hospitals and clinics to get the essential items they needed, putting the lives of healthcare workers and patients at risk. As noted by Mayor Bill de Blasio to CNN "if we don't get the equipment, we're literally going to lose lives"

**Geopolitical Instability:** Sanctions, trade wars and political unrest in different geographical regions had potential effects on the cost of vital supplies for hospitals and clinics. [[6] This is because they limit the number of available suppliers and also restrict competition which eventually leads to price spikes. An example would be political unrest between two major manufacturers of essential medical equipment for pharmaceuticals, this would create a significant price increase for the healthcare sector. There is also the issue of availability and access of medical supplies to critical regions that can be restricted by sanctions, thus establishing shortages in those regions that are already in dire need. [7]

**Supplier bankruptcy:** The financial health of a supplier can have a severe effect throughout the entire supply chain.[8] The flow of critical materials needed for manufacturing and operations can be interrupted when a key supplier encounters financial difficulties. This disruption has a domino effect such as cost increases that can significantly impact production cost and affect profit margins, production delays which grossly affect the manufacturer's ability to meet the demands of these hospitals and clinics thereby increasing lead times and penalties for late deliveries. Also, the issue of supplier reliability when looking for alternatives on short notice could be painstaking, if care is not taken incompetent suppliers that compromise on quality may be selected. Therefore, it is imperative for healthcare supply chain to implement proactive risk management strategies like Supplier base diversification, supplier financial health and detailed contingency plans to cushion the effect of a supplier disruption. [9]

**Cybersecurity attacks:** Cybersecurity threats can be in various forms such as data breaches, hacking and ransomware attacks which potentially impact the confidentiality and integrity of the supply chain.[9] Loss of sensitive information including business information, patient data and supplier data can undermine the relationship between healthcare providers and their suppliers. Healthcare Procurement, manufacturing and logistics can be disrupted when attacks that can encrypt vital data and systems are carried out especially ransomware attacks, this further has a financial impact on the healthcare organization as the face monetary demands from these hackers in order to gain back control of their systems and data, in some cases this may prove very costly and lead to non-recovery of productive time. These risks can be mitigated by regularly conducting cybersecurity risk assessments to address weaknesses within the healthcare supply chain.[11] Evaluation of the cybersecurity practices of third-party vendors should be prioritized. There is a need for constant training and education of employees and partners on cybersecurity trends and how to detect and effectively respond to potential threats.[12] Lastly healthcare organizations should invest in advanced cybersecurity technologies to protect vital data and systems.

### **3. Developing a Resilient supply chain risk management framework**

Healthcare supply chains can establish a resilient risk management framework to mitigate potential disruptions. Here, we will outline three strategies to achieve this.

#### **3.1. Contingency planning**

Developing an effective emergency preparedness is critical for healthcare organizations to ensure continuity and availability of crucial supplies during disruptions.[13] This involves creating comprehensive strategies that encompass various actions to respond effectively to unforeseen events. A thorough risk assessment should be conducted to identify potential threats like cyberattacks, natural disasters and geopolitical disruptions within the supply chain. Contingency planning also involves diversifying supplier pool as this reduces the dependency on a sole supplier, allows for faster activation, procurement and ensure alternative sources are available in case of disruption.[14] It also involves negotiating contracts with alternative suppliers in advance, specifying terms and conditions for emergency situations, a list of pre-qualified suppliers who meet the organization's requirements should be developed. Another essential method of the contingency planning process should be Rationing of critical supplies, this involves implementing inventory management systems to track and manage stock levels in real time, this further helps in quickly identifying shortages and carrying out informed decisions about rationing. Strategies to conserve supplies, such as sterilizing equipment where applicable and finding substitute supplies should be developed and implemented. The role of Data management and technology in contingency planning is essential because it helps organizations leverage on real time monitoring by utilizing technology to detect risk disruptions early and monitor supply chain activities. [15] Real-time analytics can share insights into emerging risk and ensure proactive responses.

#### **3.2. Risk identification and Assessment**

In order to maintain a stable healthcare supply chain, there is a need to understand and prepare for potential risk. This can be carried out by systematically recognizing possible disruptions and analyzing the likelihood of occurrence and their impacts. Risk identification and assessment helps organizations to be proactive in the face of uncertainty and ensure that they can be resilient and responsive to continue to provide essential healthcare services without critical disruptions. [16] The tools for risk management can include Risk mapping which is a visual tool that is used in plotting out identified risks on a map and potential impact, risk mapping enables organizations to easily see risks that are very critical and need immediate action. Another tool is the Scenario planning which entails crafting detailed plans for multiple risk scenarios like the impact of bankruptcy on a supplier. This scenario can be effectively managed in advance when organizations develop effective strategies. There is a need for the healthcare system to invest in data showing past incidents, current trends and insights of professionals to measure the probability and potential of consequences attached to each risk [17]

#### **3.3. Continuous monitoring and improvement**

It is crucial to continuously monitor the supply chain landscape for emerging risks, technological advancement and regularly update the supply chain risk management plans based on updated trends and insights. [18] This resilient SCRM framework requires more than just an initial assessment and planning phase. Real-time data and analytics are essential for monitoring the supply chain continuously, this includes monitoring the status of supplies, supplier performance and shipments while identifying any disparity from normal operations. As new information emerges, SCRM plans should be regularly updated, this could include insights from recent events, feedback from stakeholders or data derived from monitoring tools. The aftermath of a disruption should be thoroughly analyzed as this process helps to identify gaps in the current SCRM framework and provides valuable feedback for future improvements. The need for Agility and flexibility as an adaptive strategy shows how resilient a supply chain can be to changing conditions, it means that healthcare systems should have flexible strategies that can be adjusted as needed based on the updated information.[19] As part of the Adaptive strategy, healthcare system should be proactive in mitigating risk rather than wait for disruption to happen, this could come in the form of supplier diversification, investment in advanced technology or increasing safety stock levels. Lastly, organizations that foster a culture of continuous improvement and innovation ensures that new technologies and ideas are appreciated as this can lead to the development of more effective risk management strategies and improve the overall supply chain resilience.

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### **4. Blockchain Technology and its benefits**

Many existing supply chain data systems are ill-equipped to validate synchronized and authenticated shipment tracking throughout the logistics cycle.[20] Common technologies such as radio frequency identification (RFID) tags and barcodes, although widely used for product identification, suffer from limitations in data storage and supply chain

interoperability. [21] It is vital to note that in response to these challenges, blockchain technology has emerged as a promising solution, offering a platform for accurate and secure transactional records across multiple parties to facilitate supply chain traceability. [22] This technology can significantly enhance the resilience of the healthcare supply chain, as the parties involved can access critical data for precise location tracking, product identification and proper handling, ensuring that crucial medical supplies and services are delivered efficiently and effectively. These are some of the ways blockchain technology benefits the healthcare system:

**Increased transparency:** Blockchain allows for the transparent and detailed tracking of every item in the supply chain, from the manufacturer to the end user, this allows everyone in the supply chain to monitor where each item is at any given time. It provides healthcare providers with visibility into the activities of their suppliers, creating an environment that builds accountability and trust throughout the supply chain.

**Improved Traceability:** The introduction of blockchain technology has enabled end-to-end traceability of products and services, through reliable and trusted data sharing across multiple supply network levels. thereby creating less room for distrust and fraud [23] A good example would be a recall of a batch of ventilators, the blockchain ledger can readily identify where the affected equipment's are located and ensure they are sorted from circulation thereby minimizing risks to patients. Furthermore, blockchain can help verify the authenticity of products by detailing a complete history of each item from production to delivery, this ensures that only safe and genuine products are provided to healthcare providers and patients alike.

**Heightened security:** With decentralized storage, blockchain technology offers superior defense capabilities against cyberattacks which are increasingly threatening the healthcare industry.[24] This ensures that sensitive information related to patient data and medical supplies are protected. Blockchain's immutable nature means that once a transaction is entered, it cannot be altered, this acts as a secured proof of all activities in the supply chain, ensuring data integrity and protection against fraud.

**Shared Platform and enhanced communication:** Another benefit of blockchain technology is the provision of a shared platform where all stakeholders (healthcare providers, suppliers, distributors and manufacturers) in the supply chain can effectively collaborate and efforts are aligned to make coordinated decisions. This collaborative technique enhances the overall resilience of the supply chain and leads to improved and faster resolution to issues. Although collaboration and information sharing among supply chain partners are critical, organizations must protect their proprietary data from competitors.

**Operational efficiency and cost reduction:** Blockchain technology enables accelerated transaction processing, ensuring that medical supplies are delivered more efficiently and swiftly throughout the supply chain.[25] It reduces costs by minimizing stock outs and tightening inventory controls (it can decrease the average annual inventory carried, thereby reducing holding cost). This enhanced speed is crucial in emergency situations, where timely logistics can be critical for saving lives. Blockchain technology can also optimize supply chain processes by minimizing reliance on intermediaries and eliminating manual paperwork. Smart contracts, which are self-executing agreements embedded with coded terms, can automate and enforce contract conditions, thus minimizing delays and significantly reducing administrative costs.

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## 5. Case studies and Best Practices

### 5.1. Supplier Selection and Management

Suppliers should consistently demonstrate resilience, dependable delivery performance by maintaining an enviable track record for timely and accurate order fulfilment, ensuring the continuous availability of critical medical supplies during disruptions. These suppliers must be verified and evaluated based on certifications, key performance indicators (KPI) such as lead times, delivery accuracy, product quality, compliance with healthcare industry regulations and meeting stringent quality standards like Good Manufacturing Practices (GMP), to ensure that all medical supplies match regulatory requirements and are safe. [26] There is a need to also evaluate the risk profile of suppliers by evaluating their susceptibility to disruptions, financial health and geographic location. Continuous risk assessments are crucial to understanding how changes in a supplier's situation may impact the supply chain, the suppliers with lower risk profiles are selected to reduce the potential for supply chain disruptions. Healthcare organizations should conduct periodic assessments of suppliers' facilities and processes to ensure ongoing compliance with safety and quality demands, this can be in the form of documentation reviews, traceability of all products throughout the supply chain and on-site inspections.

## 5.2. Inventory Management

Effective inventory management is crucial for a resilient healthcare supply chain, ensuring that essential medical supplies are available while reducing waste, controlling costs, obsolescence and improving the overall supply chain efficiency. This proactive approach supports, enables better patient care and strengthens the healthcare supply chain's ability to respond to disruptions. The key strategies include Safety stock levels by maintaining buffer stocks against disruptions and demand variability with timely and regular adjustments based on changing needs.[27] The implementation of Just in time inventory helps in reducing holding costs and waste by ordering supplies based on need, as efficient replenishment systems ensure that the medical supplies are delivered timely. Demand Forecasting involves leveraging data-driven insights and predictive analytics to anticipate needs and plan inventory levels. A healthy collaboration with stakeholders (healthcare providers, suppliers, manufacturers and distributors) enhances demand forecasts. Cycle counts and Inventory audits should be carried out regularly to ensure accurate record-keeping and accountability, this would fish out discrepancies and significantly prevent overstocking or stockouts.[28] Technology should be integrated by leveraging inventory management software and RFID technology to streamline tracking of medical supplies and enhance inventory management.

## 5.3. Investment in Blockchain technology

Investing in blockchain technology for managing supply chains, especially in healthcare can greatly improve transparency and combat counterfeit drugs particularly in sectors such as pharmaceuticals and food where contamination have severe consequences for public health and safety. Blockchain's decentralized ledger offers a secure and transparent record of every transaction making it easier to track drugs from the manufacturer to the patients, enhance food safety, combat food fraud and facilitates product recall by auditing the entire chain.[29] By using blockchain technology, sustainability and recycling efforts in the healthcare supply chain can more accurately track the environmental impact and recycling patterns of products throughout their lifecycle. Implementing a model like the triple retry model—which integrates recycling, redistribution, and remanufacturing processes—supports circular supply chain models. This approach creates room for manufacturers to efficiently manage product components, repurpose them to create novel products and contribute to resource conservation and waste reduction efforts.

## 5.4. Tracking and Visibility

Traditional computer systems frequently lack sufficient data security measures, resulting in supply chain failures and challenges in pinpointing the origins of contamination or counterfeit drugs. Blockchain offers a robust tracking capability that can effectively combat food fraud, enhance pharmaceutical safety and expedite product recalls by thoroughly auditing the entire chain of custody, that empowers brands to proactively mitigate supply chain risks and timely trace and remove contaminated products or counterfeit medical supplies from circulation. [30] Blockchain technology offers substantial enhancements to supply chain efficiency in healthcare. Healthcare providers seek solutions that guarantee sustainability, product lifecycle transparency, waste reduction, carbon footprint tracking and promote fair trade practices.[31]A simulation study on blockchain demonstrated a notable 65% decrease in processing time for placing new orders and 60% reduction in overall operational time, this efficiency boost also decreases warehousing space requirements and enhances visibility throughout the supply chain.

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## 6. Conclusion

It is essential to prioritize supply chain risk management (SCRM) in healthcare as this can create a robust and adaptable healthcare ecosystem. By strategically managing supply chain risks, healthcare organizations can proactively identify vulnerabilities and implement measures to mitigate them, this preemptive approach not only strengthens the resilience of the supply chain but also enhances its operational efficiency and patient safety. By leveraging blockchain, healthcare providers can achieve improved transparency in product sourcing, ensuring sustainability of supply chains, track carbon footprint and promote fair trade practices. This integrated approach not only strengthens supply chain resilience but also enhances operational efficiency, reduces risks associated with counterfeit products, and safeguard patient safety. This paper outlines a strategic roadmap for healthcare organizations to effectively integrate SCRM practices; by doing so they can ensure the continuous availability of critical medical supplies and minimize disruptions.

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## Compliance with ethical standards

### *Disclosure of conflict of interest*

No conflict of interest to be disclosed.

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