CHEMICAL ENGINEERING TRANSACTIONS
VOL. 107, 2023
A publication of AIDIC
The Italian Association of Chemical Engineering
Online at www.cetjournal.it
Guest Editors: Petar S. Varbanov, Bohong Wang, Petro Kapustenko

ISBN 979-12-81206-07-6; **ISSN** 2283-9216
DOI: 10.3303/CET23107073

The Role of Blockchain and IOT in Reverse Logistics: the Impacts on the Environmental and Economical Sustainability – A Structured Literature Review

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This paper aims to present the potential of the Internet of Things and Blockchain applications in enhancing the sustainability of reverse logistics processes. Logistics operations play a vital role in supply chain management and are often referred to as the "dynamo" of the process. Reverse logistics is imperative to bridge the gap between forward logistics (the initial movement of goods) and backward logistics (the movement of products in the opposite direction) to close the supply chain loop and achieve a more sustainable operation that is both environmentally and economically efficient. To achieve this objective, the paper undertook a structured literature review using three renowned databases, namely, Science Direct, Scopus, and Web of Science, via a mapping study. The investigation focused on exploring the sustainable aspects of reverse logistics, which can help organizations attain better environmental and economic returns. Additionally, the paper emphasizes how the Internet of Things and Blockchain applications can contribute to more economical and environmentally sustainable management of reverse logistics operations. The results highlight the key strategies, benefits, barriers, research gaps, and future research directions associated with the integration of these technologies in reverse logistics operations.

1. Introduction

In recent years, the growing concerns over environmental degradation and resource depletion have necessitated a paradigm shift in supply chain management towards sustainable practices. This shift has brought increased attention to the concept of reverse logistics, which entails the effective handling and management of product returns, end-of-life materials, and waste streams. As a critical component of closed-loop supply chains and the circular economy, reverse logistics plays a pivotal role in achieving both environmental and economic sustainability objectives (Keivanpour and Kadi, 2019).

Closed-loop supply chains, also known as closed-loop systems, represent a sustainable approach to material flow management, where products, components, and materials are continuously cycled back into the system. This circular approach contrasts with the traditional linear supply chains that follow a "take-make-dispose" pattern, contributing significantly to resource depletion, waste generation, and environmental pollution. In a closed-loop supply chain, products reach their end-of-life but are not discarded; instead, they are recovered, refurbished, remanufactured, or recycled to be reintroduced into the supply chain. This integration of reverse logistics into the closed-loop supply chain model allows for efficient resource utilization, minimized waste, and prolonged product lifecycles (Júnior et al., 2022). The circular economy, an overarching concept underpinning the closed-loop supply chain approach, aims to decouple economic growth from resource consumption. By emphasizing the reuse, refurbishment, and recycling of materials, the circular economy seeks to promote sustainability and environmental preservation. Reverse logistics plays an integral role in realizing the goals of the circular economy, as it enables the efficient handling of end-of-life products and the reintroduction of valuable materials back into the production process, reducing the need for virgin resources and mitigating environmental impacts (Prajapati et al., 2022).

This study aims to explore the research gaps, key strategies, benefits, barriers and future research directions associated with the integration of reverse logistics into sustainable supply chain practices, with a specific focus

Paper Received: 14 March 2023; Revised: 03 July 2023; Accepted: 26 October 2023
Please cite this article as: Almelhem M., Süle E., Buics L., 2023, The Role of Blockchain and IOT in Reverse Logistics: The Impacts on the Environmental and Economical Sustainability – a Structured Literature Review, Chemical Engineering Transactions, 107, 433-438 DOI:10.3303/CET23107073

on their implications for environmental and economic sustainability. Through a comprehensive review of relevant literature from the ScienceDirect, Scopus and WOS databases. Through this structured literature review, it becomes evident that discussing reverse logistics in isolation from closed-loop supply chain management and the circular economy is challenging due to their intrinsic interconnectedness observed in the majority of scholarly works.

Reverse logistics sustainability has emerged as a critical area of focus for industries striving to achieve environmentally and economically responsible operations. In this context, the promising future of Industry 4.0 technologies, specifically blockchain and the Internet of Things (IoT), presents a compelling opportunity to foster sustainability and close the supply chain loop. The implementation of blockchain and IoT can revolutionize supply chain processes by enabling transparent and traceable tracking of materials and products throughout their lifecycle. These technologies facilitate collaboration among stakeholders, leading to optimized resource usage, reduced waste, and enhanced efficiency. Consequently, Industry 4.0 technologies hold great potential for creating more sustainable supply chain operations, aligning with the principles of the circular economy (Krstić et al., 2022).

2. Methods

This article conducts a rapid structured literature review to explore the role of Blockchain and IoT technologies in reverse logistics operations, following the prescribed steps outlined in Figure 1.

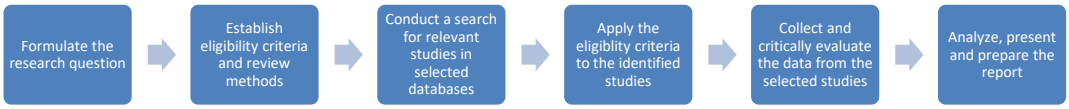

Figure 1: Literature review process steps

A structured literature review was used in this study. A rigorous and systematic approach to analyzing existing academic literature on the research topic. It aims to provide a comprehensive and unbiased understanding of the current state of knowledge, identifying gaps, patterns, and trends in the field. The process involves defining the research question, conducting comprehensive searches in reputable databases, and critically evaluating selected literature to extract relevant information. Key elements encompass inclusion and exclusion criteria, a clear search strategy, and a rigorous evaluation of study quality and validity (Dumay et al., 2016). The primary objective of this study is to address the research question: "How can the implementation of Blockchain and IoT technologies in reverse logistics operations enhance environmental and economic sustainability?" To achieve this, a structured literature review approach is adopted, involving the systematic search and categorization of relevant articles from the ScienceDirect, Scopus, and WOS databases. The following keyword combinations: "Reverse Logistics" AND "Blockchain Technology" AND "Internet of Things" AND "Sustainability" were employed during the search.

Inclusion and exclusion criteria are established to ensure that only relevant articles written in English and directly related to the research question are included, review and research document types are only included, and any overlapping articles between the databases are excluded to avoid duplication.

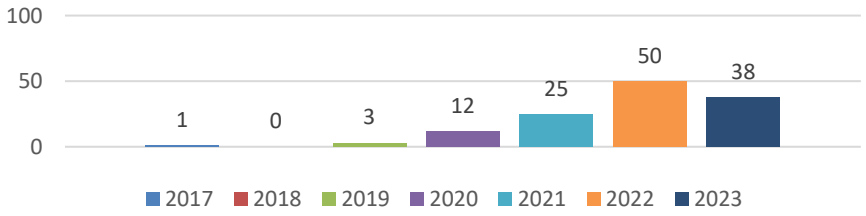

Figure 2: Number of articles per year from ScienceDirect Database

3. Results

Chapter 2 From the ScienceDirect database, no records were retrieved before 2017, while 129 results were identified between 2017 and 2023. Among these, there were 29 review articles and 100 research articles. After applying inclusion criteria, a total of 53 papers were selected for the study's analysis, directly addressing the research question or providing relevant insights. In the discussion and conclusion section, only a few articles were chosen that align with the study's objectives. Notably, when employing the same keyword combinations in

Scopus and Web of Science databases, only 1 and 2 results were obtained, indicating a significant research gap in this particular area. Consequently, the analysis reveals that the ScienceDirect database significantly played a predominant role in contributing to this study. Figure number 2 illustrates the annual distribution of articles sourced from the ScienceDirect Database.

4. Discussion

Several recent studies highlight the role of blockchain and IoT technologies in advancing sustainability and efficiency in supply chains, circular economy practices, reverse logistics, and closed-loop supply chains. These technologies offer promising solutions to common challenges and hold the potential for significant environmental and economic benefits. (Ashraf and Heavey, 2023) introduced a prototype that uses Solana blockchain and IoT to enhance supply chain traceability, reducing waste and boosting efficiency. This integration improves transparency and reliability throughout the supply chain. Böckel et al. (2021) emphasized the potential of blockchain and IoT in promoting the circular economy by reducing waste and enhancing resource efficiency in closed-loop supply chains. However, further research is needed to fully understand their environmental and economic impacts. Dutta et al. (2020) explored the vital roles of blockchain and IoT in enabling environmentally friendly practices, resource optimization, and waste reduction. These technologies create secure records, automate actions, and foster innovative business models. Huang et al. (2022) highlighted the significance of blockchain and IoT in creating sustainable circular supply chains. Their combination enhances data sharing, tracking, and material recovery, offering potential benefits such as waste reduction and increased use of renewable energy. Júnior et al. (2022) examined the application of blockchain and IoT in establishing closed-loop supply chains for the battery industry. This approach enhances sustainability, reduces waste, and improves transparency and battery performance. Musamih et al. (2022) proposed a blockchain-based solution to reduce COVID-19 vaccine waste. Their solution ensures transparency, accountability, and security, potentially reducing waste and related economic and environmental impacts. Simonetto et al. (2022) suggested that blockchain and IoT technologies play vital roles in facilitating closed-loop supply chains (CLSCs) and the circular economy. However, careful design and management are necessary to maximize environmental and economic benefits while minimizing risks in CLSC implementation. Kofos et al. (2022) agree with the previously mentioned studies on the role of blockchain and IoT and also highlight Blockchain-based platforms like TradeLens, FoodTrust, and Vinturas, which facilitate this by integrating data from various stakeholders across materials supply chains, ensuring efficient reuse and recycling of materials while eliminating waste.

Meier et al. (2023) suggest that blockchain technology can be employed from a dynamic capabilities perspective to implement Circular Supply Chain Management (CSCM). Blockchain's functionalities enable end-to-end supply chain traceability, tracking materials and information flow, and identifying areas for improvement. Blockchain facilitates secure and transparent data sharing among stakeholders, fostering effective collaboration for circular economy practices. Additionally, blockchain can create decentralized marketplaces for circular products and services, generating new revenue streams from waste streams. The paper highlights blockchain's potential to enhance sustainability and circularity in supply chain management, contingent upon the development of appropriate dynamic capabilities.

Mallick et al. (2023) emphasize the pivotal role of IoT in reverse logistics (RL), highlighting applications like real-time tracking, predictive maintenance, data analytics, and customer engagement. They stress that IoT addresses barriers to RL by improving visibility, traceability, and accountability, ultimately enhancing the management of product and material flows in the reverse supply chain. In contrast, Rejeb et al. (2020) focus on IoT's optimization of reverse logistics operations, particularly in identifying return reasons, reducing processing time, and improving inventory management. They underscore IoT's potential across diverse sectors and its ability to yield environmental and economic benefits by reducing waste, enhancing resource utilization, and increasing profitability. The mutual idea between these studies is the critical role of IoT in revolutionizing reverse logistics and supply chain operations. Both papers emphasize its potential to enhance efficiency, reduce costs, and provide real-time tracking and monitoring capabilities, ultimately contributing to the sustainability and profitability of supply chain and logistics practices.

Rejeb et al. (2022) explore IoT's potential to support the circular economy, emphasizing its role in improving reverse logistics. They highlight how IoT enhances product and material tracking, leading to more efficient circular practices. Additionally, IoT's data analysis identifies waste reduction and resource optimization opportunities, while supply chain transparency promotes responsible reuse and recycling. The paper suggests IoT's environmental benefits, including efficient resource use and waste reduction, leading to cost savings and enhanced supply chain efficiency. In contrast, Rejeb et al. (2023) assert that blockchain technology accelerates the transition to a circular economy. They identify six key themes, including transparency, smart contracts, and sustainability in sectors like waste management. While not detailing economic or environmental impacts, they stress the circular economy's goal of balancing consumption, growth, and environmental protection for future

generations. Blockchain's role in tracking products and enhancing reverse logistics is highlighted. Voulgaridis et al. (2022) explore IoT's role in promoting circular economy principles, emphasizing real-time data for resource optimization and waste reduction. Blockchain's potential for transparency, particularly in closed-loop supply chains, is acknowledged, enhancing effective reverse logistics. The paper mentions environmental and economic impacts, such as waste reduction, cost savings, and supply chain efficiency, aligning with circular principles.

Shou and Domenech (2022) introduce a blockchain-based Life Cycle Assessment (LCA) framework for improved traceability and reliable data in identifying environmental hotspots and quantifying circular potential. By applying blockchain technology to reuse markets and second-hand leather bags, the process becomes more transparent and reliable, promoting circularity through enhanced traceability and data sharing, leading to reduced environmental impact. The proposed framework aims to integrate LCA and blockchain in the fashion industry to accurately assess circular practices. It enables tracking the origin and journey of fashion products, ensuring transparency. Additionally, it suggests the potential for managing the reverse flow of materials in the fashion industry. The paper emphasizes the importance of accurately quantifying the benefits of circular strategies in reducing environmental impact using LCA within the proposed blockchain-based framework. It discusses the significant environmental impacts of the textile sector, particularly the high usage of raw materials, water, land, and Greenhouse Gas (GHG) emissions. The paper highlights the potential benefits of circular strategies, such as material reuse and alternative materials, in mitigating the environmental footprint of the fashion industry.

Sathiya et al. (2023) emphasize the significance of reliable reverse logistics in the healthcare supply chain (HSC) during the COVID-19 pandemic. This approach ensures proper medical waste disposal, returns of unused or expired products, and redistribution of excess inventory, leading to cost reduction, improved sustainability, and increased availability of critical medical supplies. To enhance the HSC, the paper proposes Chain-of-things (CoT) technology, which integrates IoT and blockchain networks. CoT facilitates secure, trusted, and traceable monitoring of HSC products, playing a vital role in addressing pandemic-induced challenges and building a resilient supply chain. It also suggests utilizing CoT technology to manage current and post-COVID-19 HSC issues, enabling smart HSC through localization, reliable reverse logistics, end-to-end visibility, and digitalization.

Srhir et al. (2023) propose integrating blockchain and IoT technologies into Supply Chain Operations Reference Model (SCOR) processes to replace intermediaries and decrease energy and resource consumption. In reverse logistics or closed-loop supply chains, blockchain and IoT can track products and materials, enhancing visibility and control, leading to waste reduction and improved efficiency. For the circular economy, blockchain and IoT facilitate data and resource sharing among supply chain actors, fostering collaboration and sustainability without intermediaries. Overall, these technologies are critical for transitioning to a circular supply chain model that promotes sustainability and efficiency. The paper discusses potential environmental impacts such as reduced energy and resource consumption, waste, and emissions, contributing to sustainable development goals. Economically, integrating Industry 4.0 technologies offers improved efficiency, reduced intermediary costs, new business models, revenue streams, and increased market competitiveness.

Mejía-Moncayo et al. (2023) highlight the potential of blockchain and Industry 4.0 (I4.0) technologies in fostering a sustainable circular economy, with a focus on remanufacturing and reverse logistics. Blockchain can facilitate the creation of quality and remanufacturability certificates, ensuring product traceability and integrity. I4.0 technologies enable the recovery, processing, and analysis of product life cycle information (PLCI) for circular manufacturing, improving end-of-life product visibility and enabling new business models. The proposed smart architecture (SA) integrates these technologies, offering a customizable and sustainable manufacturing-remanufacturing system adaptable to market changes and stakeholder interests. On the other hand, (Keivanpour and Kadi, 2019) argue that IoT plays a crucial role in enhancing the sustainability of end-of-life product management by enabling real-time data processing for informed decision-making on reusing, recycling, energy recovery, and disposal management, optimizing recovery strategies and minimizing waste and environmental impact.

Joséphine et al. (2022) examine the potential of blockchain and IoT to enhance traceability and transparency in the fashion industry, promoting sustainability and circular practices. Their focus includes tamper-proof product information records, efficient reverse logistics, and real-time data for optimizing product design and closed-loop supply chains. While they acknowledge the promise of blockchain and IoT integration, challenges like data privacy and interoperability require industry-wide standards and cooperation. The fashion industry's substantial environmental and economic impacts due to its linear and unsustainable nature underline the urgency of transitioning to more sustainable and circular value chains to mitigate adverse effects and foster positive environmental and economic outcomes. Conversely, Wang et al. (2020) underscore blockchain technology's crucial role in addressing complexities within reverse logistics and circular supply chain management, particularly in the fast-fashion sector. They propose a system architecture for blockchain-enabled circular supply

chain management and emphasize the necessity of transitioning to a sustainable circular economy. Key challenges include tracing material reuse and involving multiple stakeholders in circular supply chains. Blockchain's secure and transparent platform is presented as a solution for tracking and verifying transactions, ensuring proper material reuse and recycling, and ultimately promoting sustainability and waste reduction. The proposed system architecture, comprising a private blockchain network, smart contracts, and a user interface, is validated by experts, demonstrating practical feasibility for implementation in the fast-fashion industry. The paper underscores the potential environmental and economic benefits of transitioning to a circular economy in the fast-fashion sector, with blockchain-enabled circular supply chain management reducing waste, enhancing sustainability, improving efficiency, and generating economic advantages.

Naseem et al. (2023) discuss the role of blockchain and IoT in reverse logistics, which are digital technologies developed during Industry 4.0. Blockchain adoption can significantly impact reverse logistics by decentralizing and tracking item delivery, leading to process acceleration and cost reduction. Key points include how blockchain decentralizes and tracks delivery, enhancing efficiency and cost-effectiveness. IoT devices collect data about item location and condition, optimizing processes and minimizing waste. Adopting these technologies can grant businesses a competitive edge in the global market. However, barriers to blockchain adoption in reverse logistics must be overcome for successful implementation, including high installation costs, stakeholder resistance, and lack of top-management support. A case study in Pakistan's e-commerce industry identifies 16 barriers, grouped into organizational, technological, social, economic, and external categories, ranked using the fuzzy AHP approach. Successful adoption requires careful cost-benefit evaluation, addressing cultural and behavioral aspects, building robust technological infrastructure, and investing in appropriate blockchain tools.

5. Conclusion

The present paper endeavors to explore the potential applications of blockchain technology and the Internet of Things (IoT) within the realm of Reverse Logistics Operations. A comprehensive, structured literature review, accompanied by a meticulous mapping study, was diligently undertaken to elucidate how the integration of these cutting-edge technologies can confer significant advantages upon reverse logistics operations. Reverse logistics, denoting the process of efficiently managing the flow of products, materials, or information in reverse, from their consumption to their point of origin, has emerged as a pivotal aspect of sustainable supply chain management. Blockchain, as a decentralized and immutable ledger technology, and IoT, as an interconnected network of physical devices, hold immense promise in revolutionizing reverse logistics by ensuring transparency, traceability, and efficiency in the handling of returned goods and materials.

The meticulous mapping study carried out in this research revealed a paucity of published works on the subject in the Scopus and Web of Science (WOS) databases, with merely one and two relevant results. Additionally, the ScienceDirect database yielded 129 pertinent papers, which, though relatively limited in number, accentuated a crucial research gap in this domain. Among these, only 53 papers directly addressed or briefly touched upon the research question. Notably, these selected works overwhelmingly underscored the considerable potential of blockchain and IoT in fostering more sustainable reverse logistics operations while also promoting the closure of the supply chain loop and enhancing circular economy practices.

However, the review highlighted a notable absence of specific details or empirical data concerning the economic and environmental impacts of implementing blockchain technology and IoT in reverse logistics. Some studies argued that despite their positive potential in reducing waste and associated costs, it is imperative to thoroughly analyze the high implementation costs of these technologies to achieve an optimized solution. Such an optimal equilibrium should strike a balance between their waste reduction capabilities and cost considerations. It is equally crucial to acknowledge that the current body of literature falls short in addressing the operational aspects of reverse logistics and the precise role of these technologies in managing various aspects such as reuse, recycle, refurbishment, and disposal.

As a promising direction for future research, it is suggested that subsequent studies delve deeper into the practical implications of these technologies by employing simulations or empirical data. Such investigations should illuminate the operational facets of reverse logistics and the effective integration of smart technologies to facilitate sustainable outcomes. By doing so, researchers can contribute to bridging the existing knowledge gaps and unlocking the full potential of blockchain and IoT in revolutionizing reverse logistics operations for a more environmentally responsible and economically efficient supply chain paradigm.

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