Systematic Review

On Deploying Blockchain Technologies in Supply Chain Strategies and the COVID-19 Pandemic: A Systematic Literature Review and Research Outlook

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Abstract: The emergence of a new pandemic, known as COVID-19, has touched various sections of the supply chain (SC). Since then, numerous studies have been conducted on the issue, but the need for a holistic review study that highlights the gaps and limits of previous research, as well as opportunities and agendas for future studies, is palpable. Through a systematic literature review on blockchain technology (BCT) deployment in supply-chain management (SCM) concerning the COVID-19 pandemic, this research seeks to add to the content of previous studies and to enlighten the path for future studies. Relevant papers were found using a variety of resources (Scopus, Google Scholar, Web of Science, and ProQuest). Seventy-two articles were systematically selected, considering the PRISMA procedure, and were thoroughly analyzed based on BCT, methodologies, industrial sectors, geographical, and sustainability context. According to our findings, there is a significant lack of empirical and quantitative methodologies in the literature. The majority of studies did not take specific industries into account. Furthermore, the articles focusing on the sustainability context are few, particularly regarding social and environmental issues. In addition, most of the reviewed papers did not consider the geographical context. The results indicate that the deployment of BCT in several sectors is not uniform, and this utilization is reliant on their services during the COVID-19 pandemic. Furthermore, the concentration of research on the impacts of the BCT on SCM differs according to the conditions of various countries in terms of the consequences of the COVID-19 pandemic. The findings also show that there is a direct relationship between the deployment of BCT and sustainability factors, such as economic and waste issues, under the circumstances surrounding COVID-19. Finally, this study offers research opportunities and agendas to help academics and other stakeholders to gain a better knowledge of the present literature, recognize aspects that necessitate more exploration, and drive prospective studies.  

Keywords: blockchain; COVID-19 pandemic; digitalization; visibility; transparency; smart contracts; sustainability; supply chain management; literature review  

1. Introduction  

Many serious disease outbreaks have occurred in supply chains in the past; the World Health Organization (WHO) has recorded several epidemics and pandemics in the last decade alone [1]. Major public health crises can have serious consequences for enterprises and supply chains, such as lowering efficacy and productivity [2–4], and spreading ripple effects, compromising their resilience, sustainability, and long-term viability [5]. Unlike past outbreaks, COVID-19 has influenced all elements of the supply chain (SC) network at the same time, causing significant disruption in the supply chain’s flow [6,7]. All sectors, including supplies, transportation, and production, have been adversely impacted by interruptions caused by quarantines, the shutting-down of various sectors, and uncertainty in supply and demand due to government restrictions. Some industries, such as energy
sectors and passenger transportation, witnessed significant drops in demand [8–11]. However, the demand for essential products like healthcare materials and equipment, as well as food, has grown [12–14]. The majority of technology companies have seen a similar uptick in demand [15], due to the pandemic compelling academic organizations to utilize digital services for online teaching and forcing corporations to enable their staff to work remotely [16].

Many firms’ failures to respond promptly to increasing demand because of the COVID-19 pandemic are attributable to a lack of supply chain management (SCM) capability and coordination [17]. Some studies indicate that technology has become a significant element in deciding a company’s success or failure during COVID-19, implying that utilizing artificial intelligence (AI) and blockchain technologies (BCT) might assist SCs in becoming more resilient [14,17–22] and that these technologies assist businesses in preventing the negative consequences of future pandemics and preparing for unanticipated interruptions [23].

Considering the devastating effects of the COVID-19 pandemic on SCs, academics are increasingly focusing on the issue. In response to the rising interest, describing the present status of the literature and outlining future study prospects at this preliminary point might shed light on the gaps and shortcomings of previous studies and prevent future research in this subject from being duplicated [24]. A preliminary review of the research literature reveals that, despite the abundance of studies in the field of technology and the COVID-19 pandemic, there is a need for studies that can present the findings and analyze the shortcomings of previous studies in terms of blockchain technologies (BCT), research methodologies, industry sectors, geographical context and stability issues. Accordingly, the motivation of this study is to not only present an integrated picture of previous studies’ findings based on various factors but also to closely examine the shortcomings of existing publications and propose research agendas that could advance the current domain of research in developing a deeper understanding and controlling the repercussions of the COVID-19 pandemic.

A systematic literature review (SLR) may aid in understanding our situation, focusing on previous results, and planning based on current flaws [25]. Through an SLR, this study aims to address the following research questions. (1) What are the key findings of the existing literature on the COVID-19 pandemic in SCM, focusing on BCT, industrial sectors, methods, sustainability, and geography categorization? (2) What are the main gaps in the existing literature in each of the aforementioned criteria, based on the analysis of the findings of previous studies? (3) What are the opportunities and suggestions for future studies on using BCT in SCM in the light of the COVID-19 pandemic?

Based on an analysis of the research literature findings, we attempted to evaluate the following hypotheses.

**Hypothesis 1 (H1).** BCT deployment in different industrial sectors is not uniform; adopting one type of technology means depending on its services for that particular sector, especially during the COVID-19 pandemic.

**Hypothesis 2 (H2).** The density of research on the impacts of the BCT on SCM, taking into consideration geographical contexts, varies according to the circumstances of different nations with regard to the COVID-19 pandemic’s repercussions.

**Hypothesis 3 (H3).** The deployment of BCT is linked to supply-chain sustainability under the uncertain conditions caused by the COVID-19 pandemic.

The remainder of this work is laid out as follows. A background on BCT in SCM is presented in Section 2. The review methodology is presented in Section 3. The findings of previous studies are analyzed in Section 4. Section 5 discusses additional study prospects and focuses on the outcomes. Section 6 offers the research agendas. Finally, Section 7 concludes the paper and provides suggestions for future research.
2. The Blockchain in Supply Chain Management

Blockchain (BC) is a decentralized, distributed, and revolutionary technology that ensures the secrecy, reliability, and accessibility of all data and transactions [26]. The BCT employs a real-time cloud storage architecture [27] that allows transactions to be completed in minutes via digital platforms, all without the need for third-party verification [28]. As a peer-to-peer (P2P) distributed data infrastructure [29], BC has the potential to generate decentralized currencies, digitally automated contracts (smart contracts), and smart properties that could be managed through online services [30,31]. When the records have been added, they cannot be changed without affecting the preceding data, making them extremely secure for enterprise activities [32]. BC offers an enormous opportunity to alter every aspect of the SC, from the acquisition of raw materials through to the eventual delivery to customers [33]. It also assists in the enhancement of the effectiveness and reliability of existing digital platforms [34,35], such as the Internet of Things (IoT) and other Industry 4.0 technologies. By integrating the BC with other technologies, it is possible to establish permanent and shareable records of a product’s movement through the SC processes, as well as to improve product traceability, authenticity, and legality [36].

Although the development and use of BCT are still in their infancy [37,38], the increasing volume of literature indicates that four areas of BCT are commonly used in SCs: digitalization, visibility, transparency, and smart contracts. Large numbers of supply-chain parties are involved in international commerce, and most operations are paper-based, generating delays and disrupting the effective flow of products. BCT might help digitize paper-based documents and provide shared, immutable, and real-time tracking of all transactions across network members [39]. Furthermore, by avoiding mediators, BCT may decrease verification and transaction costs [40]; the P2P network is especially beneficial for transitory commercial partnerships since it lowers the cost of developing trust [41]. The use of visibility in supply chains has been likened to real-time tracking [42,43] and timestamping, which is the act of assigning a time-related command to a series of actions [44]. Intricacy among supply-chain players is sometimes caused by geographically distant operations and trade partners. As a result, obtaining and keeping trustworthy data is important. The BC’s purpose in this setting is to enable seamless networks and perfect visibility [45,46]. This reliability might have a direct impact on the safety of critical industries, like food and pharmaceutical companies [47]. Improved transparency might come in the form of cybercrime prevention and data-sharing security [47,48]. Due to the extremely delicate financial data of business transactions, transparency is essential for supply-chain participants as it may increase confidentiality, auditability, and operations performance [49,50]. Parties can secure product characterization and critical details with a transparent supply chain and restrict regulatory accessibility [51]. A smart contract is a digitalized transaction mechanism that implements the provisions of a contract automatically [41]. Whenever a cargo is received by the customer, a smart contract may deliver a payment to the supplier [52]. Smart contracts might cut down on the number of mediators and require fewer physical operations, lowering operating expenses [53]. Furthermore, smart contracts can automate operations, such as delivering copyright papers to suitable partners, giving agreed-upon contracts to designated parties for digital execution, and upgrading programs as mutually agreed regarding revisions or compensation situations [41,54].

3. Review Methodology

An SLR has been proven as a thorough methodology for review studies [25,55,56], and, by using this approach, we attempt to analyze the associated literature on the blockchain’s deployment in SCM during the COVID-19 pandemic. By considering the PRISMA procedure, Figure 1 illustrates the search methodology for this study.

Relevant papers were found using a variety of resources (Scopus, Google Scholar, Web of Science, and ProQuest). We looked at research articles, literature review articles, discussion papers, opinion papers, and editorial pieces, which were available in scholarly
journals. Furthermore, a reference check was performed to enhance the review resources in the final selected papers.

As shown in Figure 1, all selected databases were searched with the phrases “Blockchain” and “supply chain” and “COVID-19” or “SARS-CoV-2” or “coronavirus.” We limited our findings to articles available exclusively in scholarly journals, published in English since 2020, with a June 2021 cut-off date. There were 446 results in the search from all databases. The irrelevant results were then eliminated. In the first phase, 84 duplicated papers were excluded. In the second step, by reviewing titles, abstracts, and complete papers, we excluded 294 more articles. This process resulted in 68 distinct articles that incorporated all the search keywords found in the body content and that also had an emphasis on the SC in light of the COVID-19 pandemic and BCT deployment. In the next phase, by checking the references of the final identified articles, we found other nine papers. Finally, from the above-mentioned procedure of filtering these extra articles, four more papers resulted. In the end, the whole procedure resulted in a total of 72 unique articles for further evaluation.

These 72 articles were fully analyzed to identify the reviewed literature’s achievements in each criterion, as well as identifying the prior research’s shortcomings. Selected articles were examined from four perspectives: visibility, digitalization, transparency, and smart contracts. Based on the methodology, we determined how many of the various approaches, such as empirical, qualitative, quantitative, and decision-making approaches, have been utilized in the context of these studies. The articles are divided into subsections depending on industry sectors, such as food and agriculture, healthcare, retail, construction, etc. The selected papers were analyzed based on their geographical context in order to assess the concentration of literature in different parts of the world. Finally, based on the sustainability criteria, the publications were examined based on environmental challenges, waste management, economic concerns, and social consequences to assess the degree of involvement of the research literature with these issues. In the next step, by considering the
results of the analyses, the shortcomings and gaps of the existing literature were identified and discussed. Eventually, by recognizing these flaws, the future research agendas resulted in opportunities and suggestions for future studies. Figure 2 depicts the structure for this systematic review paper’s analytical method.

![Diagram](image_url)

**Figure 2.** Structure of the analysis process.

### 4. Results of the Literature Review Analysis

This section examined the BCT categories, methodologies, industrial sectors, geographical contexts, and sustainability issues employed in the 72 publications identified by our searching techniques. The findings revealed those journals that have published a great deal of research on the COVID-19 pandemic in SC domains, as well as the BC topics. Table 1 illustrates the distribution of recognized articles by different references for the period from January 2020 (early stages of the pandemic) to June 2021 (completion of this research).

| Journal Title                | Number of Documents |
|------------------------------|---------------------|
| International Journal of Production Economics | 5               |
| IEEE Engineering Management Review | 4               |
| Transportation Research Part E: Logistics and Transportation Review | 4               |
| Sustainability | 3               |
| IEEE Access | 3               |
| International Journal of Production Research | 2               |
| International Journal of Information Management | 2               |
| International Journal of Environmental Research and Public Health | 2               |
| Sustainability | 2               |

The contributing factors in the analysis of the selected articles are depicted in Figure 3. These factors may be found in clusters regarding BCT, methodologies, industrial sectors, geographical, and sustainable contexts, which are illustrated in different colors. There is a direct relationship between the number of occurrences where a factor appears in the reviewed papers and the size of its representative node. The greater a factor’s representative node is, the more frequently it occurs in the research literature. As a result, the factors of digitalization, visibility, transparency, explanatory, literature review, food-agriculture, healthcare, and economic issues appeared most frequently in the selected articles. Figure 3 also demonstrates the connection between the investigated factors and the rate of their co-occurrence in various studies. The thicker the line demonstrating this connection, the greater the level of co-occurrence between the factors. It can be observed that the co-occurrence of digitalization, transparency and visibility in the BCT cluster is more frequent than other factors. Furthermore, there is a significant level of co-occurrence between these three factors and the explanatory and literature review factors in the methodology cluster, the food-agriculture and healthcare factors in the Industrial Sectors cluster, and the economic issues factor in the sustainability cluster. Appendix A contains descriptive analyses of the identified papers, including a summary of the articles’ goals and findings (Table A1), the publishing characteristics, such as the BCT categories, methods, industries, geographical context, and sustainability issues (Table A2).
Table 1. Selected publications based on the journal’s title.

| Journal Title                                                                 | Number of Documents |
|-------------------------------------------------------------------------------|---------------------|
| International Journal of Production Economics                                 | 5                   |
| IEEE Engineering Management Review                                            | 4                   |
| Transportation Research Part E: Logistics and Transportation Review           | 4                   |
| Sustainability                                                                | 3                   |
| IEEE Access                                                                   | 3                   |
| International Journal of Production Research                                  | 2                   |
| International Journal of Information Management                              | 2                   |
| International Journal of Environmental Research and Public Health             | 2                   |
| International Journal of Physical Distribution and Logistics Management       | 2                   |
| Journal of Cleaner Production                                                 | 2                   |
| Journal of Enterprise Information Management                                  | 2                   |
| Journal of Supply Chain Management                                            | 2                   |
| Sustainable Production and Consumption                                        | 2                   |
| International Journal of Logistics Research and Applications                  | 2                   |
| International Journal of Operations and Production Management                 | 2                   |
| Business Strategy and the Environment                                         | 1                   |
| Industrial Management and Data Systems                                        | 1                   |
| Applied Sciences                                                              | 1                   |
| Big Data and Cognitive Computing                                              | 1                   |
| Continuity and Resilience Review                                              | 1                   |
| Critical Perspectives on International Business                               | 1                   |
| Current Research in Food Science                                             | 1                   |
| Designs                                                                       | 1                   |
| Diabetes and Metabolic Syndrome: Clinical Research and Reviews                | 1                   |
| Environment Systems and Decisions                                             | 1                   |
| Environmental Science and Pollution Research                                  | 1                   |
| European Journal of Business and Management                                  | 1                   |
| Foods                                                                         | 1                   |
| Frontiers of Business Research in China                                       | 1                   |
| Future Internet                                                               | 1                   |
| Information                                                                   | 1                   |
| International Journal of Integrated Supply Management                        | 1                   |
| International Journal of Productivity and Performance Management              | 1                   |
| JMIR Public Health and Surveillance                                           | 1                   |
| Journal of Business Research                                                  | 1                   |
| Journal of Food Quality                                                       | 1                   |
| Journal of Humanitarian Logistics and Supply Chain Management                 | 1                   |
| Journal of Property Investment and Finance                                    | 1                   |
| Journal of Purchasing and Supply Management                                   | 1                   |
| Journal of Scientific Research and Reports                                   | 1                   |
| Journal of Supply Chain Management Systems                                   | 1                   |
| Manufacturing and Service Operations Management                               | 1                   |
| Modern Supply Chain Research and Applications                                | 1                   |
| Production and Operations Management                                          | 1                   |
| Production Planning and Control                                               | 1                   |
| The International Journal of Logistics Management                            | 1                   |
| Annals of Operations Research                                                 | 1                   |
| Science of the Total Environment                                              | 1                   |
| Total                                                                         | 72                  |
4.1. Blockchain Technologies

In this study, we assessed the reviewed publications from the standpoint of BCT deployment. Articles are grouped into categories based on BCT, such as visibility, digitalization, transparency, and smart contracts. The results are demonstrated in Figure 4. Several studies (almost 52%) have linked various technologies, and these articles are categorized as multiple technologies (e.g., digitalization and visibility, digitalization and smart contracts, visibility and transparency, digitalization, visibility and transparency, digitalization, visibility and smart contracts). We split this category into different BCT combinations for further analysis. Table 2 demonstrates the findings of the reviewed articles on BCT deployment.
The findings indicate that, of all the BCT categories, digitalization had the highest frequency in the reviewed studies, with 22 articles out of 72 [3,13,57–76]. With ten articles, visibility was also one of the most common BCT [5,20,77–84]. Sixteen of the papers looked at the impact of both digitization and visibility on the SC and the COVID-19 pandemic simultaneously [5,23,85–98]. While transparency technology has received little attention in prior research, and only one study has addressed this issue [99], the combination of visibility and transparency has been the subject of nine studies in the literature that was reviewed [98,100–107]. Six studies examined the implementation of digitalization, visibility and transparency technologies in SC and the critical circumstances of COVID-19 [18,22,108–111].

### Table 2. BCT used in the reviewed studies.

| Blockchain Technologies                  | Number of Documents | References |
|-----------------------------------------|---------------------|------------|
| Digitalization                          | 22                  | Bahn et al. [57]; Betcheva et al. [58]; Butt [59]; Chamola et al. [13]; Chowdhury et al. [60]; Cordeiro et al. [61]; Fusco et al. [62]; Guo et al. [63]; Karmaker et al. [64]; Kumar [65]; Kumar and Kumar Singh [66]; Labaran and Hamma-Adama [67]; Liu et al. [68]; Narayanamurthy and Tortorella [69]; Papadopoulos et al. [70]; Paul and Chowdhury [3]; Quayson et al. [71]; Sharma et al. [72]; Siriwardhana et al. [73]; Starr et al. [74]; Sufian et al. [75]; Yeganeh [76] |
| Visibility                              | 10                  | Acioli et al. [77]; Agarwal et al. [78]; Akhigbe et al. [79]; Finkenstadt and Handfield [80]; Golan et al. [20]; Ivanov [7]; Kovác and Falagar Sigala [81]; Lin et al. [82]; Memon et al. [83]; Yang et al. [84] |
| Transparency                            | 1                   | Kumar et al. [98] |
| Smart contracts                         | 2                   | Ahmad et al. [111]; Lohmer et al. [21] |
| Digitalization and visibility           | 16                  | Choi [99]; de Sousa Jabbour et al. [23]; Di Vaio et al. [85]; Dutta et al. [86]; Gurbuz and Ozkan [87]; Ivanov and Das [88]; Ivanov and Dolgui [5]; Kazancoglu et al. [89]; Kumar and Pundir [90]; Nandi et al. [91]; Nandi et al. [92]; Platt et al. [93]; Tasnim [94]; Xu et al. [95]; Yousif et al. [96]; Zouari et al. [97] |
| Digitalization and smart contracts      | 1                   | Kalla et al. [112] |
| Visibility and transparency             | 9                   | Bakalis et al. [99]; Bumblauskas et al. [100]; Choi [27]; Choi [101]; Iftekhar et al. [102]; Kemp et al. [103]; Montechi et al. [104]; Pillai and Mohan [105]; Sodhi and Tang [106] |
| Visibility and smart contracts          | 1                   | Lin et al. [113] |
| Digitalization, visibility and transparency | 6              | Etemadi et al. [107]; Ivanov and Dolgui [18]; Remko [22]; Rowan and Galanakis [108]; Yadav et al. [109]; Zhang et al. [110] |
| Digitalization, visibility and smart contracts | 1              | Bekrar et al. [114] |
| Digitalization, transparency and smart contracts | 1              | Dolgui and Ivanov [115] |
| All blockchain technologies             | 2                   | Bamakan et al. [116]; Sharma et al. [14] |

Smart-contact technology, on the other hand, is one of the areas of BC technology that has received some slight attention in the literature, resulting in only two studies [21,112]. Furthermore, one article examining digitalization and smart contracts [113], another article evaluating visibility and smart contracts [114], one article assessing digitalization, visibility,
and smart contact technologies [115], and one research topic also looked into digitalization, transparency, and smart contract technologies [116]. Finally, two of the reviewed articles dealt with all the BCTs at the same time [14,117].

4.2. Methodologies

By reviewing the past literature in terms of research methodologies, this study attempts to evaluate the contribution of each of the approaches employed in connection to the BCT in SC and to the COVID-19 pandemic. These findings may be used to discover which techniques have been used more frequently and which methods deserve more attention. Furthermore, the data can serve as a reference for many researchers in picking the appropriate methodologies. Reviewed article methods were classified into several categories, such as empirical, quantitative, qualitative, decision making, review, and multiple methods. Figure 5 demonstrates the application rates of each of these approaches, with qualitative and review methodologies having the highest share in prior studies. After that, quantitative approaches and the use of multiple methodologies were the runners-up. The findings of the methodological evaluation of the reviewed publications are shown in Table 3.

Table 3. Summary of the methodologies employed in the reviewed studies.

| Methodology       | Particular Field      | Number of Documents | References                                                                 |
|-------------------|-----------------------|---------------------|----------------------------------------------------------------------------|
| Empirical         | Case study            | 2                   | Betcheva et al. [58]; Bumblauskas et al. [100]                             |
|                   | Survey                | 3                   | Guo et al. [63]; Lin et al. [113]; Yang et al. [84]                       |
| Quantitative      | Simulation            | 2                   | Ivanov and Das [88]; Lohmer et al. [21]                                   |
|                   | Mathematical          | 6                   | Ahmad et al. [111]; Choi [27]; Dolgui and Ivanov [116]; Karmaker et al. [64]; Kumar [65]; Paul and Chowdhury [3] |
|                   | Explanatory           | 20                  | Bahn et al. [57]; Butt [59]; Choi [27]; Choi [101]; Dolgui and Ivanov [113]; Kalia et al. [112]; Kovács and Falagar Sigala [81]; Liu et al. [89]; Nandi et al. [91]; Nandi et al. [92]; Papadopoulos et al. [70]; Pillai and Mohan [109]; Platt et al. [93]; Quayson et al. [71]; Rowan and Galanakis [108]; Sharma et al. [14]; Siriwardhana et al. [73]; Sodhi and Tang [106]; Tasnim [94]; Zhang et al. [110] |
| Qualitative       | Conceptual            | 6                   | de Sousa Jabbour [23]; Finkenzlad and Handfield [80]; Iftekhar et al. [102]; Ivanov [7]; Ivanov and Dolgui [116]; Starr et al. [74] |
|                   | Interview             | 3                   | Labaran and Hamma-Adama [67]; Remko [22]; Yeganeh [76]                    |
| Decision-making   | MCDM Methods          | 5                   | Agarwal et al. [78]; Kazancoglu et al. [89]; Kumar and Kumar Singh [66]; Yadav et al. [109]; Zouari et al. [97] |
|                   | SWOT                  | 1                   | Fusco et al. [62]                                                          |
| Review            | Literature Review     | 15                  | Acioli et al. [77]; Akhigbe et al. [79]; Bakalis et al. [99]; Bekrar et al. [114]; Chamola et al. [11]; Chowdhury et al. [60]; Cordeiro et al. [61]; Di Vaio et al. [85]; Dutta et al. [86]; Etemadi et al. [107]; Golan et al. [20]; Kumar et al. [98]; Kumar and Pandir [90]; Montecchi et al. [104]; Yousif et al. [86] |
|                   | Systematic Literature Review | 15 | Acioli et al. [77]; Akhigbe et al. [79]; Bakalis et al. [99]; Bekrar et al. [114]; Chamola et al. [11]; Chowdhury et al. [60]; Cordeiro et al. [61]; Di Vaio et al. [85]; Dutta et al. [86]; Etemadi et al. [107]; Golan et al. [20]; Kumar et al. [98]; Kumar and Pandir [90]; Montecchi et al. [104]; Yousif et al. [86] |
|                   | Explanatory and Statistical | 1 | Memon et al. [83]                                                          |
|                   | Conceptual and Survey | 1                   | Lin et al. [82]                                                           |
|                   | Conceptual and Interview | 1 | Xu et al. [95]                                                             |
|                   | Conceptual and Review  | 1                   | Sufian et al. [75]                                                        |
|                   | Case study and Review  | 2                   | Bamakan et al. [116]; Kemp et al. [103]                                   |
|                   | Mathematical and Decision-making | 1 | Sharma et al. [72]                                                          |
|                   | Survey and Statistical | 2                   | Gurbuz and Ozkan [87]; Narayananmurthy and Tortorella [69]                |
4.3. Industry Sectors

Examining the relation between BCT and various industries may aid in understanding the significance of these technologies, particularly in light of the COVID-19 outbreak. According to our findings, the food and agricultural sector has the most commonly utilized BCT, with 19 articles addressing COVID-19 conditions [5,56,57,66,71,79,82,83,85,87,89,94,100,101,103,106,109,110,114]. With 12 research papers since the outbreak, the healthcare industry has made a significant contribution to the reviewed articles. Eight of them were solely on healthcare matters [3,58,62,67,80,93,112,117], while two dealt with healthcare and transportation [81,96] and one dealt with the healthcare and retail sector [99]. Eight articles discuss various areas of the industry. Studies that covered more than two sectors at the same time were included in the multiple industries category [13,20,60,61,63,84,86,91]. From the findings, 26 of the 72 reviewed publications did not identify a specific sector and instead discussed the general function of BCT in SC and its applications in the management of COVID-19 situations. Table 4 summarizes the industrial sectors covered in the examined papers.

Table 4. Summary of industries discussed in the examined studies.

| Industrial Sector                      | Number of Documents | References |
|----------------------------------------|---------------------|------------|
| Food–Agriculture                       | 19                  | Akhigbe et al. [79]; Bahn et al. [57]; Bakalis et al. [99]; Bumblauskas et al. [100]; Di Vaio et al. [85]; Gurbuz and Ozkan [87]; Iftekhar et al. [102]; Ivanov and Dolgui [116]; Kazancoglu et al. [89]; Kumar [65]; Kumar and Kumar Singh [66]; Lin et al. [82]; Lin et al. [113]; Memon et al. [83]; Pillai and Mohan [105]; Quayson et al. [71]; Rowan and Galanakis [108]; Tasnim [94]; Yadav et al. [109] |
| Healthcare                             | 8                   | Ahmad et al. [111]; Bamakan et al. [116]; Betcheva et al. [58]; Finkenstadt and Handfield [80]; Fusco et al. [62]; Labaran and Hamma-Adama [67]; Paul and Chowdhury [3]; Platt et al. [93] |
| Healthcare and Transportation          | 2                   | Kovács and Falagara Sigala [81]; Yousif et al. [96] |
| Healthcare and Retail                  | 1                   | Kumar et al. [98] |
| Retail                                 | 1                   | Sharma et al. [72] |
| Retail and Real estate                 | 1                   | Starr et al. [74] |
Industrial Sector | Number of Documents | References
--- | --- | ---
Construction | 1 | Xu et al. [95]
Mining | 1 | Kemp et al. [103]
automotive | 1 | Agarwal et al. [78]
Transportation | 2 | Bekrar et al. [114]; Choi [27]
Multiple industries | 8 | Chamola et al. [13]; Chowdhury et al. [60]; Cordeiro et al. [61]; Dutta et al. [86]; Golan et al. [20]; Guo et al. [63]; Nandi et al. [91]; Yang et al. [84]

4.4. Geographical Context

Geographical context is a key element for establishing tailored methods for managing the COVID-19 pandemic, considering that several nations have witnessed varied rates of infection and chosen differing lockdown measures to handle the pandemic crisis. Figure 6 shows the reviewed articles according to their geographical classification.

![Figure 6. The proportion of reviewed articles, based on the geographical context.](image-url)

According to the findings, the majority of the existing publications did not focus on the national level. As a result, 44 out of 72 papers do not provide any geographical classification in their study findings. Given the novelty of the issues covered, the scarcity of information, and the research method’s heavy emphasis on qualitative and literature review, this approach is acceptable. However, some articles have looked at the outcomes on a country-by-country basis. Five papers investigated the findings in different regions of India [65,66,69,78,106]. China has been the subject of three studies [63,82,114]. The situation in Hong Kong is discussed in two articles [27,95]. The findings for these countries have been examined in certain papers, for example, one article on China and Hong Kong [84] and another on India and China [83]. Three articles were published in the United States in particular [22,80,101]. The findings in Africa and the Middle East were assessed in four papers—two in Africa [67,71], one in the Middle East [117], and one in both areas [57]. With regard to Europe, one article related to the situation in France [97] and another to Ireland [109]. Furthermore, certain articles discussed the situation in Australia [3] and Bangladesh [64]. In five studies, researchers looked at more than two nations at the same time, resulting in the multiple countries category [13,58,60,88,104]. Table 5 shows the results of the review of articles, depending on the geographical context.
Table 5. The geographical context, as discussed in the reviewed studies.

| Geographical Context       | Number of Documents | References                                                                 |
|----------------------------|---------------------|---------------------------------------------------------------------------|
| India                      | 5                   | Agarwal et al. [78]; Kumar [65]; Kumar and Kumar Singh [66]; Narayananmurthy and Tortorella [69]; Pillai and Mohan [106] |
| China                      | 3                   | Guo et al. [63]; Lin et al. [82]; Lin et al. [113]                        |
| Hong Kong                  | 2                   | Choi [27]; Xu et al. [93]                                                 |
| Middle East                | 1                   | Bamakan et al. [116]                                                      |
| Bangladesh                 | 1                   | Karmaker et al. [64]                                                      |
| China and Hong Kong        | 1                   | Yang et al. [84]                                                          |
| India and China            | 1                   | Memon et al. [83]                                                         |
| Middle East and Africa     | 1                   | Bahn et al. [57]                                                          |
| US                         | 3                   | Bumblauskas et al. [100]; Finkenstadt and Handfield [80]; Remko [22]     |
| Ireland                    | 1                   | Rowan and Galanakis [108]                                                 |
| France                     | 1                   | Zouari et al. [97]                                                        |
| Australia                  | 1                   | Paul and Chowdhury [3]                                                    |
| Africa                     | 2                   | Quayson et al. [71]; Labaran and Hamma-Adama [67]                         |
| Multiple countries         | 5                   | Betcheva et al. [58]; Chamola et al. [13]; Chowdhury et al. [60]; Ivanov and Das [88]; Kemp et al. [103] |

4.5. Sustainability Context

The ability of a company to maintain self-sufficiency in commercial activities amid uncertain economic conditions, such as the COVID-19 pandemic, is dependent on the efficient control of resources engaged in SCM [118]. Regarding sustainability issues, reviewed publications are categorized with certain sustainability topics, such as actions aimed at minimizing harmful environmental consequences (such as climate change and pollution), waste management, economic concerns, and mitigating adverse social effects.

According to the findings, only 16 of 72 articles focus on the sustainability context by considering the deployment of BCT under the conditions caused by COVID-19. Five papers examined the economic concerns [23,57,64,85,92]. Four of them concentrated on waste management [7,104,112,117]. Two articles discussed social issues, such as job insecurity and employee performance [69,77]. Environmental problems were the subject of one paper [81]. Four of the articles covered more than one issue. One looked into waste and economic issues [89], another focused on economic and social subjects [76], and two investigated waste, environmental, and economic issues [109,110]. Table 6 demonstrates the results of the review articles discussing sustainability issues.

Table 6. The sustainability context, as discussed in the reviewed studies.

| Sustainability Context            | Number of Documents | References                                                                 |
|-----------------------------------|---------------------|---------------------------------------------------------------------------|
| Waste Issues                      | 4                   | Ahmad et al. [111]; Bamakan et al. [116]; Ivanov [7]; Kemp et al. [103]  |
| Environmental Issues              | 1                   | Kovács and Falagara Sigala [81]                                           |
| Economic Issues                   | 5                   | Karmaker et al. [64]; Nandi et al. [92]; Bahn et al. [57]; de Sousa Jabbour et al. [23]; Di Vaio et al. [85] |
| Social Issues                     | 2                   | Acioli et al. [77]; Narayananmurthy and Tortorella [69]                    |
| Waste and Economic Issues         | 1                   | Kazancoglu et al. [89]                                                    |
| Economic and Social Issues        | 1                   | Yeganeh et al. [76]                                                       |
| Waste, Environmental, and Economic Issues | 2 | Rowan and Galanakis [108]; Yadav et al. [109] |
5. Discussion
5.1. Blockchain Technologies and Industry

We categorized BCT into four groups based on prior research findings: visibility, digitalization, transparency, and smart contracts. According to Table 2, digitalization and visibility have received the most attention in past studies. In total, 48 out of 72 articles deal either independently or jointly with these two themes. Transparency and smart contracts, on the other hand, were in a lesser proportion. One of the primary explanations for this unequal distribution might be the depth of deployment of these technologies in various industries. Analyzing the links between BCT’s deployment in different industrial sectors during the COVID-19 pandemic might be a key criterion for determining the importance of these technologies in handling uncertainties in various areas of the industry. Based on the findings, the food-agricultural and healthcare sectors had the highest share of studies, with 19 and 12 publications, respectively. The results in Figure 7 illustrate the connections between BCT and different sectors of industry. Digital infrastructure, remote monitoring, and tracking are just a few of the reasons why these technologies are being given more attention. The most urgent difficulties during the COVID-19 pandemic were a lack of transparency and visibility in essential demand, production capacity, distribution constraints, and storage conditions, particularly in the food-agricultural and healthcare sectors [3,119]. As a result, the demand for real-time data, monitoring, and tracking has increased. On the other hand, the fast growth in demand for goods provided by these two industries, as well as the risk of counterfeited critical medical and pharmaceutical products, has increased the significance of these technologies and their integration with transparency [57,102].

Another reason for the increased focus on digitization was the necessity of working from home (WFH) during the COVID-19 pandemic quarantine, as well as the need for various enterprises to adapt to a digital infrastructure [69,77]. Smart contracts, which focus primarily on digital contracts and transactions, are among the technologies that have garnered the least attention from academics. Two analyses may be used for further assessment. Firstly, in terms of the impact of COVID-19, this technology provides fewer services than the other technologies described for controlling the uncertain circumstances of the supply chain, as it is primarily concerned with reducing the duration of the supply chain process [41,52]. Secondly, research on COVID-19 and BCT is still in its early phases. Consequently, as more information from various industries and their performance in facing the pandemic becomes available, smart contact technology is likely to receive a larger proportion of research than it does now.
Given the above, it can be inferred that the first hypothesis of this study is valid and that the use of BCT is dependent on their services in various industries, particularly during COVID-19.

5.2. Methodologies and Geographical Contexts

Several categories have been suggested based on the previously reviewed methodologies (Table 3). Based on our results, the highest proportion of articles reviewed (35 out of 72) relates to the qualitative and review categories. The novel nature of both BCT and COVID-19 is part of the reason for so much attention being given to these two methodologies. Given the early stages of knowledge, qualitative assessments and the gathering of past findings might be of significant importance in advancing these issues, and the absence of using other techniques does not imply the inadequacy of present investigations. As time passes and more information is accessible, we should expect additional research based on empirical and quantitative methodologies from the application of BCT in various industries, particularly under uncertain situations like the COVID-19 pandemic.

By evaluating the studies geographically, it is clear that a considerable number of the articles assessed pertain to the Asian nations (15 out of 72), most commonly from China and India. The significant prevalence of COVID-19 and its rapid expansion, as well as their high populations and therefore high demand for vaccinations, are among the reasons why researchers are paying more attention to such countries. On the other hand, the outcomes revealed that studies in other countries have been sparse. In this regard, it should be emphasized that there is still a scarcity of data on how various nations are facing the COVID-19 outbreak. Because of this difficulty, a large number of publications used qualitative methodologies, and, as a consequence, they have not examined the effects of these technologies on a specific country’s performance (44 out of 72).

Although the number of articles in the research literature that looked at geographical contexts is not large enough to definitively support the second hypothesis of this study, the findings of the reviewed articles indicate that countries like China, India, the US and the Middle East, that faced the most challenges during the COVID-19 pandemic, have received more attention from researchers than any other country. As a result, the authors believe that, based on existing evidence, the second hypothesis can be verified.

5.3. Sustainability Context

Previous studies were examined based on four sustainability criteria: waste issues, environmental challenges, economic difficulties, and social concerns. The findings revealed that only a small proportion of peer-reviewed papers addressed these topics (16 out of 72). Economic and waste issues, for example, have garnered increasing interest from academics. This is because the COVID-19 pandemic has had a direct impact on SC economics; paying attention to this issue and developing suitable measures might assist businesses to survive longer. The nature of BCT, on the other hand, is compatible with waste management, and its implementation might have a beneficial impact on SC performance. Despite the fact that the novelty of COVID-19 and its unknown impacts on various areas of the SC may have resulted in a distinct lack of study in sustainable SC, there is a definite need to focus on this area of literature.

Accordingly, we may conclude that our third hypothesis is accurate as well. Although the existing literature cannot demonstrate the impacts of BCT for all factors of sustainability criteria under the circumstances of COVID-19, it is apparent that these effects are significant in the economic and waste-management areas.

6. Research Agendas for Technology Deployment in SCM

The findings point to a plethora of potential study topics in the COVID-19 pandemic considering the deployment of BCT in SCs. Although numerous studies have been posted since the COVID-19 outbreak, additional study is still needed in several research sub-
jects and sectors. This section aims to elucidate some of these important topics. Table 7 summarizes the most crucial future research issues and prospects in several disciplines.

Table 7. Future research agendas.

| Studies Context | Research Questions and Opportunities | Suggestions |
|-----------------|--------------------------------------|-------------|
| BCT context     | (1) How do transparency and smart contract technologies impact the various sectors of the industry considering the COVID-19 pandemic? (2) What are the effects of BCT deployment during the COVID-19 pandemic on SCs, especially for high-demand items? (3) How do the COVID-19 circumstances affect the willingness of several sectors of industries to use BCT? (4) How might the BCT deployment will lead to a more resilient SC for the post-COVID-19 era? (5) What are the factors that impact blockchain adoption in several sectors from the perspective of COVID-19? | Circumstances: the necessity for WFH, traceability and transparency Factors: BCT’s services in uncertain conditions, Infrastructure availability, Cost-benefit features |
| Industrial contexts | (1) How does the BCT deployment affect the agricultural-food and healthcare sectors considering the COVID-19 circumstances, particularly transparency and smart contact technologies? (2) How has the retail sector been influenced by BCT usage? (3) How do transportation and logistics engage with the usage of BCT during the COVID-19 pandemic? (4) How does the COVID-19 pandemic impact the technology and communication sectors’ markets? (5) In light of the COVID-19 pandemic, how is the energy sector, such as the oil business, engaging with the BCT? | Subject: Online shopping services Subjects: Domestic and transnational freight transportation services Uncertainty border restrictions, the uncertainty of supply and demand Subjects: Working from home requirements Social distancing necessity Subjects: Border closure influences Quarantine and avoiding the use of passenger transportation systems |
| Methodological contexts | (1) How could practical information from different industries with regard to deploying BCT be collected at the early stages of the COVID-19 pandemic? (2) What are the practical findings of various industries’ performances during and after the COVID-19 pandemic considering BCT deployment? | Methodologies: Use interview method in very early phases Use surveys in the next phases Use of decision-making methods Use statistics methods to estimate predictions, such as regression models and data learning models Use mathematical methods to analyze choice behaviors, such as logit models and stated preference experiments |
| Geographical contexts | (1) What are the geographical findings of various industries’ performance for BCT and COVID-19? | Subjects: Case studies from various sectors in various countries Literature reviews on the practices, and policies, and achievements of various industries in various nations, as well as the causes of their success or failure, considering BCT usage |
6.1. Blockchain Technological Context

Although several studies have been conducted in various sectors of BCT, including digitization and visibility, there remain gaps, particularly in transparency and smart contracts. Previous research has demonstrated that by digitization and visualization, effective services can be offered to SCs, particularly in crisis management, such as the COVID-19 pandemic. However, these definitions are incomplete for the transparency and smart contract domains, and additional study is needed in these two areas of technology. On the other hand, the majority of studies focus on evaluating the effects of various technologies under the existing circumstances of COVID-19. However, it is expected that different industries’ approaches to the deployment of other technologies would alter in the post-COVID-19 era [7,22,87]. Several experiences, such as the necessity for WFH, the benefits of traceability and transparency, and the need for confirming the authenticity of certain products, will have a significant influence on various businesses’ readiness to adopt these technologies in both the private and public sectors. As a result, the present findings on these issues are unclear, and further research is needed in this field. Furthermore, previous research findings have not identified which factors might influence the deployment of these technologies in different industries under the COVID-19 pandemic (such as services in managing uncertain conditions, the existing infrastructure in companies, the relevance
of these technologies with various sectors, cost-benefit studies for each of the technology categories, and so on).

6.2. Industrial Contexts

The food and health sectors have a significant share in the reviewed studies. However, when examining the use of various technologies in these two areas, it is evident that transparency and smart contact technologies have received little attention from scholars. On the other hand, other industries were greatly impacted by the deployment of technology during the COVID-19 pandemic, but this is rarely addressed in the examined papers. Because of quarantine and the necessity for social distancing, the retail sector has developed online shopping services [72, 120, 121]. The transportation and logistics industry is another field that was engaged in BCT during the COVID-19 pandemic, particularly those businesses that provide domestic and transnational freight transportation services [88, 115]. Uncertainty regarding border restrictions, as well as diverse supply and demand circumstances, raised the necessity for these businesses to employ additional technologies [20, 22]. Working from home has prompted many businesses of all kinds to turn to digitalization services, and this has had a huge influence on the technology and communication sectors’ markets [69]. The energy sector, such as the oil industry, has been severely impacted by the COVID-19 pandemic. Border closures, quarantine, and the avoidance of passenger transportation systems have thrown off the balance of oil supply and demand, entirely disrupting the supply chain for this product [86, 120]. Despite these significant effects, few articles concentrated on the deployment of BCT in these areas, and future studies will need to address all these issues.

6.3. Methodological Contexts

Given that COVID-19 is a fresh issue regarding all fields of knowledge, its novelty in the supply chain has also had a major impact, resulting in qualitative approaches that encompass a large proportion of the reviewed studies [22, 27, 57, 80, 102]. However, when knowledge regarding the performance of various sectors of different industries grows, it is critical for researchers to provide practical achievements regarding the topic using empirical and quantitative techniques. Furthermore, under the circumstance of a lack of practical data, methodologies such as surveys may be used to gather enough data to assemble studies using other approaches, such as statistical modeling, decision-making, and mathematical methods.

6.4. Geographical Contexts

According to our findings, researchers have not given much attention to BCT in SC under the influences of COVID-19 at the country level, because 44 publications out of 72 did not consider this issue at all. India and China, two Asian nations that have been the worst hit by the COVID-19 pandemic, have done more research on the topic than other countries [63, 65, 66, 69, 78, 82, 106, 114]. The number of studies for developed nations such as Europe, the United States, and Australia, on the other hand, has been quite limited [22, 29, 97, 109]. Although there is currently inadequate evidence available on industry performance in many nations, a broader examination, maybe from a governmental perspective, might lead to more comprehensive national performance studies. Some highlighted issues, such as evaluating government regulations on the usage of BCT, providing financial assistance to improve different industries infrastructures for accommodating these technologies, assessing the impacts of employing technology in the food-agricultural and healthcare sectors under the supervision of government organizations, and identifying the policies necessary in different nations for the post-COVID-19 period, might be addressed in future studies.
6.5. Sustainability Context

The reviewed articles are discussed from the perspective of certain sustainability issues, including environmental difficulties, waste management, economic concerns, and societal challenges. Although the use of BCT in supply-chain and logistics management has enhanced the sustainability of various businesses in recent years, the new conditions that have emerged in various industries, influenced by the COVID-19 pandemic, have shown the need for further research in this area. According to our findings, only a tiny percentage of the papers evaluated address the sustainability context [7,23,57,64,85,92,104]. However, when it comes to environmental and social concerns, this gap is clearly reflected [69,77,81]. This dilemma is exacerbated when we consider the societal issues that have arisen as a result of the COVID-19 pandemic. Working remotely as a result of quarantine, which is linked with BCT deployment, has intensified issues like employee performance and job insecurity. Environmental challenges, including climate change and greenhouse gas emissions, which have long been supply-chain concerns, have grown more complicated as a result of the COVID-19 pandemic. However, the application of BCT to these difficulties, particularly in current and post-pandemic situations, is ambiguous, and the study literature has paid little attention to them.

7. Conclusions and Future Works

In this paper, we investigated the state of practice for BCT deployment on SCM by focusing on the COVID-19 pandemic. In total, 72 articles were systematically selected and thoroughly analyzed, based on BCT, methodologies, industrial sectors, geographical classifications, and the sustainability context. The following is a summary of the research findings.

7.1. Theoretical and Practical Findings

We categorized BCT into four groups, including visibility, digitalization, transparency, and smart contracts. A large proportion of the reviewed articles have focused on digitalization and visibility; however, transparency and smart contracts had a smaller share. The findings reveal that this unequal distribution may be explained by the linkages between BCT deployments in various industry sectors during the COVID-19 pandemic. This finding supports our first hypothesis that BCT’s utilization is reliant on the services offered in a variety of sectors, especially during COVID-19. The results show that in the food and healthcare industries, digitalization and visualization technologies have been most frequently used. This direct relationship could be due to sudden changes in supply and demand, production capacity, distribution constraints, and storage conditions, resulting in a greater demand for real-time data, monitoring, and tracking. Another reason for the growing focus on digitization and visibility is the requirement for diverse businesses to adapt to digital infrastructures, particularly when COVID-19 necessitated working from home.

We noticed that most research emphasized the overall role of BCT in SC and its applications in the control of the COVID-19 pandemic rather than a specific industry sector. We think the industry-focus approach will become more important as it is very likely that consumption patterns for particular products and services [122] will be different than they were pre-COVID-19. Furthermore, we observed that the predominant methodologies of reviewed studies have been qualitative. Given the early stages of knowledge regarding the pandemic, qualitative assessments and the gathering of previous findings may be critical in moving these issues forward; however, as more information becomes available, we should expect more research based on empirical and quantitative methodologies. Again, due to the novelty of the topic and the paucity of data on how different countries are dealing with the COVID-19 pandemic, a significant percentage of the reviewed publications have not concentrated on the geographical contexts or individual country performance. Because many nations have seen varying levels of infection and have chosen different lockdown approaches to cope with the pandemic issue, we believe that a regionally focused strategy
will become increasingly relevant. As a result, the post-COVID-19 situation will be quite different, depending on the region. Despite this scarcity of data, our analysis revealed that nations such as China, India, the United States, and the Middle East, which experienced the greatest problems during the COVID-19 pandemic, have garnered more study attention than any other country. As a result, we believe that our second hypothesis may be validated based on current facts; the concentration of research on the effects of the BCT on SCM differs according to the conditions of various countries in terms of the COVID-19 pandemic’s consequences. The findings show that articles focusing on the sustainability context are few. When we explore the social and environmental issues in the context of the COVID-19 pandemic, this shortcoming is more apparent. The applicability of BCT to these challenges, particularly in the present and post-pandemic situations, is unclear, and the research literature has given them little consideration. However, based on the results, we may infer that our third hypothesis is also correct. Despite the fact that the previous studies cannot show the effects of BCT on all aspects of the sustainable factors regarding COVID-19 conditions, it is clear that these effects are significant in the areas of economics and waste management.

Last but not least, we have identified the gaps in the literature and provide research opportunities and suggestions for future studies.

7.2. Suggestions for Future Works

Based on our findings and outlook in this study, we highlight the following as immediate extensions for future studies.

According to our findings, there are substantial shortcomings in both the empirical and quantitative methods. Furthermore, in the matter of geographical contexts, not enough attention has been devoted to the utilization of different nations’ achievements in using BCT to address COVID-19-related difficulties regarding SCM. Despite the fact that BCT are utilized in many sectors in Europe and the United States, there is still a scarcity of research related to these nations. Furthermore, the proportion of sustainability studies in the research literature is quite low, and these flaws are especially evident when it comes to environmental and social concerns.

We propose that researchers explore these issues further with a positive outlook because, by the expansion of these research areas, particularly those that concentrate on the recovery and resiliency of sustainable SCs [123–125], businesses and governments can be better prepared for critical situations and increase their chances of survival in post-crisis conditions. Overall, we hope that our research will assist academics and other stakeholders in gaining a better understanding of the current literature on SCM and the ramifications of the pandemic, identifying areas that need more research, and directing future studies.

Turbulent times call for bold and innovative solutions for all the stages of SCM, from product design and production to distribution, thence to consumption. Although the focus of this study was on BCT and SCM literature during the COVID-19 pandemic, supply-chain strategies and solutions will undoubtedly be impacted by the advent of enhanced technologies such as BCT, the Internet of Things (e.g., Chadha et al. [126]), and sustainability imperatives. To that end, we next plan to work on how intelligent technologies can be aligned with both SC strategies (the logistics of SCM) regarding the United Nations Sustainable Development Goals. Various further extensions on this broad topic could examine, among others, product returns management and sustainability (e.g., Ülkü and Gürler [127]) and the integrative logistics needed for sustainable consumption and production in developing and emerging countries e.g., [128].

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Appendix A. Descriptive Analysis of Reviewed Studies

Table A1. Description reviewed articles on COVID-19 pandemic in supply chain and blockchain technologies deployment.

| References      | Research Description                                                                                                                                 |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| Acioli et al. [77] | Analyzed the influences of BCT on SC operation in the COVID-19 period. The findings indicate that Industry 4.0 may create issues such as societal inequities connected to man’s position in the global economy by replacing real employees with machinery. |
| Agarwal et al. [78] | Discussed the adoption of SC enablers to achieve greater efficiency against the COVID-19 pandemic interruption. The findings explore that among the characteristics of a resilient SC, trackability, and traceability of products get the closest attention. |
| Ahmad et al. [112] | Investigated decentralized BCTs to automate forward SC operations for the COVID-19 medical equipment. They offer a security study utilizing Ethereum algorithms to validate the dependability of smart contracts, and they explore solutions using cost analysis. |
| Akhigbe et al. [79] | Discussed the Internet of Things (IoT) technologies for livestock SC in the COVID-19 situation using a systematic review methodology. The findings show that there are enough advanced technology infrastructures to drive IoT for a variety of management objectives in BCT. |
| Bahn et al. [57] | Investigated the digitalization for sustainable agricultural-food systems in the COVID-19 conditions. The findings reveal that digital agriculture adoption is still in its early stages, with high-value agricultural output focusing on national consumers in Gulf nations and export markets in developing nations leading the way. |
| Bakalis et al. [100] | The findings show that technologies like IoT and BC are becoming essential in the risk management the food products, and the infrastructure of these technologies are closely related to key criteria like traceability, transparency, efficiency, and product quality to control COVID-19 circumstances. |
| Bamakan et al. [117] | The findings demonstrate that BCT might provide obvious advantages such as serialization, tracking, protecting IoT devices and smart contracts in pharmaceutical and medical projects. |
| Bekrar et al. [115] | Investigated the digitalizing benefits in the transportation sector facing the COVID-19. The article looked at BCT in various aspects, particularly as a permanent and trustworthy database, a monitoring tool, a smart contract function, and digital signatures. |
| Betcheva et al. [58] | Explored the SC thinking in the healthcare industry by considering the COVID-19 pandemic. The results show that the complexity in managing healthcare SCs offers opportunities for using technologies that cover visibility and transparency to develop various areas. |
| Bumblauskas et al. [101] | Investigated a BC use case in food distribution during the COVID-19 outbreak. The findings indicate that by building visible and transparent food SCs, stakeholders may obtain the required data for deciding on buying food products and supporting businesses. |
| Butt [59] | Explored the link between additive manufacturing and Industry 4.0 technologies considering the COVID-19 pandemic. The findings show that deploying technologies allow allows businesses to adapt to consumer demands more quickly, which will hasten the transition to smart manufacturing. |
| Chamola et al. [13] | Discussed the utilization of technologies like the BC, AI, and IoT to reduce the influences of the COVID-19 by a comprehensive review. |
Table A1. Cont.

| References                              | Research Description |
|-----------------------------------------|----------------------|
| Chowdhury et al. [60]                   | Reviewed the studies on the COVID-19 pandemic in SCs. The findings indicate a scarcity of research that is both empirically constructed and conceptually based. This study also presents research directions for future studies. |
| Choi [27]                               | Investigated the impacts of logistics technologies on transforming the static service operations to the dynamic home mobile service operations in the COVID-19 outbreak. According to the results, by applying BCT, operations could be more transparent, secure, and traceable. |
| Choi [102]                              | Explored the risk analysis in the logistics system during and after the COVID-19 pandemic. The findings indicate that the use of BC might be an efficient solution for several issues such as the need for remote working, enhancing transparency, and support the visibility of the logistics systems. |
| Choi [98]                               | Explored a framework for fighting against the COVID-19. The results show that using AI and BCT may enhance the traceability of patients suspected of infection, and by creating safe digital processes, you can make elections and voting easier. |
| Cordeiro et al. [61]                    | through a bibliometric analysis and systematic literature review, flaws in SCs may be used to develop public policies that increase resiliency, particularly during the COVID-19. |
| de Sousa Jabbour et al. [23]            | Investigated sustainability of SCs during the COVID-19 pandemic. They presented a framework on four principles related to engineering, collaboration, agility, and culture. Findings show that technologies, especially BCT, play an influential role in the SC agility and risk management culture. |
| Di Vaio et al. [85]                     | Discussed artificial intelligence (AI) in the agricultural-food systems by the systematic literature review. The findings suggest that focusing on digital technologies, IoT, and BC to realize traceability of SCs, especially during the COVID-19 pandemic, might be a way to make this industry sector more robust. |
| Dolgui and Ivanov [116]                 | Discussed articles in the special issue utilizing various techniques, as well as compiling the latest findings. The BC, SC robustness, ripple effect, big data, and digital systems are all examples. |
| Dutta et al. [86]                       | Investigated BCT in SC operations by considering the COVID-19 impacts. They looked at a number of industries that may benefit from BCT because of improved visibility and business process management. In addition, a future study plan for this key developing research field is created. |
| Etemadi et al. [108]                    | The findings cover a variety of topics, including BC’s potential for privacy and security problems, smart contract security, fraud monitoring, and tracking database systems to assure food safety and security. |
| Finkenstadt and Handfield [80]         | The findings show that visibility and velocity are the most important characteristics for facilitating vital judgment reliability in the health care sector. |
| Fusco et al. [62]                       | Discussed the importance of BC in health care, in particular in terms of COVID19-safe clinical practice. Findings indicate that BC may be utilized in a new process with specific attention to risk management. |
| Golan et al. [20]                       | Discussed literature on SC robustness and linkages to sectors like transportation considering the COVID-19’s circumstances. BC was presented as a mechanism for visibility between SC phases, and it may be required to prevent SC network failure. |
| Guo et al. [63]                         | The findings demonstrate that by utilizing BCT, SMEs may be able to successfully adapt to public crises (such as the COVID-19) as a result of digitalization. |
| Gurbuz and Ozkan [87]                   | Findings show that agriculture and food sectors have to adopt innovative approaches such as using modern BCT quickly to face the post-crisis uncertainty. |
| Iftekhar et al. [103]                   | Investigated BCT in the food sector for disruptive situations like the COVID-19. Findings show that the deployment of BCT in the food industry could help to provide more transparency and prevent potential food safety hazards. |
### Table A1. Cont.

| References | Research Description |
|------------|----------------------|
| Ivanov [7] | Investigated SC resilience by lean thinking during the COVID-19 outbreak. The findings provide a paradigm that connects several aspects of successful robustness and enables the efficient use of resilience abilities in value generation. |
| Ivanov and Das [88] | The results show that the role of technologies in manufacturing the goods is significant concerning the capacity flexibility and product variety during the COVID-19 pandemic. |
| Ivanov and Dolgui [18] | The findings add to SC risks management studies by improving predictive and reactive choices to make use of the benefits of SC visibility and business sustainability in global enterprises. |
| Ivanov and Dolgui [5] | Explored the viability of intertwined supply networks (ISNs) for COVID-19. The results show that SC networks are moving towards the intertwined systems in which the visibility and digitalization technologies will be used as much as possible. |
| Kalla et al. [113] | Findings show that BCT is crucial in building a more robust SC and provides a high level of access restrictions and automation through intelligently designed contracts to build a reliable environment, particularly in the COVID-19 pandemic. |
| Karmaker et al. [64] | Findings indicate that monetary assistance from the government and SC partners is needed to face the imminent impact of COVID-19 on SC sustainability. |
| Kazancoglu et al. [89] | Discussed implementation of BCT in food supply chains based on the COVID-19 disruptions. The results show that there are significant relations between governmental incentives and management and SC visibility. |
| Kemp et al. [104] | While increased disclosure rules may offer visibility for traders, policymakers, and some other parties, they suggest that the internalization of transparency standards is highly complicated. |
| Kovács and Falagara Sigala [81] | Explored the humanitarian SCs’ opportunities to mitigate and overcome SC disruptions during the COVID-19 pandemic. The findings show that technological innovations, such as using BC to trace deliveries, might be a good solution for more resiliency. |
| Kumar [65] | The findings demonstrate that using BCT in a distributed SC like COVID-19 may considerably minimize wastes and fake demand. |
| Kumar et al. [99] | Discussed the applications of industry 4.0 in the healthcare sector in the case of the COVID-19 pandemic. The findings show that technologies such as BC can act as significant drivers to build trust and transparency, reducing the impact of identified challenges. |
| Kumar and Kumar Singh [66] | The findings indicate that deploying BCT could assist all the food and agricultural stakeholders in overcoming the uncertain business environment like COVID-19’s conditions. |
| Kumar and Pundir [90] | Analyzed the deployment of BCT and IoT enablers in the pharmaceutical SC confronting the COVID-19 pandemic. The proposed framework could enhance the visibility, transparency, and privacy of the medical SC. |
| Labaran and Hamma-Adama [67] | The findings indicate some barriers to BC adoption within the Nigerian pharmaceutical SC, including the degree of knowledge of BCT between participants and governmental authorities, are extremely weak. |
| Lin et al. [114] | The findings demonstrate that the BCT, such as smart contracts and traceability, has significant influences on developing agricultural applications, and it generates a more productive food SC, particularly for post-COVID-19’s circumstances. |
| Lin et al. [82] | The findings suggest that attitudes and observed behavior controlling characteristics have a substantial and favorable impact on the desire to use BC food traceability technology to address COVID-19 disruptions. |
| Liu et al. [68] | The findings include a description of the study objectives, theoretical framework, and findings for emerging innovations such as BCT in operations and supply chain sustainability during the COVID-19 pandemic. |
| References                  | Research Description                                                                                                                                                                                                 |
|-----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Lohmer et al. [21]          | Discussed the effects of the deployment of BCT on SC Resilience by considering the COVID-19 pandemic. The findings show that the BCT could intensify collaboration through smart contracts, and that sharing data using a BC solution could be useful on the disruption duration. |
| Memon et al. [83]           | Investigated the COVID-19 situation in China and India, looking deeper into the pandemic’s influence on the food and beverage industry, as well as exploring the programs and initiatives implemented for more resiliency. |
| Montecchi et al. [105]      | Investigated the existing research on supply chain transparency. The findings provide a framework for academics to use in further research and for operators to use in their methods for new challenges that face supply chains concerning the COVID-19 conditions. |
| Nandi et al. [91]           | The findings from use cases demonstrate that BCT can help improve the global economy during the COVID-19 pandemic by supporting SC monitoring, traceability, and reactivity.                                               |
| Nandi et al. [92]           | The authors looked into how businesses might improve their flexibility and digitalization by utilizing BCT resources. During COVID-19. The findings propose a paradigm for further evaluating the link between SC resiliency and company capabilities. |
| Narayananurthy and Tortorella [69] | Discussed the influences of the COVID-19 outbreak on employee performance. Findings show that industry 4.0 technologies, particularly the BCT, moderate the enhancement of employee performance. |
| Papadopoulos et al. [70]    | Investigated the digitalization of companies during extreme and global disruptions. The findings show that digital technologies could be useful for small and intermediate enterprises to keep maintaining their activities during and after the COVID-19 pandemic. |
| Paul and Chowdhury [3]      | Devised a production recovery strategy for essential goods like healthcare products confronting the COVID-19 outbreak. Findings show that BCT may help with the recovery process and that managers can use these technologies throughout the revival period. |
| Pillai and Mohan [106]      | Discussed the blockchain usage in SCs operations in the contexts of the COVID-19 pandemic. The research concentrates on the function of BCT as a solution in a public distribution system for enhancing transparency and visibility across SC stakeholders. |
| Platt et al. [93]           | Through a comprehensive review analysis, the authors looked at the use of BCT for improving digital contact tracking and reporting. The findings suggest that BCT may have a greater impact on public health in fields other than contact tracing. |
| Quayson et al. [71]         | The study investigates how digitalization might protect the most fragile members of SC from catastrophic shocks, particularly for post-COVID-19 circumstances.                                                                    |
| Remko [22]                  | The results implicate that BCT deployment for enhancing visibility and transparency is an effective solution for improving SC resiliency during and post COVID-19.                                                                       |
| Rowan and Galanakis [109]   | The findings indicate that the usage of BCT has the potential to significantly improve safety and security, and could also offer authenticity and traceability for agricultural and food SC for confronting after COVID-19 pandemic.                                      |
| Sharma et al. [14]          | The findings suggest that technologies like AI, automation, BCT, and deep learning might be critical for improving visibility and efficiency throughout the SC.                                                                 |
| Sharma et al. [72]          | Explored the priorities for retail SCs to integrate the operational activities for the post-COVID-19 period. According to findings, to mitigate the risks posed by COVID-19, organizations could leverage new technologies like BC. |
| Siriwardhana et al. [73]    | Addressed new approaches like BCT and IoT in the retail sector, working remotely, and smart manufacturing considering the COVID-19’s conditions.                                                                 |
| Sodhi and Tang [107]        | Explored SCM challenges for extreme conditions like the COVID-19 pandemic. The paper list research opportunities for SCM in extreme conditions, such as the usage of new technologies like BC to upgrade SC capacity in distribution conditions. |
| References          | Research Description                                                                                                                                                                                                 |
|--------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Starr et al. [74]  | Developed a digital foundation for the real estate industry by using Industry 4.0 technologies. The paper provides a primer on how BCT can embrace the rapid changes after the COVID-19 situation. |
| Sufian et al. [75] | Reviewed different methodologies in smart manufacturing by evaluating the newest trends of BCT. The findings show that the proposed plan may be used as a practical tool to fill the gap between advanced technologies and their industrial applications. |
| Tasnim [94]        | Discussed a theoretical review of global food SC disruption considering the COVID-19 pandemic and digitalization by BCT. The results show that visibility and traceability have a foremost role in firms’ SCM. |
| Xu et al. [95]     | Proposed a theoretical framework that comprises four scenarios in the context of BCT for the implementation in coastal constructions considering the COVID-19’ circumstances. |
| Yadav et al. [110] | Explored the usage of BCT and IoT for developing the sustainability of agricultural-food SC under epidemic outbreaks such as COVID-19. This paper guides the organization’s managers in their strategic planning based on digitalization enablers. |
| Yang et al. [84]   | The authors conceptualize SC visibility as a mechanistic control to enhance supply chain resilience to manage crises like the COVID-19 pandemic.                                                                                     |
| Yeganeh [76]       | The study found that the key changes triggered by the COVID-19 pandemic, notably the growing impact of large technologies, are a culmination of the upheavals of the previous decades, resulting in a new sort of globalization defined by extensive accessibility and intangible value. |
| Yousif et al. [96] | Discussed IoT and BCT during and beyond COVID-19 through a comprehensive review. The findings outline potential research directions for next-generation IoT and BCT applications that could improve the SCs’ performance. |
| Zhang et al. [111] | Examined the history and prospects of operations management research. According to the findings, companies need to develop three essential capacities: connection, transparency, and consistency, to attain operating agility, resiliency, and viability in the age of Industry 4.0 age. |
| Zouari et al. [97] | Explored digitalization impacts on the SC resilience confronting the COVID-19 conditions. According to the authors, the level of digitalization and the deployment of digital technologies have a favorable influence on SC robustness. |
Table A2. Summary of the reviewed articles based on the blockchain technology, methodologies, industry, geographical context, and sustainability issues. The sign √ relates the content of the paper with the factors considered.

| References | Blockchain Technologies | Methodologies | Industry Sector | Geographical Classification | Sustainability Context |
|------------|-------------------------|----------------|-----------------|----------------------------|------------------------|
| Acioli et al. [77] | √ | √ | √ | √ | √ |
| Agarwal et al. [78] | √ | | | | |
| Ahmad et al. [112] | √ | √ | | | |
| Akhigbe et al. [79] | √ | | | | |
| Bahn et al. [57] | | √ | √ | | |
| Bakalis et al. [100] | √ | √ | | | |
| Banakan et al. [117] | √ | √ | | | |
| Bekrar et al. [115] | √ | √ | | | |
| Betcheva et al. [58] | √ | | | | |
| Bumbalas et al. [110] | √ | √ | | | |
| Butt [59] | √ | | | | |
| Chamola et al. [13] | √ | | | | |
| Chowdhury et al. [60] | √ | | | | |
| Choi [27] | √ | √ | | | |
| Choi [102] | √ | √ | | | |
| Choi [98] | √ | | | | |
| Cordeiro et al. [61] | √ | | | | |
| de Sousa Jabbour et al. [23] | √ | | | | |
| Di Vai et al. [85] | √ | | | | |
| Dolgui and Ivanov [116] | √ | √ | | | |
| Datta et al. [86] | √ | | | | |
| Etemadi et al. [108] | √ | | | | |
| Finkenrautstadt and Handfield [60] | √ | | | | |
Table A2. Cont.

| References                  | Blockchain Technologies | Methodologies | Industry Sector | Geographical Classification | Sustainability Context |
|-----------------------------|-------------------------|---------------|-----------------|----------------------------|------------------------|
| Fusco et al. [62]           | √                       |               |                 |                            |                        |
| Golan et al. [20]           | √                       |               |                 |                            |                        |
| Guo et al. [63]             | √                       |               |                 |                            |                        |
| Gurbuz and Ozkan [87]       | √                       |               |                 |                            |                        |
| Iftekhar et al. [103]       | √                       |               |                 |                            |                        |
| Ivanov [7]                  | √                       |               |                 |                            |                        |
| Ivanov and Das [88]         | √                       |               |                 |                            |                        |
| Ivanov and Dolgui [18]      | √                       |               |                 |                            |                        |
| Ivanov and Dolgui [5]       | √                       |               |                 |                            |                        |
| Kalla et al. [113]          | √                       |               |                 |                            |                        |
| Karmaker et al. [64]        | √                       |               |                 |                            |                        |
| Kazancoglu et al. [89]      | √                       |               |                 |                            |                        |
| Kemp et al. [104]           | √                       |               |                 |                            |                        |
| Kovacs and Falagara Sigala [61] | √                   |               |                 |                            |                        |
| Kumar [65]                  | √                       |               |                 |                            |                        |
| Kumar et al. [99]           | √                       |               |                 |                            |                        |
| Kumar and Kumar Singh [66]  | √                       |               |                 |                            |                        |
| Kumar and Pundir [90]       | √                       |               |                 |                            |                        |
| Labaran and Hamma-Adama [67]| √                       |               |                 |                            |                        |
| Lin et al. [114]            | √                       |               |                 |                            |                        |
| Lin et al. [82]             | √                       |               |                 |                            |                        |
| Liu et al. [68]             | √                       |               |                 |                            |                        |
| Lohmer et al. [21]          | √                       |               |                 |                            |                        |
| Memon et al. [83]           | √                       |               |                 |                            |                        |
| References | Blockchain Technologies | Methodologies | Industry Sector | Geographical Classification | Sustainability Context |
|------------|-------------------------|---------------|----------------|-----------------------------|------------------------|
| Montecchi et al. [105] | | | | | |
| Nandi et al. [91] | ✓ ✓ ✓ ✓ ✓ | | | | ✓ |
| Nandi et al. [92] | ✓ ✓ ✓ ✓ | ✓ | | | ✓ ✓ |
| Narayananurthy and Tortorella [69] | ✓ | ✓ ✓ ✓ | ✓ ✓ ✓ | ✓ ✓ ✓ | ✓ |
| Papadopoulos et al. [70] | ✓ ✓ | ✓ ✓ ✓ | ✓ ✓ ✓ | ✓ ✓ ✓ | ✓ |
| Paul and Chowdhury [3] | ✓ ✓ | ✓ ✓ | ✓ ✓ | ✓ ✓ | ✓ |
| Pillas and Mohan [106] | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ |
| Platt et al. [93] | ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ |
| Quayson et al. [71] | ✓ ✓ | ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ |
| Remko [22] | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
| Rowan and Galanakis [109] | ✓ ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
| Sharma et al. [14] | ✓ ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
| Sharma et al. [72] | ✓ ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
| Sirwardhana et al. [73] | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
| Sodhi and Tang [107] | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
| Starr et al. [74] | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
| Sufian et al. [75] | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
| Tasnim [94] | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
| Xu et al. [95] | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
| Yadav et al. [110] | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
| Yang et al. [84] | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
| Yeganeh [76] | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
| Yousef et al. [96] | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
| Zhang et al. [111] | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
| Zouari et al. [97] | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ | ✓ ✓ ✓ ✓ |
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