**Reinventing Reverse Logistics through Blockchain Technology: A Comprehensive Review and Future Research Propositions**

**Abstract**

Blockchain Technology (BCT) has effectively evolved in reverse logistics (RL) to speed up its operation by decentralising, tracing, and monitoring the goods delivered to the end consumers. This study outlines the current research fashion of BCT applicability in RL from 2015 to 22. A wide range of 226 research papers is selected from the SCOPUS database to conduct the bibliometric and network analysis for offering a comprehensive literature review on research clusters and fashions of BCT in RL. Some primary research clusters such as infrastructure development, sustainable manufacturing, logistics, circular supply chain, and waste management are identified. The network analysis has helped identify pioneer authors, journals, and countries actively involved in BCT research in RL. The content analysis findings indicate the evolution of BCT in various themes of RL. The articles also develop a result systematisation framework to concisely offer the outcomes of this research. Further, the current study provides recommendations for future research work for academic and industry practitioners based on the existing literature.

***Keywords:*** Blockchain technology; Reverse logistics; Content analysis; Systematisation framework

**1. Introduction**

Consumers can now get the things they need quickly because of current revelations in logistics technology and the advent of e-commerce. Many items are acquired, distributed, shipped, and carried out domestically and overseas. Countless goods produce or even become noxious hazards for human exposure when they reach the end of their lifespan (Alarcón et al., 2021). Improper disposing of this hazard can have major consequences for the environment and ecology as a whole (Hanafi et al., 2008). Such disposal issues, combined with overharvesting of natural assets and a finite ability to absorb all manufactured products sustainably, are growing societal awareness regarding the significance of environmental protection (Han et al., 2016). As a result of this predicament, governments are passing new legislation that encourages raw materials to reuse, reduces ecological footprint, and expands the usable life of products (Prakash and Barua, 2016). This implies that organisations must regulate reverse flows and product processing (Ravi et al., 2005) to adhere to the rules, minimise ecological effects, and optimise the monetary worth of their products and manufacturing operations to promote their brand persona (Steeneck and Sarin, 2013). Therefore, organisations seem obligated to implement reverse logistics (RL) activities in their supply chains (SCs) for competitiveness, advertising, financial, and ecological concerns (Shankar et al., 2008). Considering their relevance in operations and customer service, including a reverse logistics process (RLP) and forming suitable SC collaborations have become pressing issues (Banihashemi et al., 2019). In reality, the capacity to control returns has become a vital success component (Autry, 2005).

Logistical management is no longer restricted to conventional logistics operations and now integrates on android platforms, e-commerce portals, local retailers, and social media outlets (Shih et al., 2021). Forward logistics, as it is known, efficiently transports finished goods from suppliers to end consumers within a given timeframe. However, to incorporate the reverse logistics network in the closed-loop supply chain, some safe methods with technology intervention are required due to various return schemes and faults in handling (Subramanian et al., 2020).As a result, determining the integrity of returned goods is challenging for logistics companies. Also, with the growth of e-commerce, the requirement for reverse logistics has increased recently (Prevost, 2018) since today's buyers have a fresh outlook on acquiring by making environmentally responsible choices (GlobalTranz, 2018). According to data, reverse logistics costs in the supply chain average between 7% and 10% of the price of products (Palumbo, 2020), and the worldwide reverse logistics market was worth $635.6 billion in 2020 and is anticipated to achieve $958.3 billion by 2028, growing at a compound annual growth rate (CAGR) of 5.6 per cent (Allied Market Research, 2021). As the popularity of online shopping grows, so does the demand for improved reverse logistics to manage client returns (Souza, 2018). Also, reverse logistics expenses exceed $750 billion every year, and the need for reverse logistics has increased over the years as e-commerce has grown (Robinson, 2018).

Further, Robinson (2018) indicates that manufacturers bear the task of finding a grave site for their products in reverse logistics, and some items, such as cellphones and electronic goods, might pollute the environment and expose gadget operators' details. Recycling and refurbishing electronic goods is a rapidly expanding region of the retail industry, and when blockchain visibility is used to follow goods throughout their life spans, retrieved personal details may be preserved and eliminated without risk (Cotton, 2018).

Blockchain technology (BCT) is now the most intriguing use (Kshetri, 2018), disrupting the existing corporate model. The implementation of blockchain can facilitate sharing of information and expertise among business entities. The exchange of information among supply chain stakeholders is rising, indicating cost savings and efficiency gains (Al-Saqaf and Seidler, 2018). Almost all transactions on the blockchain are secure, more transparent, identifiable, and effective; thus, supply chain professionals should use it in their operations.

The blockchain's monitoring system will aid in the prevention of product deception and imitation (Mackey and Nayyar, 2017). Customers can analyse the transaction procedure to ensure that transactions are transparent (Tsanos and Zografos, 2016). Blockchain has the potential to revolutionise and reconstruct the interactions among all stakeholders involved in the supply chain system from the aspect of decentralised management (Subramanian, 2017). Blockchain enables improved traceability and transparency of a product's lifecycle, from raw material procurement to ultimate disposition (Cotton, 2018). As a result, the supply chain will reap significant cost-cutting and efficiency gains.

Subramanian et al. (2020) reveal that BCT can influence reverse logistics by reducing costs, improving efficiency, enhancing green initiatives, and proper documentation activities. Further, their research indicates that BCT offers to share and track individual transactions and estimates the costs associated with these activities, which shows the potential of BCT in the RL. Cotton (2018) suggests that BCT can help manufacturers comprehend the whole lifetime of their goods, even after they've been discarded, by improving the information flow in reverse logistics. Dasaklis et al. (2020) proposed a blockchain-based secure framework for RL operations. Further, the study of Dasaklis et al. (2020) indicates that the decentralised and encrypted structure of blockchain ensures that the RL data shared among the many other stakeholders are precise, reliable, fast, and usable.

GlobalTranz (2018) suggests that the automotive industry, particularly the RL chain, which includes repairs and maintenance, is another area where BCT can benefit. Douladiris et al. (2020) established a blockchain framework for the RL of medical devices. Bekrar et al. (2021) offer an explanation illustrated by examples of how various blockchain components might be used in the RL setting. This way, the past research explores the major potential of BCT in various sectors of RL, such as medical equipment, electronic sector (mobiles), e-commerce, and the automotive sector. Also, the implementation of blockchain in the logistics system will profoundly influence its operation and redefine the relationships among its participants (Xue et al., 2021). Still, no past research offers a global perspective of BCT applications in the RL. Therefore, there is a dire need to address and highlight the role of BCT in the RL area. Thus, the overall evidence from past literature leads to the formulation of the following research questions-

*RQ1. What are the potential study areas for BCT in RL in the future?*

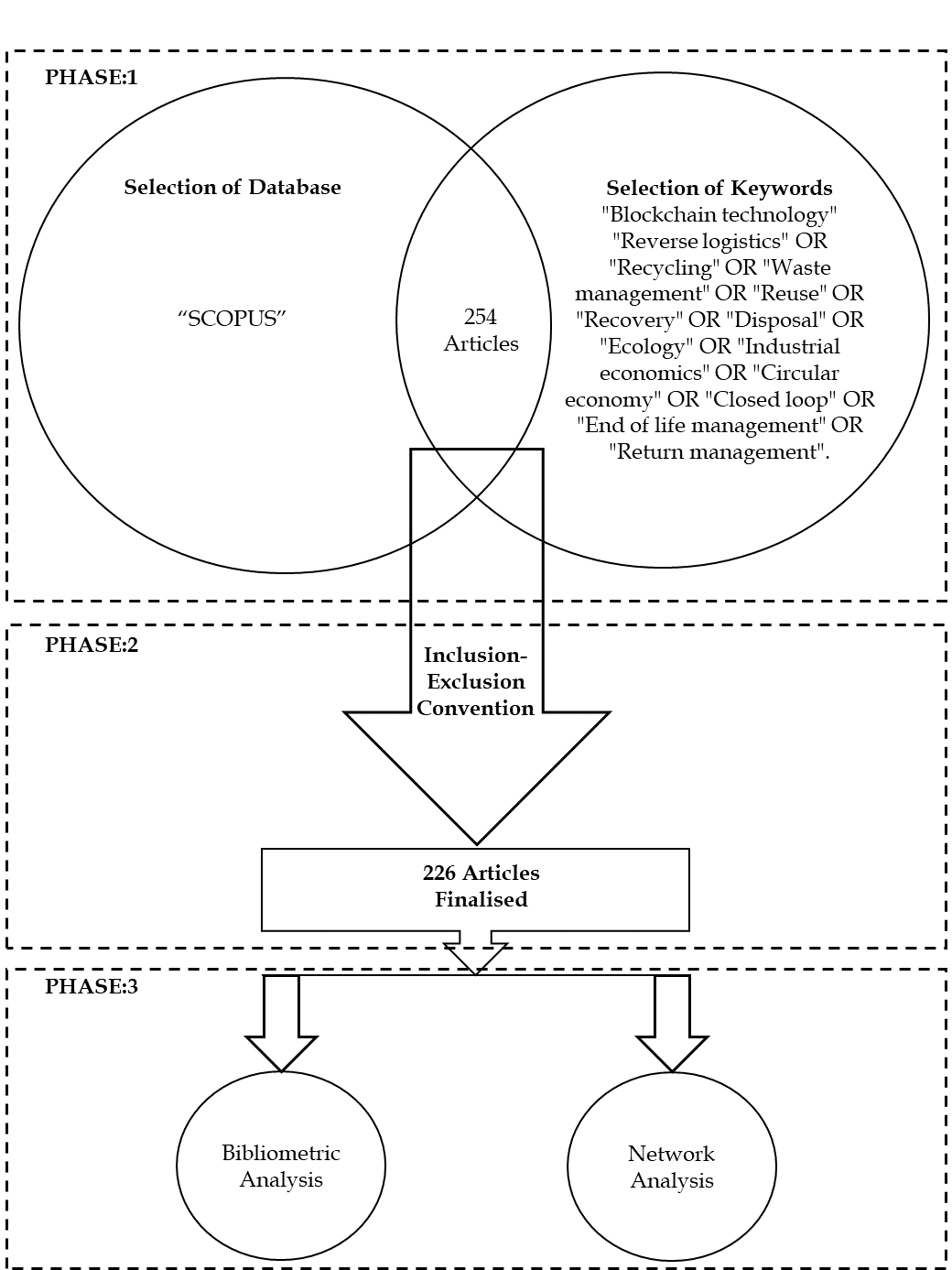
*RQ2.What are the recent research fashions in the field of BCT in RL?*

*RQ3. What are the areas of RL that BCT has supported?*

Thus, this study conducted a systematic literature review using a network and bibliometric analysis to answer the following research questions. The bibliometric and network analysis is based on the 226 articles drawn from the SCOPUS database by inserting the keywords relevant to BCT and RL. The remaining structure of the paper starts with section 2 for systematic literature review, followed by section 3 for bibliometric analysis. Further, section 4 delivers the network analysis, followed by section 5, which offers the discussion of the current paper. Finally, section 6 provides the conclusions of the current study.

**2. Systematic literature review**

A literature review assists by offering useful knowledge and feedback on the chosen research topic and outlining potential research prospects (Sharma et al., 2021). Following a review of recently reported publications on the research topic under consideration, research gaps are discovered that must be filled to increase the academic wealth of research (Tranfield et al., 2003). Systematic literature review (SLR) dismantles every investigation into its requisite elements and enables routine assessments and summaries of apposite research (Bryman, 2012). SLR begins by identifying keywords relevant to the research subject and then analysing relevant papers. Figure 1 presents a three-phase methodology used to systematically review the literature on applying BCT in RL. Further sections are evident in performing a systematic review of the present study.



**Figure 1.** Research flow used to perform a systematic literature review on BCT in RL

**2.1 Selection of Database and Keywords**

Past research suggests that SCOPUS is one of the most comprehensive research platforms which offers the articles of every reputed academic body such as Tailor and Francis, Elsevier, emerald, and springer (Sharma et al., 2021). Different search strings are prepared to find the only relevant articles. The following keywords are used in this research to perform SLR:

"Blockchain technology", "Reverse logistics" OR "Recycling" OR "Waste management" OR "Reuse" OR "Recovery" OR "Disposal" OR "Ecology" OR "Industrial economics" OR "Circular economy" OR "Closed-loop" OR "End of life management" OR "Return management".

**2.2 Inclusion-Exclusion convention**

The selection of Peer review articles in the English language is one of the vital inclusion conventions of the present study. It leads to selecting only journal articles, reviews, and conference articles. Also, the exclusion convention for the present study includes a book, book chapters, editorial, letter, note and short survey.

The current research has chosen the literature from 2015 to 2022. After inserting the various search strings, overall, 254 articles were identified and used the inclusion-exclusion convention; finally, 226 articles were selected for the present study.

**3. Bibliometric analysis**

**3.1 Trends in publication**

Current research has used bibliometric analysis and network analysis to explore the aim of this study. Strategies for bibliometric analysis are narrated as a systematic affair for identifying, describing, and assessing published studies. The use of explicit, repeatable screening and assessment processes improves the results' credibility and lowers personal biases in existing literature (Maditati et al., 2018). This research uses R (for bibliometric analysis) and VOSviewer (for network analysis).

We started by retrieving the researcher keywords from the articles in our dataset to complete the bibliographic mapping and content analysis. We looked at keyword usage in the past (between 2015 and 2022) and used both software to create a co-occurrence map to see how these topics have previously connected.

Table 1 presents the selected articles for the current study the period 2015 to 2022. It also presents the articles from various sources, the average citation of articles per year, average citations per document, and the used references. Further, this table describes the types of articles, including the number of authors and their collaboration for overall articles.

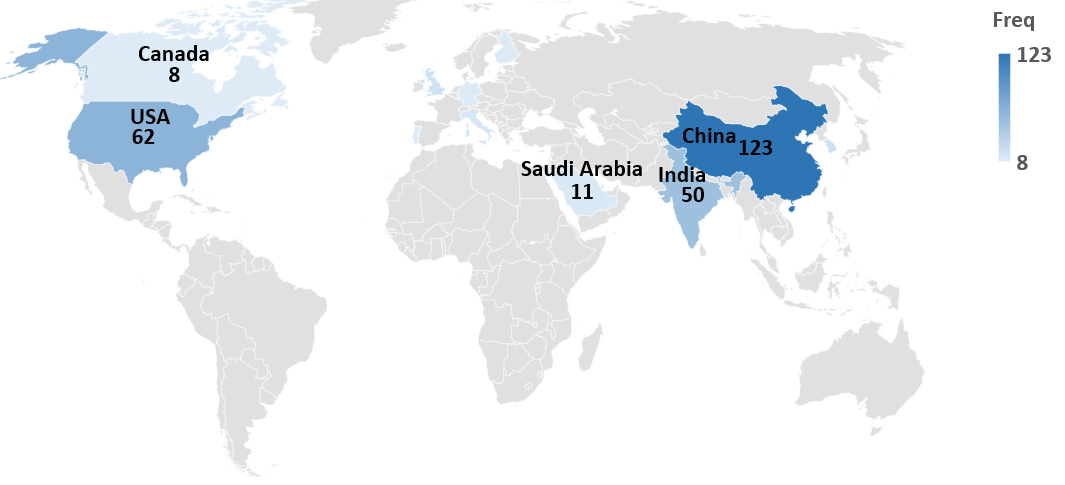
**Table 1.** Main information about the collected article for review on BCT in RL

|  |  |
| --- | --- |
| **Description** | **Results** |
| **Dataset primary information** | |
| Time duration | 2015-2022 |
| Origin (Books, Journals, Conferences, etc) | 164 |
| Dataset (Articles) | 226 |
| Mean time from publication (in years) | 0.987 |
| Mean citations/ document | 6.558 |
| Mean citations/ year/ doc | 2.973 |
| References | 8532 |
| **Articles Characteristics** | |
| Research Paper | 96 |
| conference paper | 100 |
| conference review | 20 |
| Review | 10 |
| **Contents of document** | |
| Keywords Plus (ID) | 1490 |
| Author's Keywords (DE) | 610 |
| Authors | |
| Authors | 670 |
| Author Appearances | 782 |
| Authors of single-authored documents | 15 |
| Authors of multi-authored documents | 655 |
| **Association among Author(s)** | |
| Single-authored documents | 35 |
| Articles per Author | 0.337 |
| Authors per Document | 2.96 |
| Co-Authors per Documents | 3.46 |
| Collaboration Index | 3.43 |

Next, Figure 2 presents the total papers published per year from 2015 to 2022. It is easy to understand from figure 2 that the number of BCT articles in RL is increasing per year.

**Figure 2.** Year-wise statistics of articles published in BCT in RL

Figure 3 presents the number of articles relevant to BCT in RL published in worldwide countries. It appeals to the highest number of articles published in China (123) followed by the USA (62), and India (50).



**Figure 3.** Country-wise statistics of articles published in BCT in RL

**3.2 Articles Citation Analyses for countries, authors, journals, institutions, and keywords**

Many articles on BCT in RL have been published in recent years, but it is important to analyse their citation to identify their identity in terms of references. Table 2 describes the more elaborated version of the statistics of the article. It presents the citation statistics of the articles published in BCT in RL. Table 2 suggests that the number of articles relevant to BCT in RL increases every year, but the mean citation per article decreases after 2017.

**Table 2.** Year-wise citation statistics of articles published in BCT in RL

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **Articles Count** | **Average of total citation/ article** | **Average of total citation/ year** | **Years of Citation** |
| 2015 | 1 | 20 | 3.33 | 6 |
| 2016 | 2 | 25 | 5 | 5 |
| 2017 | 4 | 40.25 | 10.06 | 4 |
| 2018 | 12 | 17.16 | 5.72 | 3 |
| 2019 | 43 | 8.42 | 4.21 | 2 |
| 2020 | 74 | 6.53 | 6.53 | 1 |
| 2021 | 85 | 2.35 | - | 0 |

Further, this section explores the citation of articles country-wise to identify the most cited articles. Findings suggest that China (328) is the pioneer in the number of total citations, followed by the USA (304), and Germany (63). The order of other countries to present the total citations in decreasing order are Germany, Saudi Arabia, Slovakia, Spain, Turkey, the United Kingdom, India, and Korea. Figure 3 indicates India as a third country that issued the supreme number of articles in BCT in RL. But, in the citation category, India becomes the second last country with the highest total citations. Still, Figure 3 and Table 3 suggest that China and the USA are two pioneer countries researching more on BCT in RL.

**Table 3.** Country-wise citation statistics of articles published in BCT in RL

|  |  |  |
| --- | --- | --- |
| **Country** | **Overall citations** | **Average citations of articles** |
| China | 328 | 9.37 |
| USA | 304 | 19.00 |
| Germany | 63 | 21.00 |
| Saudi Arabia | 48 | 48.00 |
| Slovakia | 38 | 38.00 |
| Spain | 25 | 25.00 |
| Turkey | 24 | 24.00 |
| United Kingdom | 16 | 5.33 |
| India | 12 | 1.20 |
| Korea | 12 | 1.33 |

After the country-wise citation statistics, Table 4 presents the worldwide institute-wise citation statistics of articles published on BCT in RL. The threshold value of the number of articles per institute is selected as 3 to filter the highest work done by an institute in the relevant field (BCT in RL). Table 4 indicates that Lovely Professional University (6) has published the highest number of articles in BCT in RL followed by Ryerson University (5), and the University of Florida (5). Other institutes have published four and three articles on BCT in RL.

**Table 4.** Institute-wise citation statistics of articles published in BCT in RL

|  |  |
| --- | --- |
| **Affiliations** | **No. of articles** |
| Lovely Professional University | 6 |
| Ryerson University | 5 |
| University of Florida | 5 |
| Beijing University of Posts and Telecommunications | 4 |
| Foisie Business School | 4 |
| Hanken School of Economics | 4 |
| Tsinghua University | 4 |
| Chongqing University | 3 |
| Khalifa University | 3 |
| National Penghu University of Science and Technology | 3 |

Table 5 reports the most impact corresponding author countries based on the articles counting, SCP, MCP, and MCP ratio. China (35) is the pioneer country in this segment also, which is followed by the USA (16) and India (10). All the previous tables and figures suggest that China, the USA, and India have done an excellent job publishing the articles on the BCT in RL.

**Table 5.** Corresponding author Country’s statistics of articles published in BCT in RL

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Country** | **No. of articles** | **SCP** | **MCP** | **MCP\_Ratio** |
| China | 35 | 25 | 10 | 0.28 |
| USA | 16 | 10 | 6 | 0.37 |
| India | 10 | 4 | 6 | 0.6 |
| Korea | 9 | 8 | 1 | 0.11 |
| Italy | 4 | 2 | 2 | 0.5 |
| Germany | 3 | 3 | 0 | 0 |
| United Kingdom | 3 | 2 | 1 | 0.33 |
| Finland | 2 | 1 | 1 | 0.5 |
| Iran | 2 | 1 | 1 | 0.5 |
| Latvia | 2 | 1 | 1 | 0.5 |

Further, Table 6 reports the number of articles published in various journals. The threshold of a minimum of 2 articles is used to find out the most active journal to publish the articles on BCT in RL. Table 6 indicates that Sustainability (7) is the pioneer journal that produces leading publications on BCT in RL, which is followed by IEE access (4), Journal of Cleaner Production (4), Sensors (3), and Applied Science (2). Table 6 also indicates that three journals in the top five journals are from Switzerland.

**Table 6.** Journal-wise statistics of articles published in BCT in RL

|  |  |
| --- | --- |
| **Sources** | **No. of articles** |
| Sustainability (Switzerland) | 7 |
| IEEE Access | 4 |
| Journal of Cleaner Production | 4 |
| Sensors (Switzerland) | 3 |
| Applied Sciences (Switzerland) | 2 |
| Computers in Industry | 2 |
| IEEE Internet of Things Journal | 2 |
| Industrial Management and Data Systems | 2 |
| International Journal of Logistics Research and Applications | 2 |
| International Journal of Production Economics | 2 |

After reporting the highly active journal on BCT in RL, Table 7 reports this area's highly impacted authors. Table 7 suggests that Sarkis J (6) and Zhang X (6) have issued the maximum number of articles on BCT in RL followed by Chen J (5), Li Z (5), and Yu Z (4).

**Table 7.** Author-wise statistics of articles published in BCT in RL

|  |  |
| --- | --- |
| **Authors** | **No. of articles** |
| Sarkis J | 6 |
| Zhang X | 6 |
| Chen J | 5 |
| Li Z | 5 |
| Yu Z | 4 |
| Akram SV | 3 |
| Gehlot A | 3 |
| Liu C | 3 |
| Singh R | 3 |
| Wang J | 3 |

Chart

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**Figure 4.** Authors' publications over time in BCT in RL

Figure 4 indicates the publication of articles on BCT in RL over a period of time for different authors. Figure 4 suggests that Chen J has published the articles for a longer period (2017-21) than the other authors. Sarkis J, Zhang X, Wang J, and Zhang J have published the articles for the same period (2019-21). Some other authors have published the papers between 2018-20, 2019-20, and 2020-21.

Table 8 presents the top 20 keywords used more frequently for the articles relevant to BCT in RL. The data from Table 8 suggest that Blockchain is the most occurred keyword in the published articles on BCT in RL, with 144 occurrences. Further, it is followed by the internet of things (31), supply chains (19), supply chain management (16), and sustainable development (16).

**Table 8.** Word statistics of articles published in BCT in RL

|  |  |  |  |
| --- | --- | --- | --- |
| **Words** | **Occurrences** | **Words** | **Occurrences** |
| Blockchain | 144 | network security | 14 |
| internet of things | 31 | waste management | 14 |
| supply chains | 19 | circular economy | 12 |
| supply chain management | 16 | internet of things (IoT) | 12 |
| sustainable development | 16 | commerce | 11 |
| industrial economics | 15 | data sharing | 10 |
| information management | 15 | artificial intelligence | 9 |
| digital storage | 14 | big data | 9 |
| Ecology | 14 | distributed computer systems | 9 |
| life cycle | 14 | peer to peer networks | 9 |

After reporting the most frequent keyword in the articles on BCT in RL, a word cloud of keywords is presented in Figure 5. The appearance of keywords in the word cloud of Figure 5 suggests that blockchain has the largest size, followed by the internet of things and supply chains.

Text

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**Figure 5.** Word cloud of keywords used in BCT in RL

A tree map of keywords is presented to explain the hierarchy of the keywords used in the published articles on BCT in RL. Figure 6 illustrates the ten levels of keywords tree map used in BCT in RL. It indicates all keywords at a different story, where level 1 is at the topmost level. Figure 6 demonstrates that the use of blockchain as a keyword in the articles on BCT in RL is the top priority level, followed by the internet of things, blockchain, and supply chains at level 2. Further, other keywords are lower as per their frequency in the relevant literature on BCT in RL.

Chart, treemap chart

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**Level 1**

**Level 2**

**Level 3**

**Level 4**

**Level 5**

**Level 7**

**Level 10**

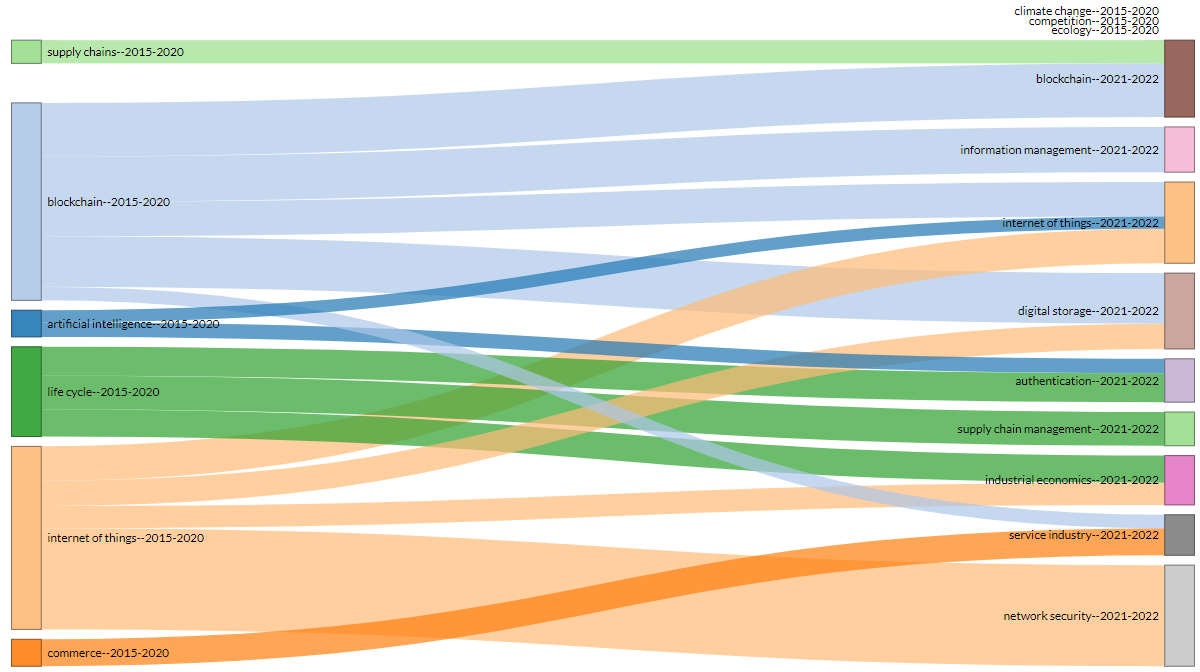
**Level 9**

**Level 8**

**Level 6**

**Figure 6.** Tree map of keywords used in BCT in RL

During the research on BCT in RL, some BCT themes evolved with RL themes over the period, which is presented in Figure 7. Overall, six themes of BCT evolved with nine themes of RL during the research on BCT in RL for 2015-22. According to Figure 7, blockchain and IoT are the two most evolving themes of BCT. Similarly, RL's two most evolving themes are network security and the internet of things



**Figure 7.** Evolutions of themes of BCT in RL over time

Table 9 presents the most impactful research on BCT in RL in the past literature. It suggests that Li et al. (2018) study is the most pioneered research, with 133 total citations and 33.25 total citations per year. Their study proposed a framework that takes advantage of recent advances in blockchain and edge computing to address the safe and decentralised needs for knowledge and service exchange in manufacturing ecosystems. Further, some other studies, such as Stanciu (2017) and Koihizadeh et al. (2020), are the most cited in the past literature.

**Table 9.** Top ten cited articles published in BCT in RL

|  |  |  |  |
| --- | --- | --- | --- |
| **Study** | **Article title** | **Total Citations** | **TC per Year** |
| (Li et al., 2018) | “Toward open manufacturing a cross-enterprises knowledge and services exchange framework based on blockchain and edge computing” | 133 | 33.25 |
| (Stanciu, 2017) | “Blockchain-Based Distributed Control System for Edge Computing” | 131 | 26.2 |
| (Kouhizadeh et al., 2020) | “Blockchain and the circular economy: potential tensions and critical reflections from practice” | 66 | 33 |
| (Esmaeilian et al., 2020) | “Blockchain for the future of sustainable supply chain management in Industry 4.0” | 54 | 27 |
| (Lohmer et al., 2020) | “Analysis of resilience strategies and ripple effect in blockchain-coordinated supply chains: An agent-based simulation study” | 52 | 26 |
| (Derhab et al., 2019) | “Blockchain and Random Subspace Learning-Based IDS for SDN-Enabled Industrial IoT Security” | 48 | 16 |
| (Liu et al., 2020) | “Industrial blockchain-based framework for product lifecycle management in industry 4.0” | 46 | 23 |
| (Kouhizadeh et al., 2019) | “At the nexus of blockchain technology, the circular economy, and product deletion” | 42 | 14 |
| (Košt’ál et al., 2019) | “Management and monitoring of IoT devices using blockchain” | 38 | 12.667 |
| (Nawari & Ravindran, 2019) | “Blockchain and Building Information Modeling (BIM): Review and applications in post-disaster recovery” | 35 | 11.667 |

Figure 8 presents the three-field plot used in this study to examine the link between keywords, countries, and leading authors.

The rectangular diagrams are used to show important elements in various colours. The rectangle's height illustrates the association between many variables such as keywords, countries, and leading authors. The wider the rectangle, the more connections between the different components.

Chart

Description automatically generated with low confidence

**Figure 8.** Three field plots for BCT in RL

Figure 8 shows the position of various components in the diagram, such as countries on the left, leading authors in the middle, and the keywords on the right side. The most frequent keywords used in the relevant research are blockchain, followed by the most impactful leading author, Sakis J, and China as the most impactful country.

**4. Network analysis**

**4.1 Authors Co-occurrence**

There were 670 authors among the 226 documents, and we chose only those who had published a minimum of two articles. As a result, the total number of authors was lowered to 68. Due to the network's limited interconnectivity, four clusters of just 13 writers were created in the author collaboration network, while other authors were ignored. According to the author network, Li Z and Zhang X were the most collaborative authors, with 6 and 5 linkages to other authors.

Diagram

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**Figure 9.** Authors' collaboration for BCT in RL

**4.2 Countries Co-occurrence**

There were 57 countries, but we only chose those with at least two articles out of the 226 papers. As a result, the total number of authors was lowered to 36. Seven clusters of just 31 countries were developed in the country collaboration network, while additional countries were overlooked due to the network's limited connection. According to the country network, China and the USA were the most collaborative countries.

Diagram

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**Figure 10.** Country collaboration for BCT in RL

**4.3 Keywords Co-occurrence**

There were 1911 keywords in the 226 documents, and we chose only those that appeared at least twice. As a result, the total number of keywords was lowered to 65. Figure 11 depicts a keyword overlay visualisation.

Map

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**Figure 11.** Keyword overlay visualisation for BCT in RL

**4.4 Bibliographic coupling**

Bibliographic coupling refers to how connected items are based on how many references they have in common. The advantages of bibliographic coupling are the capacity to create visualisation maps drawn from the most cited publications, present views for existing research problems, and advice for forthcoming studies (Jones and Gatrell, 2014).

We chose only those documents with at least five citations from a total of 226 documents. As a result, the total number of papers was reduced to 58. Due to the network's limited connectivity, five clusters of just 53 documents were established in the bibliographic coupling. Figure 12 depicts the bibliographic coupling network. Cluster one (red) is the largest cluster, with 16 articles, followed by clusters green and blue, each with 11 items, and cluster yellow with 10 items. With five items, the violet cluster is the smallest. The leading publications in each cluster are described in the appendix Table A1.

Map

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**Cluster 5 (Violet): BCT in waste management**

**Cluster 2 (Green): BCT in logistics**

**Cluster 4 (Yellow): BCT in sustainable manufacturing**

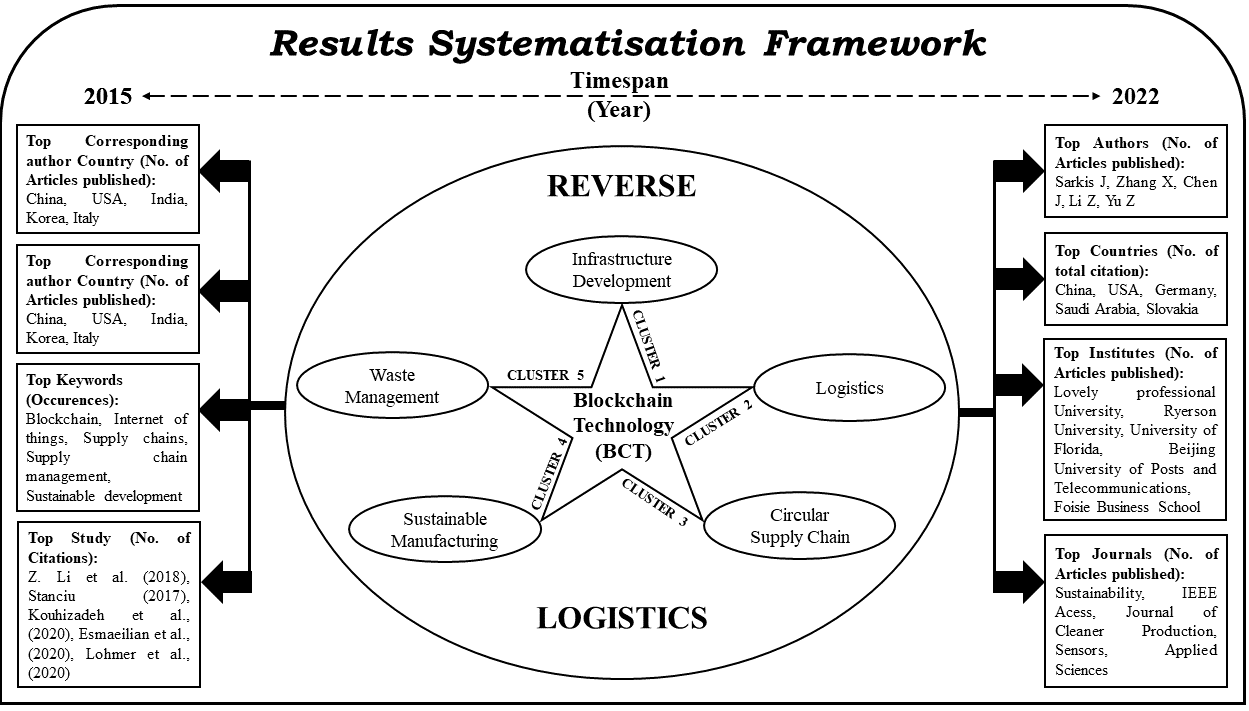
**Cluster 3 (Blue): BCT in circular supply chain**

**Cluster 1 (Red): BCT in infrastructure development**

**Figure 12.** Bibliographic coupling network for BCT in RL

**5. Discussion and implications**

To summarise the overall research, a result systematisation framework is illustrated in Figure 13. Further, this section explains the numerous cluster formation according to the role of BCT in various RL themes. Also, this section will identify the top five types of research of every cluster to understand the trend, approach, and direction of research for the particular cluster.



**Figure 13.** Results Systematisation Framework of BCT in RL

**5.1 Cluster Analysis**

A total of five clusters are constructed based on the number of articles in each cluster and the role of BCT in various RL areas. The largest number of articles comes under cluster 1, and the lowest number of articles are under cluster 5. Furthermore, this section will address the “RQ1. What are the potential study areas for BCT in RL in the future?” along with the cluster analysis. A description of various clusters is as follows:

**5.1.1 Cluster 1 (Red): BCT in infrastructure development**

Cluster 1 consists of 16 articles (30.19% of the total articles) that offer BCT applications in various infrastructure development projects. The study of Stanciu (2017) is the top-cited (131) research, explored the IEC 61499 standard for distributed control systems and discussed existing work on the deployment of function blocks performed by the blockchain. Next, pioneer research from Nawari and Ravindran (2019) provides an in-depth examination of BCT and its implications in the built envelope and an examination of BCT's possible association with the Building Information Modeling (BIM) process. Further, Li (2018) examines the principles, characteristics, and applications of the IoT, energy internet, and big data in smart city infrastructure. Ongena et al. (2018) has used a decision science methodology to formalise weak points and assess applying a blockchain approach to reduce the highlighted problems. Qun Song et al. (2021) propose a backup peer system and internal data isolation and transmission methods and develop a different supply chain system dependent on IoT and management frameworks.

Thus, cluster 1 focuses on the various roles of BCT in infrastructure development through multiple research methods and proposed frameworks. Further, Table 10 explores the research questions of the individual study of cluster 1 and future research recommendations.

**Table 10.** Research question (s) and future research recommendations for cluster 1

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Cluster 1 (Red): BCT in infrastructure development** | | | | |
| **S.No.** | **Author (s)** | **Year** | **Research question(s) [RQ]** | **Future research recommendations [FRR]** |
| **1.** | Stanciu | 2017 | **RQ1:** How other IEC standards, such as 14776, 19770, and 62541 can contribute to the same blockchain environment setting? | **FRR1:** Other IEC standards in the same blockchain settings can also be explored and tested to compare their performance and select the best one to offer the optimise output. |
| **RQ2:** What are the potential benefits of standardising distributed ledger technology (DLT)? | **FRR2:** Industries can collaborate worldwide to establish global DLT and BCT standards. It will help implement BCT at the mass level, and also it will ease the adoption of BCT in daily routine things. |
| **2.** | Nawari and Ravindran | 2019 | **RQ3:** What other sectors can benefit from the integrated BCT-BIM framework? | **FRR3:** Several concerns associated with post-catastrophe retrieval efforts, including infrastructures, logistics, and services, might be included in the integrated BCT-BIM framework. |
| **3.** | Li | 2018 | **RQ4:** How BCT can support the development of smart cities without putting an overburden of expense? | **FRR4:** The practical implementation of P2P light-heavy architecture can be explored to observe its influence on smart city infrastructure. |
| **4.** | Ongena et al. | 2018 | **RQ5:** What are the possible ways to fully understand the instances in which BCT might be beneficial or detrimental? | **FRR5:** Practical implementation of BCT can help to understand the actual potential of BCT. Also, many case studies datasets can validate the BCT outcomes and also it can help to propose and establish some more perceptive theories related to BCT applications. |
| **RQ6:** What is the role of BCT in the logistics of waste management? | **FRR6:** BCT applications can help to track the various wastes. But, it is needed to explore practical cases which will clear the picture of BCT's contribution to logistical waste management. |
| **5.** | Qun Song et al. | 2021 | **RQ7:** What are the possible areas where the IoT management framework can be implemented? | **FRR7:** First, the practical accessibility of the IoT management framework needs to be validated in economic feasibility. After that, the IoT management framework can be used in multiple sectors such as construction, logistics, and manufacturing to reduce illegal access to resources. |
| **RQ8:** Is it possible to integrate the IoT management framework into some digital technologies? | **FRR8:** It will be a great area of research for scholars and practitioners to practically implement or integrate IoT management framework on or with some digital technologies, such as cloud and edge computing. This will also give a huge exposure and clarity to the broad applicability of the IoT management framework in digital technologies. |

**5.1.2 Cluster 2 (Green): BCT in logistics**

Cluster 2 consists of 11 articles (20.75% of the total articles) that offer BCT application in the logistics area. Lohmer et al. (2020) is the top impactful study of this cluster, suggesting that BCT positively influences supply chain resilience and used simulation to validate it. The study identifies visibility, agility, and velocity can be strengthened by the application of BCT. Košt’ál et al. (2019) introduced a private blockchain to enhance IoT device architecture management and supervision. The third most impactful study in this line is Ar et al. (2020), which suggests transportation as the most viable operation of the possible blockchain application. Also, their study suggests security as the most important and scalability as the least important factor for viable logistics operations. The next inline research is Böckel et al. (2021) which offers how BCT can lead the circular economy towards sustainable development through its tools such as IoT, sensors, and artificial intelligence. Cheung et al. (2021) reviewed the existing studies on cybersecurity in logistics and supply chains. Also, their study suggests that BCT is still at its early stage in the transportation and logistics sector.

Thus, cluster 2 focuses on the numerous aspects of BCT in the transportation and logistics sector and identifies the implementation of BCT in this area is at its infant stage. It needs more attention to deliver sustainable outcomes in the logistics area. Table 11 explores the potentials cluster 2 by raising the research questions and recommending future research propositions.

**Table 11.** Research question (s) and future research recommendations for cluster 2

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Cluster 2 (Green): BCT in logistics** | | | | |
| **S.No.** | **Author (s)** | **Year** | **Research question(s) [RQ]** | **Future research recommendations [FRR]** |
| **1.** | Lohmer et al. | 2020 | **RQ9:** What is the impact of various digital technologies on Supply Chain resilience? | **FRR9:** Different potential application scenarios of many digital technologies, such as Cloud and SaaS, Artificial intelligence, Cybersecurity, and Biometrics, in supply chain risk management (SCRM) should be conducted with an in-depth analysis of the impact of these digital technologies on supply chain resilience. As a result, these digital technologies' various uncertainty application areas on existing tenacity measures may be examined. |
| **R10:** What uses BCT in supply chains and manufacturing networks? | **FRR10:** The application of BCT in supply chain operations and production systems must be investigated theoretically and experimentally, for example, to identify opportunities and limitations. |
| **2.** | Košt’ál et al. | 2019 | **R11:** What extensions are possible in the current improved architecture? | **FRR11:** Various public key infrastructures (PKI), such as Hierarchical and WoT types, can be integrated rather than the traditional ones in the current improved architecture for blockchain solutions. |
| **R12:** What other blockchain platforms can be used for this architecture? | **FRR12:** Practitioners and researchers canimplement this architecture on many blockchain platforms, such as IBM Blockchain, Ethereum, R3 Corda, Tezos, etc., to explore the potential of this architecture. Also, it will validate this architecture and generalise for multiple blockchain platforms. |
| **3.** | Ar et al. | 2020 | **R13:** How can BCT be used for global logistics industries? | **FRR13:** Newblockchain assessment framework can be proposed considering some variables, such as cost and revenue for logistics industries. Also, that framework can be validated by global data to generalise that framework worldwide. This will confirm the potential of BCT in logistics industries. Further, the validation will help this framework to adopt at the global level. |
| **4.** | Böckel et al. | 2021 | **R14:** What is the role of BCT in circular economy and sustainable development? | **FRR14:** BCT helps track the material flow and can support reducing the various wastes. Also, BCT consumes a high amount of energy. Therefore, researchers can propose a conceptual framework with a unary relationship between BCT, circular economy, and sustainable development. After that, the framework can be validated locally and globally to know the limit of the relationship. Then, a framework can be implemented in real industry settings. |
| **5.** | Cheung et al. | 2021 | **R15:** How much cybersecurity is essential in logistics and supply chains? | **FRR15:** Technological advancements have imposed risks on logistics and supply chain security. Therefore, it will be a good area for scholars to explore the role of various digital technologies to offer security and service to improve logistics and supply chain. Some practical studies can help strong propositions in this area. |

**5.1.3 Cluster 3 (Blue): BCT in circular supply chain**

Cluster 3 offers insights into BCT deployment in the circular supply chain area with 11 articles (20.75% of the total articles). The top two most cited and impactful research of this cluster are Kouhizadeh et al. (2019) and Kouhizadeh et al. (2020), with citations 66 and 42, respectively. Kouhizadeh et al. (2020) examine the role of BCT in various dimensions of the circular economy with the help of different case studies. The study of Kouhizadeh et al. (2019) established a concept that creates a link between BCT, product deletion and the circular economy. This cluster's third most impactful research is Upadhyay et al. (2021), which investigates the role of BCT in a circular economy in social responsibility and sustainability.

Further, their research suggests that BCT plays an essential role in the circular economy. Wang et al. (2020) emphasise managing the complexities of the circular supply chain of the fast fashion industry with the help of BCT and establishing a system architecture that is BCT based circular supply chain. Mukherjee et al. (2021) investigate the applicability of BCT in the agricultural supply chain for its sustainable development. Further, their study has identified some key benefits of BCT in the agricultural supply chain, such as data protection, decentralisation, information integrity, smart contracts, increased sustainability, secure supply chain development, and a common database.

Thus, cluster 3 indicates that BCT is very useful in the circular supply chain, and BCT is deployed very aggressively in the circular supply chain for its improvement and sustainable development. Next, Table 12 presents the research questions extracted from the different studies of cluster 3 and proposes further research recommendations.

**Table 12.** Research question (s) and future research recommendations for cluster 3

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Cluster 3 (Blue): BCT in circular supply chain** | | | | |
| **S.No.** | **Author (s)** | **Year** | **Research question(s) [RQ]** | **Future research recommendations [FRR]** |
| **1.** | Kouhizadeh et al. | 2019 | **RQ16:** How can blockchain deploy in the product deletion decision process? | **FRR16:** Blockchain helps to make product deletion decision process. Still, there is a scarcity of research that confirms this relationship. Therefore, case studies have a huge scope to validate and establish that relationship. Also, sensitivity analysis can help to evaluate and establish the relationship between blockchain and the product deletion decision-making process. |
| **2.** | Kouhizadeh et al. | 2020 | **RQ17:** Can BCT be seen as a one-size-fits-all solution? | **FRR17:** There is a dire need of understanding the implementation level of BCT in various industries. Because the solutions offered by BCT may vary as per its implementation level, researchers should explore the role of BCT in various industries as per its implementation level and then observe the outcomes offered by BCT. This will clear the picture of BCT's role in various industries and help to understand whether BCT is a one-size-fits-all solution or not. |
| **3.** | Upadhyay et al. | 2021 | **RQ18:** What is the role of BCT in social responsibility within the circular economy model? | **FRR18:** There is a possibility of introducing the structuring of social responsibility structurally in the circular economy model. After that, the deployment of blockchain can be investigated theoretically and empirically. |
| **RQ19:** What are the possible challenges in implementing blockchain in the circular supply chain? | **FRR19:** Various barriers, such as policies, legislation, and infrastructure, are needed to study the implementation of BCT, especially in developing countries. |
| **4.** | Wang et al. | 2020 | **RQ20:** How blockchain can be used to sustain the fast fashion for a circular supply chain? | **FRR20:** BCT is a realistic way to connect customers' and needs with the objectives of various partners in the supply chain, resulting in the transition to a circular economy model. Still, the implementation of blockchain in the fashion industry is nascent, opening a research floor in this area to develop a sustainable architecture. That architecture can be evaluated and established with the help of practical cases and pilot experiments. Thus, BCT will be helpful in the sustainable fashion industry in the circular supply chain. |
| **5.** | Mukherjee et al. | 2021 | **RQ21:** What benefits can blockchain offer towards the supply chain's sustainability? | **FRR21:** There is a huge scope to compare the outcomes of traditional and blockchain-enabled supply chains. The clarity from this comparison will help researchers understand the sustainable outcomes offered by blockchain in the supply chain. Also, it will establish a philosophy of supply chain sustainability achievement through blockchain implementation. |

**5.1.4 Cluster 4 (Yellow): BCT in sustainable manufacturing**

Cluster 4 consists of 10 articles (18.87% of the total articles) and focuses on the role of BCT in sustainable manufacturing. This cluster's top-cited (133) study is Li et al. (2018), which offers a framework for cross-enterprise knowledge and service sharing that incorporates cutting-edge technologies like blockchain and edge computing. Esmaeilian et al. (2020) offers an overview of BCT and Industry 4.0, and investigate the potential of blockchain in a sustainable supply chain. Zhu et al. (2020) explore the reformation of China's energy sector with the help of BCT. Shojaei (2019) investigates the application of BCT to improve the information management system of the construction industry.

Shojaei et al. (2021) suggest that BCT is a booster and enabler for the circular economy, especially in built envelop. Their study used a synthetic case study to validate the proposition of BCT as an enabler of the circular economy.

Thus, this cluster suggests that BCT is feasible and adaptable technology in various sectors such as financing, accounting, and construction. Also, BCT can be used as an enabler for these sectors and help sustain them. Finally, table 13 helps identify the research questions from the author's research of cluster 4 and helps to propose the research recommendations for the future scholar.

**Table 13.** Research question (s) and future research recommendations for cluster 4

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Cluster 4 (Yellow): BCT in sustainable manufacturing** | | | | |
| **S.No.** | **Author (s)** | **Year** | **Research question(s) [RQ]** | **Future research recommendations [FRR]** |
| **1.** | Li et al. | 2018 | **RQ22:** What is the practical use of integrating blockchain and other digital technologies with cross-enterprise knowledge and services exchange framework? | **FRR22:** Integrating blockchain and other digital technologies with cross-enterprise knowledge and services exchange framework could be deployed in manufacturing industries to observe its practical use. Researchers can look into open manufacturing's business models. The production process's total quality, efficiency, and effectiveness could all be boosted with the establishment and implementation of the framework. |
| **2.** | Esmaeilian et al. | 2020 | **RQ23:** What are the limitations of BCT needed to be addressed to identify its actual potential? | **FRR23:** As the amount of consumers and the magnitude of Blockchain platforms grows, scalability issues must be dealt with; safety and confidentiality inside of Blockchain networks should be gotten better; computational effectiveness and power usage of Blockchain networks web should be enhanced; more effective majority opinion frameworks and intelligent contracts systems should be designed; and the prospective workforce should indeed be knowledgeable on this digital technology, as well as its social and ethical implications. These are the areas that need to be explored in detail. |
| **3.** | Zhu et al. | 2020 | **RQ24:** How BCT can be deployed worldwide to overhaul the energy industry? | **FRR24:** BCT offers a distributed trade network that aids in creating a circular economy and sustainable energy usage. Therefore, it is indeed an area of research to identify the potential of BCT in the energy sector. Also, this kind of exploration can lead global industries to implement BCT to achieve sustainable energy consumption. |
| **4.** | Shojaei | 2019 | **RQ25:** What are the barriers to BCT implementation in industries with disaggregated structures? | **FRR25:** The disaggregated industries offer a loose structure, making it difficult to implement new technologies such as blockchain. Therefore, there is a potential study area to explore the barriers and possibilities of implementing blockchain in disaggregated structure industries. |
| **5.** | Shojaei et al. | 2021 | **RQ26:** What possible environment is needed to trigger a circular economy through BCT? | **FRR26:** BCT enables tracking of individual equipment’s energy usage that helps control and reduce waste. For that, there is a requirement of an environment for a cultural shift and scientific data assistance to acquire, preserve, and distribute the necessary data. Therefore, it is an open area of research that future scholars can explore. Furthermore, this kind of study will help establish a standard environment for achieving a circular economy through BCT. |

**5.1.5 Cluster 5 (Violet): BCT in waste management**

Cluster 5 consists of only five articles (9.44% of the total articles), which highlights the role of BCT in the area of waste management. Liu et al. (2020) proposed an industrial blockchain framework based on Product lifecycle management (PLM) to achieve the decentralisation, openness, and interoperability of Industry 4.0. Further, they have simulated this framework through experiments to check its effectiveness. Tozanli et al. (2020b) have established a discrete simulation model to obtain an estimated cost for disassembly to order environment. The other study by Tozanli et al. (2020a) offers a new approach to comparing various products trade-in policies from the perception of disassembly to order systems and using technology as an advantage. Stafford and Treiblmaier (2020) investigated the deployment of BCT in e-documentation of the USA's healthcare system and used a ground theory for this investigation to explore the academia and practical perception of BCT e-healthcare settings. Bekrar et al. (2021) review the issues and practical works at the intersections of RL, blockchain, and transportation as a digitalisation tool.

Thus, this cluster focuses on the role of BCT in various types of waste management in Industry 4.0, transportation, circular economy, and RL. Also, this section highlights how BCT can be used as an effective tool in all these sectors. Next, Table 14 describes the various research questions find out during the formation of cluster 5 and offers future research recommendations.

**Table 14.** Research question (s) and future research recommendations for cluster 5

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Cluster 4 (Yellow): BCT in sustainable manufacturing** | | | | |
| **S.No.** | **Author (s)** | **Year** | **Research question(s) [RQ]** | **Future research recommendations [FRR]** |
| **1.** | Liu et al. | 2020 | **RQ27:** How industrial blockchain-based PLM framework will react in real industrial settings? | **FRR27:** The proposed industrial blockchain-based PLM framework will use to conduct knowledge transfer and service interchange in the industrial sector. Still, its practical applicability from the perception of technology and organisation is unclear. Therefore, there is a need of validating this framework in a real business environment. Thus, it will validate the framework and offer an understanding of customisation in the framework. |
| **2.** | Tozanli et al. | 2020b | **RQ28:** What areas can which customised BCT offer profits to stakeholders of a circular supply chain in sustainability? | **FRR28:** IoT-embedded products in a blockchain integrated model can help to estimate the cost of a disassembly-to-order system in the system of returned goods. Similarly, this model can be used to forecast the costs of profit share of other stakeholders. Therefore, this could be a possible area of research where triple bottom line (TBL) sustainability can be achieved in a circular supply chain model through some customised BCT system. |
| **3.** | Tozanli et al. | 2020a | **RQ29:** How digital twins through BCT can offer financial benefits in the various sectors? | **FRR29:** The option of item return is a difficult issue for producers because exchange programs could result in cost burdens in the long term due to numerous item uncertainty. Digital twin technology through blockchain platform helps trace the items on a real-time basis in the overall supply chain. Therefore, the monetary benefits of implementing digital twin through BCT is a potential area to explore. |
| **4.** | Stafford and Treiblmaier | 2020 | **RQ30:** How BCT can offer security towards data and records of various industries? | **FRR30:** BCT could use a distributed system to allocate records and data in many places rather than in one place. This will offer a robust security system for data and documents. Therefore, it could be a possible future area of research on how this system is sustainable? Also, What are the ways BCT can strengthen its security system in many industries? |
| **5.** | Bekrar et al. | 2021 | **RQ31:** How BCT can lead to the circular economy through transportation and reverse logistics? | **FRR31:** BCT can trace the actual timelines of reverse logistics as well as the transportation. BCT can deliver transparency in reverse logistics and reduce transportation waste through indications of needed transport for a particular task. This real-time tracking can help optimise resource consumption and avoid financial fraud in reverse logistics. Therefore, this could be a possible research area to identify the potential of BCT to achieve a circular economy in the nexus of reverse logistics, transportation, and circular economy. |

**5.2 Research outcomes**

The current research offers an exhaustive review with bibliometric and network analysis on the contribution of BCT in various aspects of RL. The SLR is conducted based on 226 articles drawn from the SCOPUS. The exhaustive overview of leading authors, countries, journals, collaborating authors, research flow, and other network statistics is presented through bibliometric analysis. Further, this section will discuss the outcomes of this research by trying to answer the research questions this study.

***5.2.1*** ***RQ2. What are the recent research fashions in the field of BCT in RL?***

The current research trends of BCT in RL are investigated with the help of bibliometric analysis of various aspects such as authors, keywords, countries, citation networks, author collaboration, and journals of various countries. The existing research trend identifies the numerous latest and past tools of BCT used in the field of RL to improve the various industries' functioning. Also, the previous sections suggest that the research on BCT in RL is increasing especially after 2015. In continuation to answer the RQ1, the research identifies that IoT, big data, energy internet, and BCT are emerging in smart cities (Li, 2018). BCT is used to improve the automation in buildings by Smart Contract (SC) technology and Hyperledger Fabric (HLF) technology (Nawari and Ravindran, 2019). Past research has introduced a makeshift supply chain based on IoT, different backup peer systems, and internal data isolation and transmission methods (Qun Song et al., 2021). IEC 61499 function blocks (FBs) as an application of BCT are used as a foundation for a shared control system (Stanciu, 2017).

Also, some literature-based research in BCT has been conducted in past studies. Cheung et al. (2021) reviewed the logistics and supply chain management cybersecurity literature, Böckel et al. (2021) conducted an SLR to locate the priority pattern and the hidden area needed to manage BCT and circular economy, Mukherjee et al. (2021) performed a combined approach of SLR and professional help to highlight the BCT in the supply chains from agricultural outlook, and Esmaeilian et al. (2020) conducted an SLR to investigate the examines the capability of Blockchain in achieving sustainability and circular economy goals. Some other literature work is also done in the relevant area such as Shojaei (2019) conducted a literature review to find out the ways by which BCT can enhance information management systems of the construction sector, Lohmer et al. (2020) conducted a theoretical analysis to offer the insight of BCT effect on supply chain management.

This way, past research suggests that various BCT tools have been deployed in recent years to offer RL's smooth and flawless functioning. Also, various literature-based and framework proposition researches are conducted based on BCT and the associated areas such as circular economy and Industry 4.0 to torch the recent and past studies.

***5.2.2 RQ3. What are the areas of RL that BCT has supported?***

The present research elaborates on the various areas of RL where BCT is deployed to offer help and assistance. Although the literature of 226 articles is used in this paper, the group of 53 articles was used to identify the application of BCT in various RL areas based on different clusters. Also, a group of researchers is identified based on their work on applying BCT in RL.

The study by Li (2018), Nawari and Ravindran (2019), Ongena et al. (2018), Qun Song et al. (2021), and Stanciu (2017) elaborates on the use of BCT in infrastructure development. Their research investigates how digital tools such as IoT, blockchain, big data, and energy internet assist in the construction sector, especially to contribute to infrastructure development. Also, their research explores the blindspots of BCT to highlight the improvement area of blockchain to offer a better contribution to infrastructure.

The research of Ar et al. (2020), Böckel et al. (2021), Cheung et al. (2021), Košt’ál et al. (2019), and Lohmer et al. (2020) highlights the application of BCT in logistics area. Their research is based on theoretical analysis, literature review, and framework proposition to highlight the role of BCT in logistics. Simultaneously, these studies recommend how BCT could be improved more in logistics.

The studies conducted by Kouhizadeh et al. (2019), Kouhizadeh et al. (2020), Wang et al. (2020), Mukherjee et al. (2021), and Upadhyay et al. (2021), and are based on the numerous applications of BCT in the circular supply chain. Their work focuses on some nexus of BCT with other emerging and existing tools to identify the weakness and strengths of BCT in the circular supply chain. Further, these studies develop and establish a system architecture to carry the role of BCT in the circular supply chain towards sustainability and social responsibility.

Some researchers such as Esmaeilian et al. (2020), Li et al. (2018), Shojaei (2019), Shojaei et al. (2021), Zhu et al. (2020) explore the contribution of BCT in the sustainable manufacturing area. These studies proposed a cross-enterprise framework which led the research to enlighten the role of BCT in sustainable manufacturing.

Finally, the research conducted by Bekrar et al. (2021), Liu et al. (2020), Stafford and Treiblmaier (2020), Tozanli et al. (2020a), and Tozanli et al. (2020b) identified the role of BCT in waste management areas. Their studies highlight the role of BCT in waste management with the help of simulation experiments and discreet models.

Thus, this section elaborates on the role of BCT in various areas of RL. The research of past scholars highlights the application of BCT in RL areas and offers the outlooks of various methodologies, emerging tools, and frameworks in the relevant area.

**7. Conclusion**

The current research offers a comprehensive review of the contribution of BCT in various areas of RL. A total of 226 articles of duration 2015-2022 were selected, and bibliometric and network analysis is conducted with the help of R and VOSviewer software. Numerous keywords such as Blockchain Technology, Reverse Logistics, Blockchain etc., were used to widely cover the content on the role of BCT in various RL areas. The network analysis of the articles extracted from the SCOPUS database led to the form of the five primary clusters (based on the role of BCT in various industrial areas), such as infrastructure development, logistics, circular supply chain, and sustainable manufacturing, and waste management.

The content analysis identifies and highlights the applicability of BCT in different areas of RL through numerous models and architectures such as discreet simulation models and system architecture. Also, these models and architecture are validated by various cases studies and real experiments settings. The research also highlights some software, functions blocks, BCT tools, and systems such as Smart Contract (SC) technology and Hyperledger Fabric (HLF), Internal data isolation and transmission methods, backup peer system, chain codes, and IEC 61499 standard, which are already in use or in proposition to use in the various real-world settings. These existing and emerging software, functions blocks, BCT tools, and systems help to identify the actual potential of BCT in various RL dimensions.

The current research is novel through its exhaustive review and data analysis of literature to offer insights into past studies on BCT in RL and recommend the expected future outcomes of this research domain. Also, this article explores the various clusters based on the application of BCT in the specific domain of RL. The thematic overview of cluster analysis helps to identify the numerous latest tools and techniques of blockchain, which will help managers to implement them in real industrial settings to obtain the expected outcomes.

**References**

Alarcón, F., Cortés-Pellicer, P., Pérez-Perales, D. and Mengual-Recuerda, A. (2021). A reference model of reverse logistics process for improving sustainability in the supply chain. Sustainability, 13(18), 10383. [CrossRef]

Al-Saqaf, W. and Seidler, N. (2017). Blockchain technology for Social Impact: Opportunities and challenges ahead. Journal of Cyber Policy, 2(3), 338–354. [CrossRef]

Allied Market Research. (2021). Reverse Logistics Market Report (A04829). Retrieved March 28, 2022, from https://www.alliedmarketresearch.com/reverse-logistics-market

Ar, I. M., Erol, I., Peker, I., Ozdemir, A. I., Medeni, T. D. and Medeni, I. T. (2020). Evaluating the feasibility of blockchain in logistics operations: A decision framework. Expert Systems with Applications, 158.

Autry, C. W. (2005). Formalisation of reverse logistics programs: A strategy for managing liberalised returns. Industrial Marketing Management, 34(7), 749-757. [CrossRef]

Banihashemi, T. A., Fei, J. and Chen, P. S. (2019). Exploring the relationship between reverse logistics and sustainability performance. Modern Supply Chain Research and Applications, 1(1), 2-27. [CrossRef]

Bekrar, A., Cadi, A. A. E., Todosijevic, R. and Sarkis, J. (2021). Digitalising the closing-of-the-loop for supply chains: A transportation and blockchain perspective. Sustainability (Switzerland), 13(5), 1–25.

Böckel, A., Nuzum, A.-K. and Weissbrod, I. (2021). Blockchain for the Circular Economy: Analysis of the Research-Practice Gap. Sustainable Production and Consumption, 25, 525–539.

Bryman, A. (2012). Social Research Methods, 4th ed., Oxford University Press, New York, NY. [CrossRef]

Cheung, K.-F., Bell, M. G. H. and Bhattacharjya, J. (2021). Cybersecurity in logistics and supply chain management: An overview and future research directions. Transportation Research Part E: Logistics and Transportation Review, 146.

Cotton, A. (2018, October 16). Blockchain implications on reverse logistics. HOBI. Retrieved March 28, 2022, from https://hobi.com/blockchain-implications-on-reverse-logistics/blockchain-implications-on-reverse-logistics/

Cui, J and Liu, J. (2016). VOSviewer-based mining of territorial hot research topics. Information Research 2: 13–16. [CrossRef]

Dasaklis, T. K., Casino, F. and Patsakis, C. (2020). A traceability and auditing framework for electronic equipment reverse logistics based on blockchain: The case of mobile phones. 2020 11th International Conference on Information, Intelligence, Systems and Applications (IISA.

Douladiris, K., Dasaklis, T., Casino, F. and Douligeris, C. (2020). A Blockchain framework for reverse logistics of used medical equipment. 24th Pan-Hellenic Conference on Informatics.

Esmaeilian, B., Sarkis, J., Lewis, K. and Behdad, S. (2020). Blockchain for the future of sustainable supply chain management in Industry 4.0. Resources, Conservation and Recycling, 163.

GlobalTranz. (2018, July 30). Use of blockchain in Supply Chain & Logistics: Looking to examples across industries for better understanding. GlobalTranz Enterprises, LLC. Retrieved January 12, 2022, from https://www.globaltranz.com/use-of-blockchain-in-supply-chain-logistics/

Han, X., Wu, H., Yang, Q. and Shang, J. (2016). Reverse channel selection under remanufacturing risks: Balancing profitability and robustness. International Journal of Production Economics, 182, 63-72.

Hanafi, J., Kara, S., and Kaebernick, H. (2008). Reverse logistics strategies for end‐of‐life products. The International Journal of Logistics Management, 19(3), 367-388.

Jones, O. and Gatrell, C. (2014). The future of writing and reviewing for IJMR. International Journal of Management Reviews, 16(3), 249–264. [CrossRef]

Koshy, K., Fowler, A. J., Gundogan, B. and Agha, R. A. (2018). Peer review in Scholarly Publishing Part A: Why do it? International Journal of Surgery: Oncology, 3(2), 56.

Košt’ál, K., Helebrandt, P., Belluš, M., Ries, M. and Kotuliak, I. (2019). Management and monitoring of IoT devices using blockchain. Sensors (Switzerland), 19(4).

Kouhizadeh, M., Sarkis, J. and Zhu, Q. (2019). At the nexus of blockchain technology, the circular economy, and product deletion. Applied Sciences (Switzerland), 9(8).

Kouhizadeh, M., Zhu, Q. and Sarkis, J. (2020). Blockchain and the circular economy: potential tensions and critical reflections from practice. Production Planning and Control, 31(11–12), 950–966.

Kshetri, N. (2018). Blockchain's roles in meeting key supply chain management objectives. International Journal of Information Management, 39, 80-89. [CrossRef]

Li, S. (2018). Application of blockchain technology in smart city infrastructure. Proceedings - 2018 IEEE International Conference on Smart Internet of Things, SmartIoT 2018, 276–282.

Liu, X. L., Wang, W. M., Guo, H., Barenji, A. V., Li, Z. and Huang, G. Q. (2020). Industrial blockchain based framework for product lifecycle management in industry 4.0. Robotics and Computer-Integrated Manufacturing, 63.

Li, Z., Wang, W.M., Liu, G., Liu, L., He, J. and Huang, G.Q. (2018), "Toward open manufacturing: A cross-enterprises knowledge and services exchange framework based on blockchain and edge computing", Industrial Management & Data Systems, Vol. 118 No. 1, pp. 303-320.

Lohmer, J., Bugert, N. and Lasch, R. (2020). Analysis of resilience strategies and ripple effect in blockchain-coordinated supply chains: An agent-based simulation study. International Journal of Production Economics, 228.

Mackey, T.K. and Nayyar, G. (2017). A review of existing and emerging digital technologies to combat the global trade in fake medicines. Expert Opinion on Drug Safety, 16(5), 587-602. [CrossRef]

Maditati, D. R., Munim, Z. H., Schramm, H.-J. and Kummer, S. (2018). A review of Green Supply Chain Management: From Bibliometric Analysis to a conceptual framework and future research directions. Resources, Conservation and Recycling, 139, 150–162.

Mukherjee, A. A., Singh, R. K., Mishra, R. and Bag, S. (2021). Application of blockchain technology for sustainability development in agricultural supply chain: justification framework. Operations Management Research.

Nawari, N. O. and Ravindran, S. (2019). Blockchain and Building Information Modeling (BIM): Review and applications in post-disaster recovery. Buildings, 9(6).

Ongena, G., Smit, K., Boksebeld, J., Adams, G., Roelofs, Y. and Ravesteijn, P. (2018). Blockchain-based smart contracts in waste management: A silver bullet? 31st Bled EConference: Digital Transformation: Meeting the Challenges, BLED 2018, 345–356.

Palumbo, M. (2020, April 21). The case for a reverse logistics variable cost model. PanurgyOEM. Retrieved March 28, 2022, from https://www.panurgyoem.com/the-case-for-a-reverse-logistics-variable-cost-model/

Prakash, C. and Barua, M. (2016). A combined MCDM approach for evaluation and selection of third-party reverse logistics partner for Indian electronics industry. Sustainable Production and Consumption, 7, 66-78.

Prevost, C. (2019, March 26). FR8 network: Blockchain's powerful potential for reverse logistics. FreightWaves. Retrieved January 12, 2022, from https://www.freightwaves.com/news/blockchain/fr8-network-reverse-logistics

Qun Song, A., Chen, Y., Zhong, Y., Lan, K., Fong, S. and Rui Tang, B. (2021). A Supply-chain System Framework Based on Internet of Things Using Blockchain Technology. ACM Transactions on Internet Technology, 21(1).

R Core Team. (2019). R: A Language and Environment for Statistical Computing. Vienna: R Foundation for Statistical Computing.

Ravi, V., Shankar, R. and Tiwari, M. (2005). Analysing alternatives in reverse logistics for end-of-life computers: ANP and balanced scorecard approach. Computers & Industrial Engineering, 48(2), 327-356.

Robinson, A. (2018, September 4). Recapturing reverse logistics expenses through blockchain. Supply chain 24/7. Retrieved March 28, 2022, from https://www.supplychain247.com/article/recapturing\_reverse\_logistics\_expenses\_through\_blockchain/cerasis

Saunders, M.N.K., Lewis, P. and Thornhill, A. (2012). Research Methods for Business Students, 6th ed., Pearson Education Limited, Harlow. [CrossRef]

Shankar, R., Ravi, V. and Tiwari, M. (2008). Analysis of interaction among variables of reverse logistics: A system dynamics approach. International Journal of Logistics Systems and Management, 4(1), 1.

Sharma, R., Jabbour, C.J.C. and Lopes de Sousa Jabbour, A.B. (2021). Sustainable manufacturing and industry 4.0: what we know and what we don't. Journal of Enterprise Information Management, 34(1), 230-266.

Shih, D. H., Huang, F.-C., Chieh, C.-Y., Shih, M.-H., and Wu, T.-W. (2021). Preventing return fraud in reverse logistics—a case study of ESPRES solution by Ethereum. Journal of Theoretical and Applied Electronic Commerce Research, 16(6), 2170–2191.

Shojaei, A. (2019). Exploring applications of blockchain technology in the construction industry. ISEC 2019 - 10th International Structural Engineering and Construction Conference. https://doi.org/10.14455/isec.res.2019.78

Shojaei, A., Ketabi, R., Razkenari, M., Hakim, H. and Wang, J. (2021). Enabling a circular economy in the built environment sector through blockchain technology. Journal of Cleaner Production, 294.

Souza, K. (2018, October 8). The supply side: Blockchain implications on reverse logistics. Talk Business & Politics. Retrieved March 28, 2022, from https://talkbusiness.net/2018/10/the-supply-side-blockchain-implications-on-reverse-logistics/

Stafford, T. F. and Treiblmaier, H. (2020). Characteristics of a Blockchain Ecosystem for Secure and Sharable Electronic Medical Records. IEEE Transactions on Engineering Management, 67(4), 1340–1362.

Stanciu, A. (2017). Blockchain Based Distributed Control System for Edge Computing. Proceedings - 2017 21st International Conference on Control Systems and Computer, CSCS 2017, 667–671.

Steeneck, D. W. and Sarin, S. C. (2013). Pricing and production planning for reverse supply chain: A review. International Journal of Production Research, 51(23-24), 6972-6989.

Subramanian, H. (2017). Decentralised blockchain-based electronic marketplaces. Communications of the ACM, 61(1), 78-84. [CrossRef]

Subramanian N., Chaudhuri A. and Kayıkcı Y. (2020). Blockchain Applications in Reverse Logistics. In: Blockchain and Supply Chain Logistics. Palgrave Pivot, Cham. https://doi.org/10.1007/978-3-030-47531-4\_8

Tozanli, O., Kongar, E., and Gupta, S. M. (2020a). Evaluation of waste electronic product trade-in strategies in predictive twin disassembly systems in the era of blockchain. Sustainability (Switzerland), 12(13).

Tozanlı, Ö., Kongar, E. and Gupta, S. M. (2020b). Trade-in-to-upgrade as a marketing strategy in disassembly-to-order systems at the edge of blockchain technology. International Journal of Production Research, 58(23), 7183–7200.

Tranfield, D., Denyer, D. and Smart, P. (2003). Towards a methodology for developing evidence-informed management knowledge by means of systematic review. British Journal of Management, 14(3), 207–222. [Cross Ref]

Tsanos, C.S. and Zografos, K.G. (2016). The effects of behavioural supply chain relationship antecedents on integration and performance. Supply Chain Management: An International Journal, 21(6), 678-693. [CrossRef]

Upadhyay, A., Mukhuty, S., Kumar, V. and Kazancoglu, Y. (2021). Blockchain technology and the circular economy: Implications for sustainability and social responsibility. Journal of Cleaner Production, 293.

Wang, B., Luo, W., Zhang, A., Tian, Z. and Li, Z. (2020). Blockchain-enabled circular supply chain management: A system architecture for fast fashion. Computers in Industry, 123.

Xue, X., Dou, J. and Shang, Y. (2021). Blockchain-driven supply chain decentralised operations – information sharing perspective. Business Process Management Journal, 27(1), 184-203.

Zhu, S., Song, M., Lim, M. K., Wang, J. and Zhao, J. (2020). The development of energy blockchain and its implications for China’s energy sector. Resources Policy, 66.

Zupic, I. and Čater, T. (2015). Bibliometric Methods in management and organisation. Organizational Research Methods, 18(3), 429–472. [CrossRef]

**Table A1:** Lead articles from the clusters

| **Authors** | **Title** | **Links** | **TLS** | **Citation** | **Approach** |
| --- | --- | --- | --- | --- | --- |
| **Cluster 1 (Red): BCT in infrastructure development** | | | | | |
| (Li, 2018) | “Application of blockchain technology in smart city infrastructure” | 20 | 27 | 31 | Assessing the role of digital technologies in building smart cities and BCT with their relevant qualities and assimilating their commonalities. Also, their respective alternatives are proposed to address issues of digital platforms. |
| (Nawari & Ravindran, 2019) | “Blockchain and Building Information Modeling (BIM): Review and applications in post-disaster recovery” | 24 | 31 | 35 | The study looks into how BCT could enhance the building licensing process utilising Smart Contract (SC) technology and Hyperledger Fabric (HLF) with the help of a survey and proposed framework. |
| (Ongena et al., 2018) | “Blockchain-based smart contracts in waste management: A silver bullet?” | 21 | 35 | 9 | Construct trouble spots and analyse the applicability of utilising a blockchain solution to ameliorate the difficulties highlighted using a design science technique. |
| (Qun Song et al., 2021) | “A Supply-chain System Framework Based on Internet of Things Using Blockchain Technology” | 18 | 20 | 8 | Propose a different supply-chain system based on IoT and frameworks of management. Also, Internal data isolation and transmission methods and a backup peer system were proposed. |
| (Stanciu, 2017) | “Blockchain-Based Distributed Control System for Edge Computing” | 17 | 19 | 131 | The application of BCT as a foundation for hierarchical and distributed control systems is presented in this study |
| **Cluster 2 (Green): BCT in logistics** | | | | | |
| (Ar et al., 2020) | “Evaluating the feasibility of blockchain in logistics operations: A decision framework” | 23 | 64 | 24 | Use quantitative analysis to look at the practicality of BCT in the logistics business. |
| (Böckel et al., 2021) | “Blockchain for the Circular Economy: Analysis of the Research-Practice Gap” | 30 | 66 | 11 | A gap analysis is conducted between research and practice using a systematic review to recognise the patterns of priorities and research and practice opportunities and common unseen areas that need to be handled in BCT and circular economy. |
| (Cheung et al., 2021) | “Cybersecurity in logistics and supply chain management: An overview and future research directions” | 11 | 16 | 8 | Review the studies on how to improve logistics and supply chain management's cybersecurity. |
| (Košt’ál et al., 2019) | “Management and monitoring of IoT devices using blockchain” | 13 | 20 | 38 | A private blockchain is used to develop a new architecture for supervising IoT systems. The bulk of the structure is predicated on-chain code, that manages CRUD (Create, Read, Update, Delete) activities, encryption, and access control. |
| (Lohmer et al., 2020) | “Analysis of resilience strategies and ripple effect in blockchain-coordinated supply chains: An agent-based simulation study” | 22 | 59 | 52 | A theoretical analysis is conducted to discuss the impact of BCT on supply chain management. |
| **Cluster 3 (Blue): BCT in circular supply chain** | | | | | |
| (Kouhizadeh et al., 2019) | “At the nexus of blockchain technology, the circular economy, and product deletion” | 31 | 132 | 42 | Propositions are offered from the literature and a new nexus concept is developed for blockchain, product deletion, and circular economy. |
| (Kouhizadeh et al., 2020) | “Blockchain and the circular economy: potential tensions and critical reflections from practice” | 28 | 125 | 66 | Blockchain applications case studies in diverse industries, at differing stages of acceptance, and for various organisational reasons are examined and debated. |
| (Mukherjee et al., 2021) | “Application of blockchain technology for sustainable development in the agricultural supply chain: justification framework” | 23 | 73 | 7 | A review of the literature and professional perspectives from the agriculture sector is conducted to draw attention to the blockchain advantage in supply chain management. |
| (Upadhyay et al., 2021) | “Blockchain technology and the circular economy: Implications for sustainability and social responsibility” | 23 | 53 | 32 | Examine the current and prospective contribution of BCT to the circular economy through sustainability and social accountability. |
| (Wang et al., 2020) | “Blockchain-enabled circular supply chain management: A system architecture for fast fashion” | 29 | 103 | 18 | Design a system architecture for blockchain-enabled circular supply chain management and confirmed by two specialists in BCT and supply chain management. |
| **Cluster 4 (Yellow): BCT in sustainable manufacturing** | | | | | |
| (Esmaeilian et al., 2020) | “Blockchain for the future of sustainable supply chain management in Industry 4.0” | 25 | 50 | 54 | A literature review to summarise the past work on Industry 4.0 for the sustainability of supply chains. Then, It examines the potential of Blockchain, a new technology, as a tool for achieving sustainability and circular economy goals. |
| (Li. Z et al., 2018) | “Toward open manufacturing a cross-enterprise knowledge and services exchange framework based on blockchain and edge computing” | 20 | 32 | 133 | Provide a decentralised architecture comprised of various layers such as customer, enterprise, application, intelligence, data, and infrastructure built on BCT and edge computing technologies. Also, the usefulness of the framework is demonstrated by the case study. |
| (Shojaei, 2019) | “Exploring applications of blockchain technology in the construction industry” | 7 | 8 | 19 | Using the literature, investigate how BCT can be used to improve the construction industry's information management systems. |
| (Shojaei et al., 2021) | “Enabling a circular economy in the built environment sector through blockchain technology” | 13 | 23 | 12 | This article examines blockchain as a potentially useful tool for facilitating circular economy (CE) in the built envelope. To demonstrate the possibility of blockchain as a CE enabler in the built environment, a blockchain model has been proposed and validated by a synthetic case study. |
| (Zhu et al., 2020) | “The development of energy blockchain and its implications for China’s energy sector” | 12 | 19 | 28 | Investigates how BCT can be used to catch up with China's energy sector. Also,  look at how BCT is progressing in the energy industry and look at some examples of energy-related blockchains around the globe. |
| **Cluster 5 (Violet): BCT in waste management** | | | | | |
| (Bekrar et al., 2021) | “Digitalising the closing-of-the-loop for supply chains: A transportation and blockchain perspective” | 20 | 43 | 5 | This study aims to examine the present study and issues at the intersection of RL, transportation, and blockchain as a digitalising mechanism. The possible advantages of BCT on many parts of RL and transportation operations are shown by cases. |
| (Liu et al., 2020) | “Industrial blockchain-based framework for product lifecycle management in industry 4.0” | 21 | 28 | 46 | A framework based on industrial blockchain-based PLM is proposed, and a simulation experiment is performed to inspect the framework's effectiveness. |
| (Stafford & Treiblmaier, 2020) | “Characteristics of a Blockchain Ecosystem for Secure and Sharable Electronic Medical Records” | 8 | 8 | 10 | The purpose of this article is to establish an outlook from industry and academic practice on the applicability of BCTs for electronic health documents, safety, and collection using a grounded theory method to qualitative approach of electronic healthcare archives in the United States users. |
| (Tozanli et al., 2020a) | “Evaluation of waste electronic product trade-in strategies in predictive twin disassembly systems in the era of blockchain” | 21 | 16 | 13 | A discrete event simulation model is developed from the manufacturer's perspective. Based on forecast indications, the model tracks and simulates the behaviour of product-recovery activities. The system's behaviour is then tested using Taguchi's Orthogonal Array design as design-of-experiment research under different testing settings. Depending on the system's insights, a logistics regression model is employed for the simulated data to obtain appropriate trade-in purchase prices for retrieved end-of-life goods. |
| (Tozanli et al., 2020b) | “Trade-in-to-upgrade as a marketing strategy in disassembly-to-order systems at the edge of blockchain technology” | 10 | 43 | 23 | The projected cost of the disassembly-to-order system is determined using a discrete-event simulation model. Using this price in the trade-in policy model, appropriate benefits for different goods attributes are then estimated. |