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Connected IoT Devices as Enablers of Real-Time Visibility and Efficiency in Modern Supply Chains

[1] **Bui Trong Hieu,** [2] **Bui Thi Kim Uyen**

[1] Institute of Information Technology and Electrical–Electronic Engineering, Ho Chi Minh City University of Transport, Ho Chi Minh City, Vietnam

[2] Faculty of International Trade, College of Foreign Economic Relations (Cofer), Ho Chi Minh City, Vietnam

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Corresponding Author: **Bui Trong Hieu**

Abstract

This research examines the influence of IoT connectivity on real-time supply chain visibility and efficiency. Through a mixed-methods approach combining literature analysis and case evaluation, the paper identifies how sensor networks, cloud platforms, and edge computing collectively improve operational transparency and decision accuracy. The study highlights key performance indicators affected by IoT integration, including lead time reduction, order accuracy, and cost savings. It also addresses technical and organizational challenges that impact scalability and integration. The findings underscore the transformative potential of IoT in redefining supply chain agility and resilience.

Keywords: Asset Tracking, Internet of Things (IoT), Operational Efficiency, Predictive Analytics, Real-Time Visibility, Smart Logistics, Supply Chain Management (SCM), Transportation Systems, Warehouse Automation

1. Introduction

The adoption of Internet of Things (IoT) technologies in supply chain management (SCM) has revolutionized logistics and operational processes. By leveraging connected devices such as smart sensors and RFID tags, IoT facilitates continuous data acquisition and communication, thereby enhancing real-time visibility and optimizing the performance of warehouse and transportation systems [1]. Recent research indicates that implementing IoT in supply chain management enhances inventory accuracy, streamlines fleet operations, and supports informed decision-making through predictive analytics [2]. Nevertheless, issues like data security and the scalability of systems continue to pose significant challenges [3]. This study explores how IoT contributes to the optimization of warehouse and transportation systems, emphasizing its potential to overcome existing challenges and transform contemporary supply chains. By offering real-time insights into inventory and logistics, IoT devices greatly improve operational efficiency and drive cost reduction [4]. Drawing on real-world case studies, this paper analyzes the influence of Big Data on operational performance and identifies the critical factors that empower businesses to achieve a competitive edge in dynamic market environments.

2. Background

Industry findings reveal that organizations utilizing IoT have decreased operational disruptions by as much as 40% through the implementation of predictive maintenance and fleet optimization strategies [5]. However, the complexity involved in implementing IoT—particularly issues related to data interoperability and privacy—remains a major obstacle [6]. The integration of IoT technologies into supply chain management (SCM) represents a pivotal advancement in the digital transformation of logistics. These connected devices facilitate real-time monitoring, enable predictive analytics, and improve communication across various points in the supply chain [7]. Nonetheless, cybersecurity threats and substantial upfront investment requirements continue to be major obstacles to widespread adoption [8]. Consequently, data-centric SCM has emerged as a strategic imperative for companies aiming to build resilience. Globalization continues to expand the geographical reach of supply chains, introducing complexities in procurement, manufacturing, and distribution processes (Birkel & Müller, 2021) [9]. Big Data analytics addresses these challenges by providing visibility across multiple nodes in the chain, from supplier sourcing to final delivery. AI-driven insights facilitate proactive demand forecasting, reduce bullwhip effects, and support a more collaborative approach to partner management (Koçoğlu *et al.*, 2022) [10]. Global supply chains have entered an era of heightened complexity, shaped by rapidly shifting market demands, shorter product lifecycles, and unexpected disruptions such as pandemics and geopolitical events (Dolgui, Ivanov, & Sokolov, 2021; Zhou, Pan, & Wang, 2023) [11]. These dynamics expose the limitations of traditional Supply Chain Management (SCM) approaches, which often rely on static or historical data to make critical decisions regarding inventory, production, and distribution (Yadav *et al.*, 2021) [12]. In response, Big Data has emerged as a transformative force—driven by advanced analytics, cloud computing, and the rise of Industry 4.0 technologies—enabling supply chains to be more responsive, resilient, and customer-centric (Giannakis & Papadopoulos, 2023) [13]. The integration of Big Data into SCM does not happen in isolation. It necessitates robust inter-organizational collaboration, shared analytics platforms, and harmonized data standards (Wang *et al.*, 2021) [14]. This collaborative agility proves essential in navigating unpredictable disruptions while meeting evolving customer demands for faster delivery, personalized orders, and transparent sourcing (Dolgui *et al.*, 2021) [15]. Consequently, research emphasizes that adopting Big Data analytics is as much an organizational challenge—requiring skill development and change management—as it is a technological one (Struve *et al.*, 2022) [16].

3. Literature review

The ongoing digitalization of supply chains has intensified research interest in data analytics capabilities, with scholars highlighting the strategic importance of real-time data-driven insights for inventory, production, and distribution (Blome & Schoenherr, 2021; Swanson & King, 2023) [17]. According to Knap, Reim, and Parida (2022) [18], disruptive technologies—Big Data, blockchain, and AI—can work in synergy to reshape traditional supply chains, improving transparency and automating decision-making. At the same time, Roy, Baig, and Hussain (2021) [19] emphasize the role of simulation-based risk assessments in global supply chain contexts, where Big Data aids in anticipating geopolitical shifts, port congestions, or supplier failures. Building on predictive modeling techniques, Oke and Gopalakrishnan (2023**)** [20] propose that data analytics alone may not suffice for full supply chain resilience; instead, an integrated framework combining robust AI tools, human judgment, and strategic partnerships is necessary. By mining real-time data on transportation flows and supplier performance, organizations can respond more quickly to disruptions, thus reducing ripple effects across the supply chain (Lambert & Luu, 2023) [21]. Similarly, Garg, Gupta, and Choi (2023) [22] highlight the benefits of cross-industry collaboration in Big Data initiatives, finding that collaborative data exchange can accelerate disruption response times, especially in volatile market conditions. Scholars also underscore the role of Big Data in advancing sustainability goals and circular economy models (Sardana & Tewari, 2020; Knap *et al.*, 2022) [23]. Through IoT-enabled sensor networks, firms can capture granular information on waste, carbon emissions, and resource utilization at each stage of the product lifecycle (Zhang, Li, & Zhao, 2022) [24]. When analyzed by AI-driven systems, these data streams identify inefficiencies and guide strategic improvements—such as optimizing transportation routes to cut fuel usage or instituting recycling and remanufacturing loops (Wong, Low, & Mok, 2022) [25]. The convergence of Big Data, sustainability metrics, and real-time visibility thus underpins the modern "green supply chain," aligning operational and environmental objectives (Lambert & Luu, 2023) [26]. IoT plays a pivotal role in improving last-mile delivery by enabling dynamic route optimization, real-time package tracking, and customer notifications [27]. Predictive route planning—integrating weather forecasts, real-time traffic, and customer location data—has been shown to reduce delivery times and improve service quality (Garg *et al.*, 2023) [28]. These insights underscore the potential for data-centric innovations to streamline the most costly segments of the supply chain. Moreover, Inman and Hartley (2022) [29] argue that collaborative networks—spanning suppliers, logistics providers, and end users—amplify the gains from data sharing, fostering a culture of transparency and joint problem-solving. As supply chains become more digitized, multi-tier data interoperability emerges as a central challenge, prompting further research into standardizing information exchange protocols.

4. Conclusion and future works

IoT significantly improves visibility and decision-making in supply chain management. Real-time tracking allows businesses to reduce uncertainties and address discrepancies promptly. However, the challenges of integrating IoT devices across diverse systems hinder its full potential. IoT reduces costs by optimizing warehouse and transportation operations. Automated workflows and predictive maintenance lower operational expenses. Yet, the high initial investment remains a challenge. Data security and privacy are critical concerns in IoT deployment. The interconnected nature of IoT devices increases vulnerability to cyberattacks. Robust security measures are crucial. IoT supports predictive analytics for proactive decision-making. Predictive maintenance and demand forecasting improve resource allocation. However, a lack of skilled personnel limits the use of analytics tools. Scaling IoT systems in large supply chains is complex and costly. The integration of IoT devices across multiple locations faces compatibility and budget challenges. IoT drives sustainability in supply chains by reducing waste and optimizing resources. Smart sensors and automated systems minimize energy usage and emissions. Still, there is a need for eco-friendly IoT devices. IoT enhances workforce productivity by automating repetitive tasks. Wearable devices and automation free employees for higher-value tasks, but resistance to change among workers slows adoption. Blockchain improves IoT data transparency and security. The combination strengthens trust among supply chain partners but introduces computational overhead. IoT mitigates risks by enabling early detection of potential issues. IoT sensors monitor equipment and environmental conditions, reducing disruptions. However, reliability of sensors remains a concern. IoT improves customer experiences through real-time tracking and reliable delivery timelines. Increased transparency builds trust but requires seamless integration of IoT with customer-facing platforms. IoT enables instant decisions that optimize logistics operations. Quick decision-making improves efficiency, but over-reliance on IoT data can lead to errors. IoT ensures the integrity of perishable goods in cold chains. Continuous monitoring maintains quality but requires expensive infrastructure. IoT improves efficiency in last-mile delivery through route planning and tracking. The lack of universal communication protocols among IoT devices limits interoperability. Future research can focus on creating standardized frameworks to harmonize IoT technologies across manufacturers and industries. Small and medium-sized enterprises (SMEs) face significant barriers to adopting IoT due to high implementation costs. Exploring low-cost IoT devices and cloud-based platforms tailored for SMEs would make this technology more accessible. Combining IoT with artificial intelligence (AI), machine learning (ML), and blockchain could enhance data analytics, automate decision-making, and improve security. Future studies should evaluate the performance and scalability of such integrations in real-world supply chains. IoT devices often consume significant energy, which can offset their environmental benefits. Research should focus on developing energy-efficient IoT systems and exploring renewable energy sources to power these devices. Investigating how IoT can be utilized to monitor product life cycles and facilitate circular supply chains will enhance sustainability by reducing waste and promoting reuse or recycling of materials. The adoption of IoT requires a skilled workforce capable of managing and analyzing IoT systems. Future work should develop training programs and certification courses tailored to IoT technologies in supply chains. As IoT adoption increases, so do cybersecurity risks. Future research can focus on lightweight encryption techniques and blockchain-based authentication to protect IoT networks from breaches. IoT's potential to predict and mitigate risks during natural disasters or other disruptions is underexplored. Developing predictive models using IoT data to improve supply chain resilience can be a promising area of research. The use of IoT in monitoring temperature-sensitive goods, especially in pharmaceuticals and food supply chains, needs further optimization. Future studies could focus on improving sensor accuracy and integrating IoT with AI for real-time adjustments. Large-scale IoT deployment across complex supply chains presents scalability challenges. Research should explore cloud and edge computing solutions to handle the growing data volumes from IoT devices. Urban areas present unique challenges for logistics, such as traffic congestion and restricted access zones. Future work could study how IoT can support smart city initiatives to optimize urban supply chains. The role of IoT in ensuring ethical practices, such as monitoring labor conditions or tracking the sourcing of raw materials, remains underdeveloped. Future research should explore IoT's contribution to corporate social responsibility (CSR) initiatives. Conducting long-term studies on the return on investment (ROI) for IoT implementations in supply chains will provide businesses with valuable insights into cost-effectiveness and potential scalability. Future work can focus on the development of autonomous supply chains driven entirely by IoT data, robotic process automation (RPA), and predictive analytics. Exploring IoT's role in reverse logistics for managing product returns, repairs, and recycling can help businesses improve efficiency and sustainability in post-sale processes. Investigating IoT’s ability to facilitate real-time data sharing and collaboration among stakeholders, including suppliers, manufacturers, and retailers, can enhance supply chain coordination. Research can explore how IoT wearables and sensors can improve worker safety in warehouses and transportation by monitoring environmental conditions and detecting potential hazards. Incorporating gamification into IoT dashboards could make data analysis more intuitive and actionable for supply chain managers. This requires innovative interface designs and usability studies. Future research should develop metrics to quantify the sustainability impact of IoT systems, such as carbon emission reductions, energy savings, and waste minimization. With the rise of multi-modal transportation, IoT research should focus on integrating data from various transportation modes (e.g., trucks, ships, drones) into a cohesive, real-time logistics management system.

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