Financial and Economic Risk in Developing Markets
Volume 1, Number 1, 2022

Integration of the Internet of Things in Supply Chain Management Towards a Sustainable Green Supply Chain

Khoiron Nur Ashari[1]

[1] Universitas Sarjanawiyata Tamansiswa, Yogyakarta, Indonesia

Abstract

Article history:
Received: February 7, 2022
Revised: March 9, 2022
Accepted: April 15, 2022
Published: June 30, 2022

Keywords:
Green Supply Chain,
Industry 4.0,
Internet Of Things,
Sustainability,
Supply Chain Management.

Identifier:
Zera Open
Page: 72-88
https://zeraopen.com/journal/ferdm

The rapid advancement of the Fourth Industrial Revolution has accelerated the implementation of a wide range of digital technologies such as the Internet of Things, Artificial Intelligence, and big data analytics across numerous industrial and service sectors, with Supply Chain Management being one of the most significantly affected. This ongoing transformation not only focuses on enhancing operational efficiency, reducing costs, and enabling automation, but also contributes to strengthening long-term sustainability efforts through the framework of Green Supply Chain Management. Internet of Things specifically provides the technological capability to integrate and process real-time data from a variety of connected devices and sensors, allowing continuous monitoring of energy usage, optimization of transportation and logistics networks, reduction of waste generation, and compliance with increasingly stringent environmental regulations. Despite its potential, the adoption of IoT in Green Supply Chain Management faces persistent challenges including high implementation expenses, cybersecurity vulnerabilities, and the urgent need for advanced digital skills. Literature reviewed suggests that IoT can accelerate the transition toward sustainable, transparent, and competitive supply chains while simultaneously strengthening corporate reputation and market advantage.

1. Introduction

The development of digital technology over the last two decades has spurred a major transformation in the industrial world, known as the Fourth Industrial Revolution or Industry 4.0. This transformation is characterized by the application of technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), big data analytics, and cyber-physical systems that can holistically integrate the physical and digital worlds (Xu et al., 2018). The implementation of these technologies not only increases automation and efficiency but also expands opportunities for business innovation, including in the context of Supply Chain Management (SCM). However, behind these great opportunities, there are also challenges such as cybersecurity risks, social inequality, and the need for new skills in managing advanced technology (Calderaro & Craig, 2020). The concept of Supply Chain Management has long been the backbone of business activity, as it focuses on coordinating the flow of goods, information, and finances from suppliers to final consumers.

However, in traditional practice, SCM faces a number of challenges, such as high operational costs, distribution delays, and limited visibility in increasingly complex global supply chains (Choi et al., 2021). This situation demands new breakthroughs to improve transparency, timeliness, and effectiveness in supply chain management. On the other hand, global pressure related to sustainability is growing stronger. Environmental regulations, consumer awareness of ecological impacts, and increased investor interest in green business practices are pushing companies to adapt with Green Supply Chain Management (GSCM) strategies. This concept combines the principles of sustainability with supply chain management, covering

emission reduction, efficient energy use, waste management, and the optimization of environmentally friendly logistics (Alsamhi et al., 2019). With increasing consumer preference for eco-friendly products, companies that implement GSCM have the opportunity to build a positive reputation while increasing competitiveness in the global market. It is in this context that IoT plays a strategic role. IoT allows physical devices such as sensors, vehicles, and industrial machines to connect to each other to collect, process, and transmit data in real-time without direct human interaction (Andronie et al., 2021).

In SCM, the use of IoT supports the optimization of transportation, monitoring of storage conditions, and product tracking throughout the supply chain. With this integration, companies can improve the accuracy of decision-making, reduce distribution costs, and minimize the risk of delays (Yang et al., 2017). Furthermore, within the GSCM framework, IoT is not only a tool for efficiency but also a catalyst for sustainability. For example, IoT sensors can monitor energy use in detail, detect leaks in the production chain, and provide real-time data on greenhouse gas emissions. This data can then be analyzed with artificial intelligence to formulate strategies for significant environmental impact reduction (Marinakis et al., 2020). In addition, the implementation of blockchain integrated with IoT can increase supply chain transparency, allowing consumers and regulators to trace the origin of products and compliance with environmental standards.

Despite this, the integration of IoT in GSCM is not without obstacles. The relatively high cost of technology implementation remains a major barrier, especially for small and medium-sized enterprises. In addition, cybersecurity issues are a

serious concern due to the high risk of data leaks in connected systems. Other challenges include the need for new technical skills among the workforce and the lack of uniform global standards related to the application of IoT in the context of sustainability. Considering these opportunities and challenges, it is important to review the latest literature on the role of IoT in supporting GSCM. Through a literature review, this research aims to provide a comprehensive overview of how IoT supports the transformation of SCM towards a more efficient, transparent, and sustainable green supply chain.

2. Literature Review

2.1. Internet of Things (IoT) in Supply Chain Management (SCM)

Recent literature shows that IoT is one of the key technologies in supporting the transformation of supply chains towards a more efficient and responsive model. IoT works by connecting physical devices through sensors that can collect, process, and transmit data in real-time. In the context of SCM, this technology provides significant benefits such as increased supply chain visibility, transportation optimization, and more accurate inventory management (Yang et al., 2019).

Choi et al. (2021) emphasize that after the COVID-19 pandemic, companies have been increasingly encouraged to adopt digital technology due to the need for global supply chain resilience. IoT enables companies to better predict demand, reduce the risk of distribution delays, and detect logistical disruptions early on. Andronie et al. (2021) add that the integration of IoT with artificial intelligence supports data-driven decision-making processes, thereby improving operational

efficiency and reducing costs. However, the adoption of IoT in SCM is not without challenges. Lee et al. (2021) identify barriers in the form of high implementation costs, concerns related to cybersecurity, and a lack of global standards governing device interoperability. These barriers are a particular problem for small and medium-sized enterprises that often have limited resources. Nevertheless, the research shows a significant increase in the use of IoT as a strategy for strengthening competitiveness in SCM (Xu et al., 2018).

2.2. IoT in Green Supply Chain Management (GSCM)

The concept of Green Supply Chain Management (GSCM) emerged in response to increasing pressure from environmental regulations and consumer demand for eco-friendly products. The application of GSCM emphasizes energy efficiency, waste reduction, and emission monitoring throughout the supply chain. IoT is a key supporting technology because of its ability to integrate environmental sensors, production devices, and transportation systems to generate relevant data for sustainability (Alsamhi et al., 2019). Primadasa et al. (2019) confirm that IoT encourages green business practices by increasing transparency and accountability in global supply chains. For example, the use of sensors can detect excessive energy consumption or monitor air quality at production sites. Marinakis et al. (2020) add that big data analysis from IoT devices helps companies identify inefficient energy consumption patterns, allowing them to develop emission reduction strategies.

In addition, the integration of IoT with blockchain is increasingly being discussed in recent literature as a way to increase traceability and trust in the supply chain. Balzarova (2021) emphasize that the combination of IoT and blockchain

allows consumers and regulators to verify the origin of products and compliance with sustainability standards transparently. Nevertheless, limitations in terms of regulations and international standards, requiring collaborative efforts to create a more structured ecosystem. The literature shows that IoT has a dual role in supporting GSCM: first, by increasing operational efficiency through real-time data, and second, by strengthening the sustainability aspect by providing better visibility of environmental impacts. This is in line with the global trend towards a green economy and sustainable business that focuses not only on financial gain but also on social and environmental responsibility.

3. Methods

This study uses a literature review method to analyze the role of the Internet of Things (IoT) in supporting Supply Chain Management (SCM) and Green Supply Chain Management (GSCM). A literature review was chosen because it allows researchers to collect, integrate, and compare findings from various recent academic studies without conducting direct field experiments. With this approach, the research can identify patterns, trends, and research gaps relevant to the development of digital technology, especially IoT, in the context of sustainable supply chains.

The data collection process was carried out by searching for scientific articles published and referenced on Google Scholar. The inclusion criteria included research that discusses: the application of IoT in supply chain management, the connection between IoT and sustainability practices or GSCM, and publications that have theoretical and practical relevance to the transformation of Industry 4.0.

Articles that are only opinion-based or do not have a strong empirical basis are not included in this study. The literature analysis stage was carried out using a thematic approach, by grouping the research results into two main dimensions, namely: IoT in improving SCM operational efficiency, and IoT as an enabler in the implementation of GSCM. This thematic approach allows for the construction of a more structured narrative on how IoT not only functions as a technological tool but also as a catalyst in the transformation efforts towards a green supply chain.

In addition, this method also uses a comparative analysis approach, where the results from various studies are compared to identify similarities and differences in findings. For example, some studies emphasize the benefits of IoT in inventory visibility, while others focus more on the contribution of IoT to carbon emission reduction. This comparative analysis is important to provide a more comprehensive overview of the dynamics of IoT application in global supply chains. The next step is to synthesize the literature, which is to integrate the research findings into a complete conceptual framework. The synthesis is carried out by paying attention to the opportunities, challenges, and managerial implications of IoT implementation. This includes an analysis of technological aspects (sensors, big data, AI), economic aspects (cost efficiency, increased competitiveness), and social-environmental aspects (sustainability, regulatory compliance, and corporate social responsibility).

Finally, the validity of this research is enhanced by triangulating sources, namely using various literatures from reputable international journals and relevant local scientific articles. Thus, this research not only focuses on global findings but also considers the context of implementation in developing countries that have

different dynamics. Through this literature review method, it is hoped that a comprehensive understanding will be obtained of how IoT can change the traditional supply chain paradigm into a system that is more efficient, adaptive, and oriented towards sustainability

4. Results

The results of this literature review show that the Internet of Things (IoT) has become one of the key technologies in the transformation of Supply Chain Management (SCM) and Green Supply Chain Management (GSCM) in the era of the Fourth Industrial Revolution. Analysis from various studies shows that IoT has a significant impact on increasing the efficiency, transparency, and sustainability of global supply chains. The implementation of this technology not only focuses on operational aspects but also supports sustainability strategies that are increasingly gaining attention from regulators, consumers, and investors.

From a traditional SCM perspective, the main challenges that companies often face are limited visibility, the complexity of coordination between actors, high operational costs, and distribution delays. IoT emerges as a solution to overcome these limitations by providing real-time data from various points in the supply chain. Sensors installed on vehicles, warehouses, and production equipment can monitor inventory conditions, product locations, and transportation status with a high degree of accuracy. This enables faster and more precise decision-making, and prevents losses due to distribution delays or stockouts. Research conducted by Yang et al.

(2019) confirms that the application of IoT in SCM has a direct impact on increasing supply chain visibility and logistics efficiency.

In addition to operational benefits, IoT also plays an important role in increasing supply chain resilience, especially after the COVID-19 pandemic which triggered major disruptions to global distribution. Choi et al. (2021) highlight that companies are increasingly encouraged to adopt digital technology, including IoT, in an effort to anticipate uncertainty and external disruptions. Through sensor-based monitoring, companies can more quickly detect potential logistical obstacles and mitigate risks. Thus, IoT not only increases cost efficiency but also strengthens adaptive capabilities in facing global dynamics.

In the context of GSCM, the literature shows that IoT plays a strategic role in supporting sustainability practices. The use of environmental sensors allows for the monitoring of energy consumption, greenhouse gas emissions, and the level of waste generated during the production and distribution process. The data obtained can be analyzed using artificial intelligence algorithms to identify inefficient areas and formulate emission reduction strategies. For example, IoT can help optimize transportation routes to reduce fuel consumption and carbon footprint. These findings are in line with the research of Alsamhi et al. (2019) who emphasize that the integration of IoT in GSCM can increase a company's compliance with environmental regulations while building a positive image in the eyes of consumers.

Furthermore, the literature results show a trend of combining IoT with other technologies such as big data analytics and blockchain to strengthen supply chain sustainability. Big data analysis from IoT sensors helps companies recognize

inefficient energy or transportation patterns, while blockchain provides full transparency of product origins and their production processes. Balzarova (2021) explain that the combination of IoT and blockchain creates a more reliable traceability system, so that consumers and regulators can verify the authenticity and compliance of products with sustainability standards. This not only encourages public trust but also makes it easier for companies to meet increasingly strict green certification standards in various countries.

On the other hand, the results of the literature review also show a number of challenges that need to be anticipated. Lee et al. (2021) identify barriers in the form of high investment costs, cybersecurity risks, and a lack of global regulations governing the interoperability of IoT devices. The security challenge is a serious concern given that the data collected by IoT is sensitive and vulnerable to attacks. The risk of data leaks or cyber attacks can harm the company financially and reduce consumer trust. In addition, the limited ability of small and medium-sized enterprises to adopt IoT creates a digital gap that can widen the competitive disparity.

However, the results of the analysis show that the global trend tends to increasingly support the adoption of IoT in SCM and GSCM. Stricter environmental regulations encourage companies to adopt sustainable practices, while consumers are increasingly aware of the importance of environmentally friendly products. Primadasa et al. (2019) confirm that IoT can be a catalyst for companies to implement green technology while increasing brand reputation. Companies that successfully integrate IoT with sustainability strategies are predicted to gain long-

term benefits in the form of consumer loyalty, attractiveness to investors, and global competitiveness.

In addition, the literature results also indicate that IoT plays a role in creating new data-based business models. The sharing economy and digital banks are examples of how real-time data from IoT devices can open up business opportunities that did not previously exist. In the context of SCM, data collected from IoT can be monetized through analytical services or collaborative platforms that connect various stakeholders in the supply chain. This is in line with the Industry 4.0 trend that emphasizes the integration of the digital and physical worlds through cyber-physical systems.

From the overall results of the literature study, it can be seen that the role of IoT in SCM and GSCM cannot be seen only as additional technology, but as a main pillar in the transformation of supply chains towards a direction that is smarter, more efficient, and sustainable. The benefits generated are not only limited to reducing operational costs, but also concern increasing global competitiveness, fulfilling environmental regulations, and creating social value through sustainability practices.

In general, the results of this analysis can be summarized in several main points. First, IoT makes a real contribution to improving the operational efficiency of the supply chain through real-time visibility, demand prediction, and transportation optimization. Second, IoT supports GSCM practices by providing environmental data that can be used to reduce emissions, save energy, and increase compliance with regulations. Large amount of data processing at ever expanding IoT network is the reason for ever increasing power consumption and consequently

resulting in large quantity of diverse technological wastage's which results in negative impact on human's health and global environment (Albreem et al., 2021)

Third, the integration of IoT with other technologies such as AI, big data, and blockchain increasingly expands the potential for its application in creating a transparent and sustainable supply chain. Fourth, although there are challenges in the form of costs, security, and global standards, the literature shows that the future trend leads to an increase in the adoption of IoT, both due to regulatory pressure and consumer demand. Thus, the results of this literature study show that IoT has a strategic role in strengthening modern supply chains. This technology not only answers short-term operational needs but also becomes a foundation for the development of business models that are adaptive, sustainable, and competitive in the digital era.

5. Discussion

The results of the literature review that have been analyzed show that the Internet of Things (IoT) has a strategic role in driving the transformation of Supply Chain Management (SCM) and Green Supply Chain Management (GSCM). However, to understand the deeper implications, a discussion is needed on the relevance of the findings, implementation challenges, and future development directions. From the perspective of supply chain efficiency, IoT is proven to be able to answer the main challenges of traditional SCM, such as limited visibility and the complexity of coordination. With sensors connecting various points in the supply chain, companies can obtain valuable real-time data to optimize inventory, predict

demand, and minimize distribution delays. This shows that IoT not only functions as a technological aid but as an important foundation for data-driven decision-making. These findings are in line with the literature that confirms that digitalization is the key to creating a resilient and responsive supply chain to global market dynamics.

The integration of IoT with sustainability principles strengthens the role of this technology as an enabler for GSCM. The use of sensors to monitor energy consumption, carbon emissions, and transportation conditions provides a great opportunity to reduce the environmental impact of logistics and production activities. In addition, data analysis from IoT can generate specific recommendations regarding areas for improvement, so that companies can be more targeted in carrying out green strategies. This discussion is important because it shows that IoT not only functions to improve operational efficiency but also as an important instrument in helping companies meet increasingly strict environmental regulations and answer consumer demands that are more aware of sustainability issues.

Although the benefits are significant, the adoption of IoT in SCM and GSCM faces a number of major challenges. The high cost of infrastructure investment is one of the main barriers, especially for small and medium-sized enterprises that have limited resources. Another challenge is the risk of cybersecurity, given that the data collected by IoT is sensitive and vulnerable to attacks. This discussion is important because it shows that the success of IoT implementation does not only depend on technological aspects, but also on organizational readiness, regulation, and security.

There are research gaps that still need to be bridged. Most of the literature focuses on the benefits of IoT in the context of large companies or developed countries, while its application in developing countries is rarely discussed in depth. In fact, differences in infrastructure, regulations, and technological readiness can affect the effectiveness of IoT in supporting SCM and GSCM. Therefore, further research is needed to explore IoT implementation models that are suitable for the local context, so that the benefits of this technology can be felt more inclusively.

The discussion on the future shows that IoT will play an increasing role in creating a smarter, more adaptive, and sustainable supply chain if it is combined with other technologies such as artificial intelligence (AI), big data analytics, and blockchain. This integration allows for automated decision-making, full transparency in product traceability, and predictive analysis to minimize risk. This means that IoT is not just a stand-alone technology, but part of a wider digital ecosystem within the framework of Industry 4.0.

Finally, this discussion confirms that although the adoption of IoT presents challenges, the global trend shows an increasingly clear direction towards the digitalization of supply chains based on sustainability. The push of environmental regulations, consumer pressure, and long-term competitive opportunities will continue to strengthen IoT's position as a key technology in SCM and GSCM. Therefore, it is important for companies, regulators, and academics to continue to collaborate in developing an implementation framework that is inclusive, safe, and in line with global and local needs.

6. Conclusion

This literature study confirms that the Internet of Things (IoT) is one of the main pillars in the transformation of Supply Chain Management (SCM) and Green Supply Chain Management (GSCM) in the era of the Fourth Industrial Revolution. The results of the analysis show that IoT can increase the visibility, efficiency, and responsiveness of the supply chain through real-time data monitoring that allows for faster and more accurate decision-making. In the context of sustainability, IoT supports the reduction of energy consumption, emissions, and waste through sensor-based control integrated with artificial intelligence.

Nevertheless, there are challenges that cannot be ignored, such as high investment costs, cybersecurity risks, and limited infrastructure readiness, especially in developing countries. However, global trends show a positive direction with increasing environmental regulatory pressure, consumer demands for eco-friendly products, and the integration of IoT with other technologies such as AI, big data, and blockchain that strengthen supply chain transparency and sustainability.

Thus, IoT is not only relevant for answering short-term operational problems but also has a strategic role in forming a more resilient, adaptive, and sustainable supply chain in the future. The success of its implementation will be greatly determined by the collaboration between companies, regulators, and academics in designing a system that is inclusive, safe, and in line with global and local needs.

References.

Albreem, M. A., Sheikh, A. M., Alsharif, M. H., Jusoh, M., & Yasin, M. N. M. (2021). Green Internet of Things (GIoT): applications, practices, awareness, and challenges. *Ieee Access*, *9*, 38833-38858.

Alsamhi, S. H., Ma, O., Ansari, M. S., & Meng, Q. (2019). Greening internet of things for greener and smarter cities: a survey and future prospects. *Telecommunication Systems*, *72*(4), 609-632.

Andronie, M., Lăzăroiu, G., Iatagan, M., Uţă, C., Ştefănescu, R., & Cocoşatu, M. (2021). Artificial intelligence-based decision-making algorithms, internet of things sensing networks, and deep learning-assisted smart process management in cyber-physical production systems. *Electronics*, *10*(20), 2497.

Balzarova, M. A. (2021). Blockchain technology–a new era of ecolabelling schemes?. *Corporate Governance: The International Journal of Business in Society*, *21*(1), 159-174.

Calderaro, A., & Craig, A. J. (2020). Transnational governance of cybersecurity: policy challenges and global inequalities in cyber capacity building. *Third world quarterly*, *41*(6), 917-938.

Choi, T. M. (2021). Risk analysis in logistics systems: A research agenda during and after the COVID-19 pandemic. *Transportation Research Part E: Logistics and Transportation Review*, *145*, 1-8.

Lee, E., Seo, Y. D., Oh, S. R., & Kim, Y. G. (2021). A Survey on Standards for Interoperability and Security in the Internet of Things. *IEEE Communications Surveys & Tutorials*, *23*(2), 1020-1047.

Marinakis, V., Doukas, H., Tsapelas, J., Mouzakitis, S., Sicilia, Á., Madrazo, L., & Sgouridis, S. (2020). From big data to smart energy services: An application for intelligent energy management. *Future Generation Computer Systems*, *110*, 572-586.

Primadasa, R., Sokhibi, A., & Tauhida, D. (2019, August). Interrelationship of green supply chain management (GSCM) performance indicators for palm oil industry in Indonesia. In *IOP Conference Series: Materials Science and Engineering* (Vol. 598, No. 1, p. 012034). IOP Publishing.

Xu, H., Yu, W., Griffith, D., & Golmie, N. (2018). A survey on industrial Internet of Things: A cyber-physical systems perspective. *Ieee access*, *6*, 78238-78259.

Yang, Y., Pan, S., & Ballot, E. (2017). Innovative vendor-managed inventory strategy exploiting interconnected logistics services in the Physical Internet. *International Journal of Production Research*, *55*(9), 2685-2702.