

BLOCKCHAIN IN LOGISTICS IN THE CONTEXT OF SUSTAINABLE DEVELOPMENT

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Purpose: The aim of the research conducted was to identify the main research areas in scientific articles addressing blockchain in logistics in the context of sustainable development.

Design/methodology/approach: The study was conducted between April and August 2024. A review of Scopus database data was conducted. Scientific articles, extracted according to bibliometric query Q1, were submitted for analysis. Based on the adopted criteria, 74 scientific articles were identified and further analyzed according to the author's keywords using the VOSviewer software. A systematic literature review of scientific publications that referred to blockchain issues in logistics and sustainability was also used.

Findings: Nine author keywords most frequently used in the analyzed publications were identified, which were followed by references to the words contained in the title of this study, namely blockchain in logistics and sustainability. The analysis made it possible to see that the word blockchain did not co-occur only with the word blockchain technology, which is considered reasonable.

Research limitations/implications: The limiting factor of the present study is the choice of database, which was limited to the Scopus database and the bibliometric query Q1 constructed as part of the first stage of the research considerations undertaken. Nevertheless, as the analyses conducted in this article indicated, this procedure was justified since the few studies indicated were only concerned with the Scopus database itself. In addition, it allows and enables expert planning of future studies, which will be aimed at repeating these studies in the future to check the results or verify new research areas.

Originality/value: The study conducted is unique compared to those conducted so far, which is confirmed by the constructed bibliometric query Q1. Within the framework of the analysis performed, future relevant research directions were identified, such as addressing the issue of green blockchain. According to the authors, the article can inspire other researchers and those interested in blockchain, logistics and sustainability issues.

Keywords: blockchain, green blockchain, logistics, supply chain, sustainability.

Category of the paper: Literature review.

1. Introduction

Today's business, in various sectors of the economy, is undergoing deep and rapid transformations both under the influence of Industry 4.0 and in the pursuit of sustainable development. Undoubtedly, technological development can help achieve the goals of sustainable development, supporting the initiatives undertaken in all pillars of sustainable development: economic, environmental and social. The support of certain technological solutions, i.e. blockchain, for example, in these necessary transformations is recognized. These transformations are taking place through increased resource efficiency, optimized logistics and innovative business models (Hong, Xiao, 2024)

Logistics plays a rather important role in the entire ecosystem, as it not only contributes significantly to economic performance, but also has a role in environmental and social aspects. Also mentioned blockchain, which in addition to its economic and informational impact also has the potential to accelerate sustainability. Many of the solutions that blockchain has were developed in response to the pursuit of sustainability (Mulligan et al., 2023). This includes its potential to track assets and record transactions in the business network (Abbas, Myeong, 2024). Blockchain as an innovative solution of Industry 4.0 can be implemented and used in virtually all industries also in logistics. The use of blockchain in logistics can correlate with improved efficiency, reduced processing costs, transaction and product security, improved data quality, increased customer satisfaction and greater brand trust (Wodnicka, 2019).

The aim of the research undertaken in this article relates to the presentation of the main research areas undertaken simultaneously addressing issues related to blockchain, logistics and sustainability. In addition, the specific goal was to identify future research directions in the subject matter undertaken. Scientific exploration was carried out on the Scopus database using a specially constructed Q1 bibliometric query. VOSviewer software (version 1.6.20) was also used to graphically present the results obtained. In the context of fully realizing the main and specific objective set, this study was oriented towards a systematic literature review (SLR). This type of literature review was used to review articles selected according to the bibliometric query of this study and directed to the Scopus database.

The article consists of four parts and references. The introduction of this paper presents the issue of sustainability and the issue of blockchain in logistics using the literature on the subject. The choice of the topic is justified, and the purpose of the research and research methods to help achieve it are presented. The research work schedule is described in the material and research methods section. Here, the Q1 bibliometric inquiry is also presented. In the next section, reference is made to the results obtained and a discussion is made based on them. The analyses undertaken conclude the last part of this article.

2. Material and Method

The research described in this article was carried out in three stages. The adopted research stages were assigned specific research activities and a period for their implementation. A graphical representation of the research methodology is presented in Figure 1.

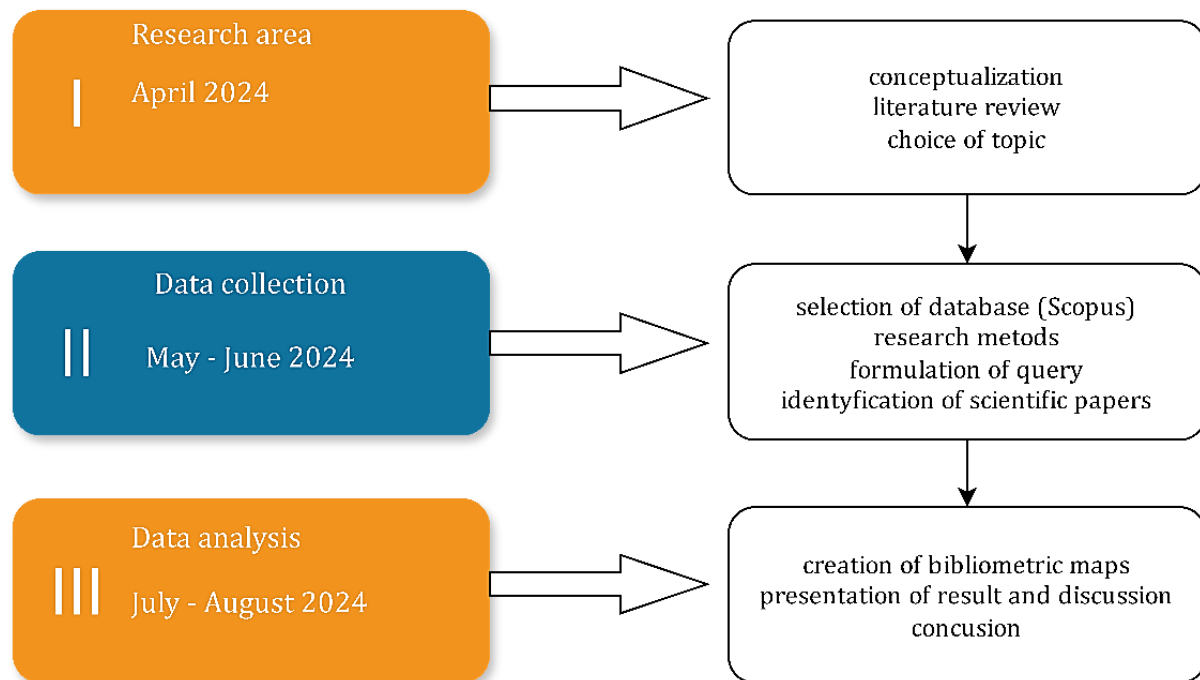


Figure 1. Research procedure stages and timeline.

Source: Authors' elaboration.

Research considerations began with the selection of the topic area for the study. A general review of the literature was carried out, which addressed the topic of blockchain in logistics and sustainability. The analyzed sources came from various databases, including mainly the Scopus database and Google Scholar. At this stage of analysis, a research objective was also set for this article, which was to identify key research areas undertaken by researchers in the field of issues covered in the title of this paper.

In the second stage of the research conducted, the research methods and tools were identified, and the variables used for the bibliometric query were defined. The constructed bibliometric query Q1 for conducting bibliometric analysis is presented in Table 1. The Scopus database was used to conduct this analysis. The selection of the database was purposeful. The authors of this article chose the Scopus database because it is widely used in various types of bibliometric analysis (Kozar, Bolimowski, 2024b, 2024a), and it is also considered by researchers to be one of the largest databases where the most reputable journals in the field of economics, or business, are located (Ben Youssef, Mejri, 2023).

Table 1.*Search Query syntax details*

Symbol	Query syntax
Q1	TITLE-ABS-KEY (blockchain AND logistic AND (sustainability OR "sustainable development")) AND PUBYEAR > 2016 AND PUBYEAR < 2024 AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (DOCTYPE , "ar"))

Source: Authors' elaboration.

The conducted review of Scopus database data included articles in English published between 2019 and the end of 2023 and concerned the verification of titles, abstracts and keywords in the identified articles that referred to blockchain issues in logistics and sustainability. Based on the adopted criteria, 74 scientific articles were identified for further analysis. These analyses were carried out in the next stage of the research using the VOSviewer software. As a result, 270 author keywords were obtained and subjected to a unification procedure. The application of this procedure was in order:

- eliminating language errors,
- eliminate the use of abbreviations,
- standardize spelling for author keywords by choosing one variation of English,
- standardize author keywords by using the plural or singular for a given author word.

Unification was done for 14 keywords and thus 256 author keywords were left for further analysis. These words were used to create bibliometric maps, which were generated in VOSviewer software (1.6.20 version) using co-occurrence, author keywords and full counting options. The minimum number of co-occurrences of author keywords was assumed to be 5. They were also rechecked at the verity selected keywords step, resulting in the exclusion of author keyword bibliometric analysis as a research method. In the next step of the research, a discussion and conclusion were made based on the results obtained.

3. Results and discussion

In accordance with the research steps outlined above and the established criteria, two bibliometric maps were generated, visualized graphically in Figure 2 and Figure 3. Each map consists of 9 author keywords most frequently used in the analyzed publications, which were followed by references to the words contained in the title of this paper, namely blockchain in logistics and sustainability. The analysis of the co-occurrence of the identified author keywords is presented in detail, both as a bibliometric map (Figure 2) and as quantitative bibliometric data captured in clusters (Table 2).

The map titled Author keywords co-occurrences in full counting method of Q1 results (Figure 2) shows author keywords that were automatically classified into one of three clusters by the VOSviewer software. Each cluster is marked with a different color. In the case presented, the colors are red, green and blue.

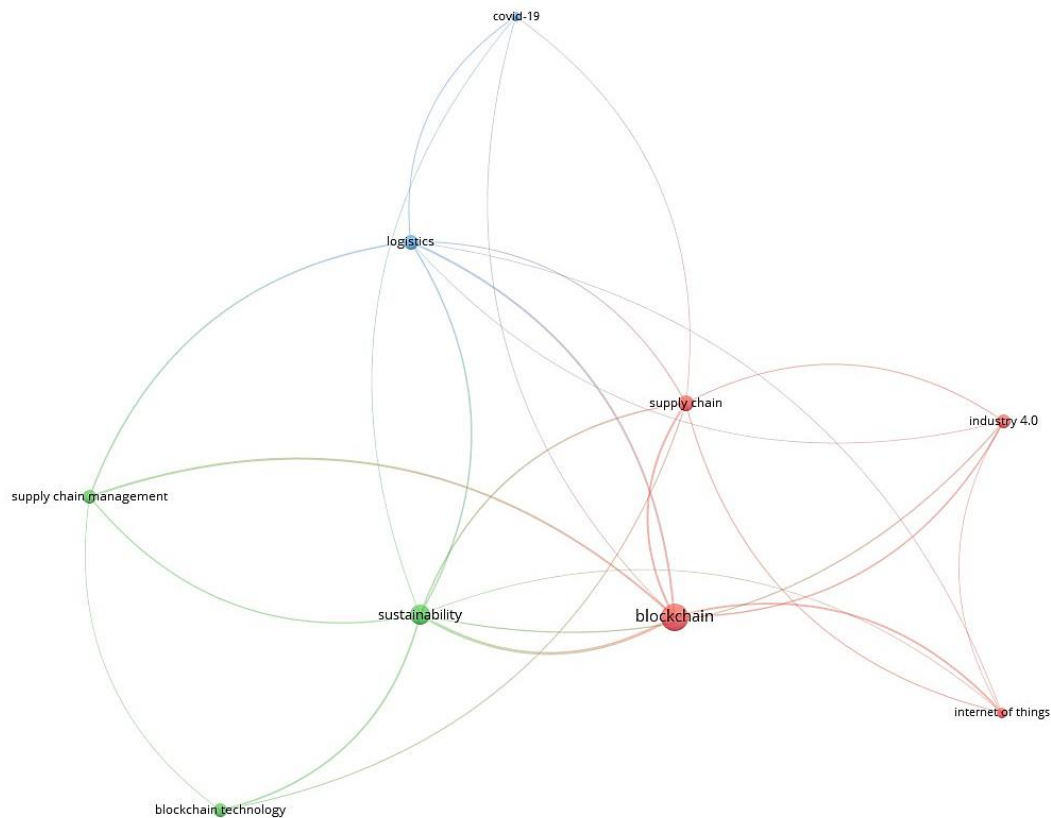


Figure 2. Author keywords co-occurrences in full counting method of Q1 results.

Source: authors' elaboration in VOSviewer software (1.6.20 version).

Each of the clusters presented contains specific author's keywords and values obtained according to the three measures used. The bibliometric measures used: links, total links strength, co-occurrences. Based on these, it can be indicated that in the analyzed articles the most frequent author keywords are blockchain (red cluster), Sustainability (green cluster) and logistics, thus the words contained in the title of this article (Table 2).

Table 2.

Cluster of author's keywords visible in Figure 2

Cluster	Composition of keyword clusters by links, total link strength, co-occurrences			
	Autor's Keywords	Links	Total links strength	Co-occurrences
Red	Blockchain	7	45	38
	Industry 4.0	5	11	9
	Internet of things	5	11	6
	Supply chain	7	20	12
Green	Blockchain technology	3	8	10
	Supply chain management	4	15	10
	Sustainability	8	34	21
Blue	Covid-19	4	5	5
	logistics	7	21	11

The lowest co-occurrence rate according to the established criteria in this study is 5.

Source: Authors' elaboration.

Another bibliometric map was generated to highlight the author's blockchain keyword (Figure 3). The analysis made it possible to see that this word did not co-occur only with the word blockchain technology. This is reasonable from the point of view of defining blockchain as a technology.

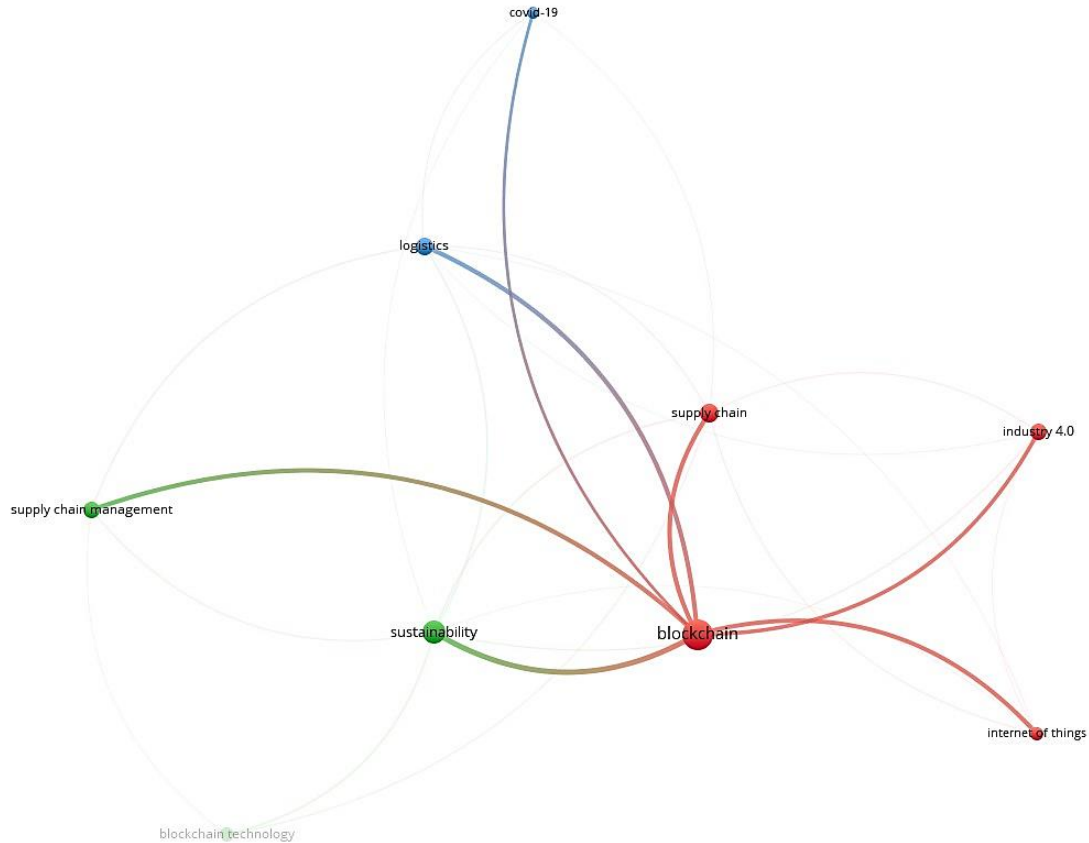


Figure 3. Keyword “blockchain” relations with other keywords.

Source: Authors’ elaboration in VOSviewer software (1.6.20 version).

To complete the analysis, another bibliometric map was generated focusing attention on the author's blockchain technology keyword (Figure 4). This action was taken to indicate what author keywords are linked to it. In the case of the author keyword blockchain technology, it can be seen that it is linked to only three words and these are supply chain (Bekrar et al., 2021; Rejeb et al., 2021), supply chain management (Zhu et al., 2022) and sustainability (Bekrar et al., 2021; Khan et al., 2022; A. Kumar et al., 2022; Rejeb et al., 2021; Zhu et al., 2022).

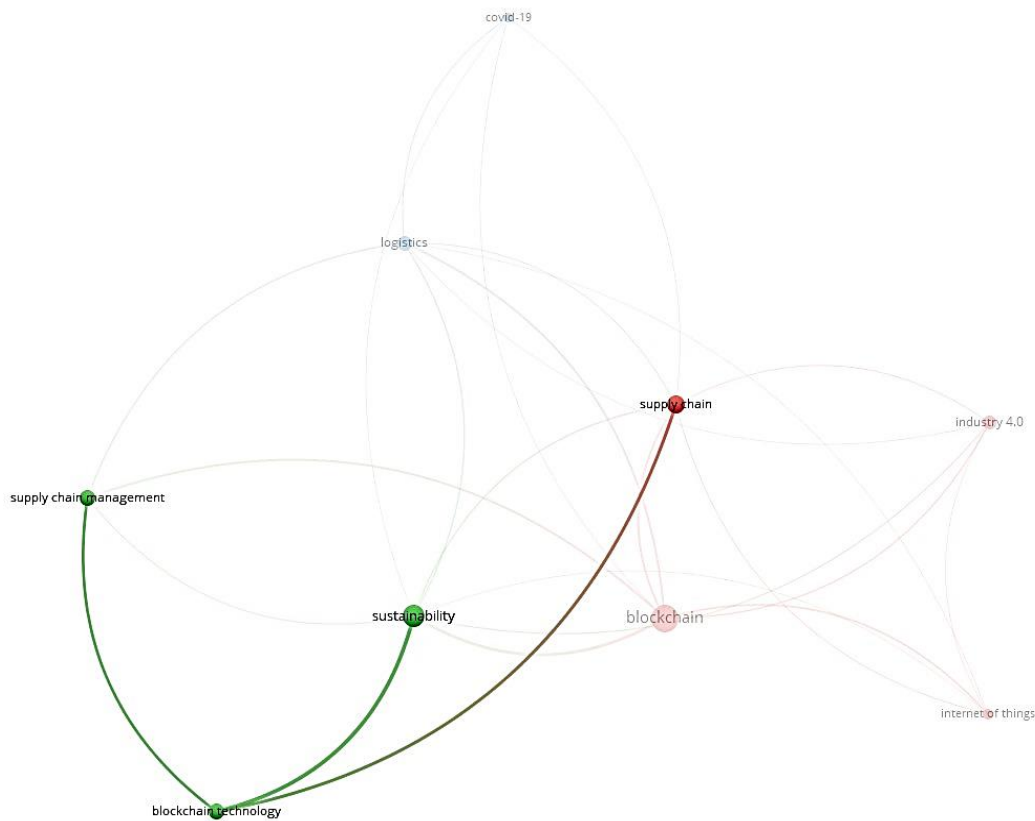


Figure 4. Keyword “blockchain technology” relations with other keywords.

Source: Authors’ elaboration in VOSviewer software (1.6.20 version).

An analysis of the articles shown in this bibliometric study indicated that some of them contained results of bibliometric analyses that were made using data from different databases. The authors of these studies most often used the Web of Science database (Barbosa, 2021; Lam et al., 2023; Prados-Castillo et al., 2023; Vincek et al., 2023) or combined it with the Scopus database (Altarturi et al., 2023; Ayan et al., 2022; Rejeb et al., 2021). Among the research studies, one can also notice those that used only the Scopus database, although there was a decided minority of these (Mejía-Moncayo et al., 2023). Also selected were those studies in which the authors used completely different databases for their analyses, i.e. Science Direct and IEEE Xplore (Wong et al., 2022), or used a range of databases, i.e. Science Direct, Emerald, EBSCOhost, IEEE Xplore, Proquest, Springer, Taylor & Francis, Wiley Online, Scopus and JSTOR (Mageto, Luke, 2020). It should be noted that there were also research studies that did not identify the database on which the analysis was conducted (Bekrar et al., 2021; Kumar et al., 2022; Park, 2020).

This study analyzed the contents of bibliometric queries constructed by researchers in their papers. Such an exercise was aimed at identifying what research differences there are between the articles taken for the study and the presented article. As a result, it can be concluded that the study conducted is unique from those conducted so far. For some of the articles, it is impossible to verify the bibliometric query, as the researchers do not explicitly indicate them (Ahad et al., 2020; Bekrar et al., 2021; Cheshmberah, Beheshtikia, 2020; Remondino,

Zanin, 2022; Vincek et al., 2023). Some of the analyzed articles did not notice the words used by the authors of this study, i.e. blockchain, logistics, sustainability, in the bibliometric queries (Altarturi et al., 2023; Mageto, Luke, 2020; Sreenivasan et al., 2023).

There were also studies where bibliometric queries used only one of the words indicated in this article and referred to different issues. Sustainability appeared in conjunction with agricultural supply chain (Barbosa, 2021; Shen, Panichakarn, 2023) or Industry 4.0, 5.0, circular economy, manufacturing (Mejía-Moncayo et al., 2023). The word blockchain has been used to refer to the issue of tourism (Prados-Castillo et al., 2023) or agriculture (Liu et al., 2021). In contrast, the word logistic has been combined with digital twin, transportation, manufacturing, warehouse, among others (Lam et al., 2023).

Among the articles analyzed, one can also see a reference to blockchain and logistics issues, which are additionally combined with the word supply chain omitting the word sustainability (Rejeb et al., 2021). In the study, sustainability appeared in proposals for further research as an interesting research issue. There are also studies that refer to the issues of blockchain, logistics and sustainability at the same time, but do not focus only on these issues presenting a broader research focus. In addition, they address distributed ledger technology, supply chain, smart contracts, triple bottom line, green and clean in their bibliometric query (Ayan et al., 2022).

According to the analysis, the first articles on the issues identified in this article appeared in 2019, and they were 2 articles (Treiblmaier, 2019; Zagurskiy, Titova, 2019). As presented in Table 3, the most cited articles were those related to the supply chain and its sustainability. These studies mainly referred to barriers to the adoption of blockchain technology in supply chains in the context of their sustainability (Position 1., 2., 5.). They also addressed the use of blockchain in green logistics to improve environmental sustainability in e-commerce supply chains (position 4.). As the authors of this paper point out, blockchain has intangible benefits i.e. trust, transparency and openness of data, and allows to develop sustainability in e-commerce supply chain by increasing transparency, traceability, and security of supply chains and their financing. This could also represent a breakthrough in the development of sustainable economies. Among the most cited articles, there was also an article presenting the smart city concept in light of technical aspects taking into account blockchain (position 3.). It emphasized the need to develop sustainable smart cities in a way where sustainability is at the center of governance, policies, business, residents and all other actors in smart city systems. Here it is worth mentioning that among the opinions of researchers, blockchain has great potential in promoting the sustainable development of city logistics (Tian et al., 2021).

Table 3.*The five most frequently cited publications on the analysed issues*

Author and data	Position	Document Title – Cited by
10.1016/j.ijpe.2020.107831 (Kouhizadeh et al., 2021)	1.	Blockchain technology and the sustainable supply chain: Theoretically exploring adoption barriers - 659
10.1016/j.resconrec.2020.105064 (Esmailian et al., 2020)	2.	Blockchain for the future of sustainable supply chain management in Industry 4.0 - 470
10.1016/j.scs.2020.102301 (Ahad et al., 2020)	3.	Enabling technologies and sustainable smart cities - 338
10.3390/SU12103968 (Lahkani et al., 2020)	4.	Sustainable B2B E-commerce and blockchain-based supply chain finance - 109
10.1016/j.techsoc.2020.101427 (Sahebi et al., 2020)	5.	Expert oriented approach for analyzing the blockchain adoption barriers in humanitarian supply chain - 107

Source: Authors' elaboration based on Scopus database, 6 August 2024.

The author's keyword analysis allowed to see that Blockchain, as one of the technological solutions of Industry 4.0, plays an important role in the field of logistics, changing the previously adopted solutions in traditional logistics and in revolutionizing various aspects of the supply chain mainly from its functions (Vincek et al., 2023). Due to the complexity and lack of transparency of traditional supply chains, the introduction and development of blockchain has become a very interesting solution to streamline supply chain logistics processes and make them more sustainable (Yontar, 2023). Researchers indicate that it helps organizations overcome operational challenges by ensuring the security and authenticity of the information they use (Ada et al., 2021) within their operations. Companies as well as customers can benefit from multilateral data sharing and be informed about the causes of supply network disruptions, identify potentially unsafe suppliers, carriers and rogue customers, and respond quickly to changes (Yin, Ran, 2022). Changes in this case should be defined very broadly, meaning they are changes that occur in the company's external and internal environment.

The Internet of Things (IoT) is also within the scope of the research areas presented in Figure 2. The reference to this issue in the scope of ongoing research is justified because in order to achieve multilateral data exchange and real-time decision-making, Internet of Things technology is necessary (Tan et al., 2020). Accordingly, blockchain combining with IoT (Wu et al., 2021) provides an innovative solution for stakeholders (Altarturi et al., 2023) to store and proactively monitor various collected information along with business processes and provides opportunities to manage data generated by smart devices in a distributed and efficient manner (Alqarni et al., 2023). The conclusion that blockchain and the Internet of things are two promising and growing technologies that an increasing number of companies are using to achieve sustainability goals is also recognized (Kumar et al., 2023). At the same time, the approach is apparent that in order to achieve blockchain-based green logistics for sustainable development and sustainable logistics operations, it is necessary to take into account other Industry 4.0 technologies, as highlighted by some researchers (Tan et al., 2020).

By handling and storing large amounts of information about both products and supply chains, blockchain can help improve the main areas delineated in terms of sustainability. In the economic area, it can affect parameters such as reducing the cost and time of completed

transactions, in the environmental area by continuously tracking products it can help reduce rework and recalls, while in the social aspect it can strive for fair and safe labor practices (Ghadge et al., 2022). It is also recognized that in the environmental area, blockchain support can occur not only in terms of tracking products, but also their actual carbon footprint, and thus help determine the exact amount of carbon tax each company should pay. This solution can also streamline corporate performance reporting and provide opportunities for companies to monitor sustainability (Esmailian et al., 2020).

By analyzing the author's keywords selected in this study, it was possible to see that the problem of reverse logistics appears in the context of a research area such as logistics. Admittedly, the research problem related to reverse logistics is not visible in the bibliometric maps obtained in this study, but it is taken up by researchers in the analyzed articles. In them, the authors refer to the potential of blockchain in reverse logistics (Bekrar et al., 2021) as a solution to help realize green and sustainable logistics (Wu, 2022) at various stages of the reverse supply chain to maximize the recovery of materials from returned or waste products (Krstić et al., 2022) and to promote green behavior among consumers in particular related to recycling by encouraging participation in deposit-based recycling programs (Esmailian et al., 2020). However, too narrow a reference has been made to the issue of end-consumer responsibility in product disposal, which is already an area of research among numerous researchers (Skurpel, Wodnicka, 2023; Wodnicka, Skurpel, 2021). In this context, the role and importance of blockchain technology should be stated in future research.

Nevertheless, it should be noted that with the development of blockchain, the main problem of blockchain sustainability is its energy consumption. The high computing power required for important proof-of-work consensus systems consumes many megawatts of energy, which translates into higher environmental carbon emissions (Kouhizadeh et al., 2021). This aspect, according to the authors of this study, is quite important from the perspective of sustainable development, and not noticeable in the bibliometric map obtained (Figure 2). Therefore, they point to green blockchain as directions for further research. Undoubtedly, these issues are important directions of scientific consideration of blockchain in logistics in the context of sustainable development. Given the currently noticeable focus of research in the green direction, it would furthermore be advisable to direct future research around blockchain issues also to green issues already noticed in scientific research related to logistics issues such as greenwashing (Wodnicka, 2023), or green supply chain (Kozar et al., 2023).

4. Conclusion

The study carried out in this article proves that the stated research goal of identifying the main research areas undertaken by researchers in the issue of blockchain in logistics in the

context of sustainable development has been achieved. Nine research areas most frequently addressed in research articles were identified.

A limiting factor for the present study is the choice of database, which was limited to the Scopus database. Nonetheless, as the analyses in this article have shown, this procedure was justified due to the fact that the few studies indicated were exclusively on the Scopus database itself. In addition, the research conducted is unique due to the Q1 bibliometric query, which, as the analyses showed, differs from previous studies. The design of the bibliometric query in this article allows for expert planning of future research to replicate this research in the future. This will make it possible to check the results or verify new research areas. According to the authors, the article can inspire other researchers, logistics students and business practitioners interested in blockchain, logistics and sustainability.

Undoubtedly, research targeting blockchain in logistics is being undertaken by researchers in the field of sustainability. Nevertheless, it should be noted that it is discussed more often in the context of its implementation in supply chains to more efficiently manage them and the information and data they hold. The issues discussed relate to various issues such as, for example, the closed loop economy (Esmailian et al., 2020), the automotive industry (Ghadge et al., 2022), the agri-food market (Yadav et al., 2021), e-commerce (Altarturi et al., 2023; Lahkani et al., 2020), pallet management (Wu et al., 2021), smart city (Ahad et al., 2020), green logistics (Tan et al., 2020), construction (Xu et al., 2023).

Blockchain, in addition to the positive aspects it has (e.g. decentralized structure, inter-process integrity, efficient and fast, because in real time, exchange of information, risk management, inter-process integrity, high security measures, systematic data management and its immutability, anonymity, fewer errors and delays) also has weaknesses, which researchers include, among others, high energy consumption (Yontar, 2023). In this context, an interesting direction for future research and scientific consideration of blockchain in logistics in the context of sustainable development becomes green blockchain. This is undoubtedly a research gap that needs to be addressed to investigate whether blockchain can have green features and what important differences it has.

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