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Review

Beyond the Bitcoin Hype: A Structured Study of Blockchain's Impact and Potential in Today's Digital World

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Abstract: The development and application of blockchain-based technologies have been overshadowed by the performance of cryptocurrencies and the belief that these are all that this technology has to offer. This idea has led to the question on numerous occasions if this technology is just expectations or if there are indeed applications that solve problems in today's world. This bibliometric study on the current state of blockchain applications in the context of digital transformation seeks to break down the myth that this technology is just expectations, synthesizing and ordering the wide variety of topics that arise from this relationship. The results showed that the development of blockchain in the context of digital transformation is growing at an exponential rate, and with this, its applications have come to cover a large part of the industries, interact with other technologies, and establish objectives of all kinds. Based on these topics of technologies, industries, operational objectives, and strategic objectives, a structure is proposed that will serve as a guide for the development of new solutions to some problems, research, applications, and integrations with other technologies.

Keywords: blockchain; digital transformation; bibliometrics; Industry 4.0

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1. Introduction

"Blockchain technology has long been associated with cryptocurrencies such as Bitcoin, but there is so much more that it has to offer, particularly in how public and private organisations secure, share and use data,"—Steve Davies, Global Leader, PwC UK [1].

The development of blockchain technology was initially aimed at cryptocurrency-based monetary systems, leading to extremely high expectations and countless adherents [2]. This is not surprising as many have enriched themselves through the Bitcoin market and the crypto market activity has grown steadily. This monetary commitment sustains such high expectations and leads many to claim blockchain as one of the most-disruptive technologies with capabilities to genuinely transform the world [3]. However, the reality shows that there are some issues with blockchain technology, which has given rise to a discussion of whether it is solely rooted in expectations rather than promoting benefits and transformation. This has led to a division among scholars, with one group advocating in favor of blockchain's potential [3] and the other more skeptical, placing doubts on its benefits [4].

The persisting controversy is problematic, as it leads to confusion and low construct clarity, giving rise to the question of whether blockchain can bring augmented value or is merely blended with Bitcoin and its ups and downs [5]. Current financial figures offer support to the optimistic views. The global blockchain technology market is valued at USD 10.02 million with an expected annual growth rate of 87.7% until 2030, of which the

financial market segment accounts for 37%. Cryptocurrencies represent only a portion of this financial market segment [6]. Thus, value stems mainly from other sources than cryptocurrencies. Despite the above, blockchain continues to be confused with cryptocurrencies or Bitcoin specifically. This problem has been captured in some surveys, showing that 2 out of 3 people in the U.S. believe that blockchain is the same as cryptocurrencies and 1 out of 2 believe it is the same as Bitcoin [7]. This situation shows that there is even more ignorance on the subject, confirming that the hype around Bitcoin has overshadowed the whole picture about blockchain. Meanwhile, other research shows that business decision-makers still struggle to grasp blockchain's potential applications, often failing to embed the technology into innovation and value-added activities [8]. This context reveals that there is a lack of understanding of blockchain, in general [9], as well as in the academic and organizational spheres, with a greater concern for the latter as the implementer of these systems.

We agree with [7,10] that, given the exponential growth of blockchain and its presence in more and more industries, organizational leaders, entire industries, and regulators must gain a better understanding of the technology's promising applications and its potential for digital transformation. Likewise, we agree with [9] that, when reviewing the current literature on the subject, we find that most of the articles on this technology are of a technical and descriptive nature. Thus, some work of this nature shows the benefits of blockchain, such as real-time, transparent information exchange through shared systems in port and maritime transport [11], unified systems for education to overcome territorial limitations [12], the basis for business model innovation in the pension industry [13], and the redesign of entire supply chain networks, improving transparency, reducing waste, and protecting against unethical information manipulation [11,14,15]. Without exception, blockchain's applications come together with other technologies such as the cloud, the Internet of Things (IoT), and artificial intelligence (AI) [16–18]. These aspects, combined with the persisting confusion and controversy, are ingredients that emphasize the complexity surrounding the application of blockchain and the plurality in the relationship with other digital transformation technologies.

Against this background, the literature has promoted several reviews and bibliometric analyses. The studies are, nevertheless, of a specific nature, focusing on a specific industry, such as education [19], or on a specific field, such as management and business [20] and supply chains [21]. Only one study attempted to provide a holistic literature review, but included only a few studies in its sample because many studies were not available at the time, failing to find comprehensive clusters and order in the literature [10]. In general, existing reviews do not provide an orderly and clarifying structure on what topics are dealt with in the development of blockchain in the context of digital transformation, thus aligning with the existing controversy and supporting the existence of chaos and disorder in the body of knowledge.

To cover this gap, the goal of this study was to clarify the current status of the application of blockchain technology in the context of digital transformation by showing its impact in today's world. In doing so, we highlight how digital transformation gives significant purpose to the implementation of blockchain. In terms of this goal, we understand digital transformation as a process that involves the development of new business models that are unique to the firm or industry, which requires changes that involve the entire organization. This phenomenon goes beyond digitization and is not just about implementing technology, but about giving it a strategic purpose that allows, for example, achieving barrier-free interaction between all participants in a supply chain. We intend to change the prevailing perception of this technology and dispel the recurring confusion that links it to cryptocurrencies. We achieved this through an analysis that considered the evolution of the literature in this field and its current structure. We aimed to break down the latter into an understandable structure that accurately reflects the current state of research in the field. The ambition was not only to provide a necessary update to the existing analysis, but also to clearly connect blockchain and digital transformation. We considered this necessary because emerging technologies such as blockchain are not an end in themselves;

organizations are not interested in just acquiring them, but in perceiving the most benefits from them. In this sense, the current context or end of digital transformation gives purpose to the adoption of them. To this end, we conducted an in-depth bibliometric study, combining the R program bibliometrix with VOSviewer. We provide a temporal overview that helps identify which literature feeds this relationship, which are the most-relevant articles to date, what its structure is, as well as identify countries and leading journals in this field. Our findings show that blockchain in the context of the digital transformation literature can be organized into four clusters: technologies, industries, operational objectives, and strategic objectives. These findings offer valuable insights into the advancement of blockchain within the digital transformation context and its status. They elucidate the specific industries where blockchain technology is being applied, its integration with other technologies, the operational objectives it pursues, and the organizational goals that drive its implementation. Additionally, the article provides some of the challenges that exist in the digital transformation and discusses how blockchain is contributing to this process and what new issues its implementation is generating.

This paper is organized as follows. Section 2 details the methodology used to obtain the bibliometric results. Section 3 presents the results obtained. Section 4 analyzes the results from a theoretical point of view, and finally, Section 5 discusses the practical implications of the results obtained.

2. Materials and Methods

A bibliometric analysis was conducted to recreate a performance analysis and science mapping to help us identify the structure of the literature, its most-significant contributions, and its development over time. The latter sought to provide a review of the past, present, and future of the relationship between blockchain and digital transformation. This was achieved by carrying out a co-citation analysis, a bibliographic coupling, and a co-word analysis. With this purpose, the following four stages proposed by Donthu et al. [22] were followed.

2.1. Aims and Scope Definition

The first step is the definition of the objectives and the scope of the bibliometric analysis, which are related to the retrospective performance and structure of a research field and the volume it possesses [22]. For this purpose, objectives were defined considering the three general questions that bibliometrics can answer [23]. The main objectives defined are the recognition of the past (intellectual base), present (literature structure), and future (conceptual structure dynamics) of this relationship. Additionally, it seeks to name the most-relevant articles, journals, and countries in the literature and see what can be concluded.

2.2. Techniques for Bibliometric Analysis

In the second step, the bibliometric techniques necessary to achieve the proposed objectives were chosen. As a result of this process, we decided to initially conduct a performance analysis of the documents to be analyzed, which considered their main information and the most-relevant articles, countries, and journals. Subsequently, a science mapping analysis was carried out, which included co-citation analysis, bibliographic coupling, and co-word analysis. The co-citation analysis helped us identify the intellectual base of the literature, allowing us to recognize its beginnings [22]. The bibliographic coupling gave us the articles with the most-significant impact. Finally, the co-word analysis was carried out to identify the formation of clusters and the dynamics of their topics [23].

2.3. Data Collection

For the third step, the topics of blockchain and digital transformation were searched in all Web of Science database fields, using the following search "Blockchain" AND "Digital transformation" with no exclusion criteria. By the latter, we mean that there is no definition of dates, authors, journals, or any other exclusion parameter. As the relationship between

these terms is recent, only 192 publications were found between 2018 and 2022. Since this study covered all aspects of this relationship, all publications were downloaded in bib format to be processed in bibliometrix and plain text format for use in VOSviewer. Regarding the data collected, all the publications' fields were chosen to carry out a complete analysis.

2.4. Bibliometric Analysis and Report of the Findings

For the analysis of the extracted data, bibliometrix and VOSviewer were used. With the first one, the primary information about the documents was obtained, as well as a specification about its annual growth, the identification of the most-productive countries and journals, and the recognition of the most-relevant articles. With the second one, the co-word and co-citation network visualizations were obtained, along with overlay and density visualizations for the first one.

3. Results

3.1. Performance Analysis

The establishment and development of the relationship between blockchain and digital transformation in the scientific literature are recent, having an average age of 1.84 years. As can be seen in Table 1, 192 documents published on the Web of Science between 2019 and 2022 were found, coming from 121 different sources. The publications consisted mostly of scientific articles (154 publications), followed by reviews (33 publications) and a smaller number of editorial materials (5 publications).

Table 1. Summary of publications on blockchain and digital transformation.

Description	Value
Timespan	2018–2022
Sources	121
Documents	192
Articles	154
Reviews	33
Editorial material	5
Authors	675
Authors of single-authored docs	18
Annual growth rate %	102.55
Document average age	1.84
Average citations per doc	13.11
References	12853

The production over the years, as shown in Table 2, presents an upward trend, with more than half of the documents published in 2022 (101). The remaining papers were published in the previous four years, with 43 articles in 2021, 31 in 2020, 11 in 2019, and just 6 in 2018. A comprehensive review of scientific output in this research field indicates an annual growth rate of 103 %.

Table 2. Number of articles over the years.

Year	Articles
2022	101
2021	43
2020	31
2019	11
2018	6

In Table 3, in an examination of scientific production, considering the country of origin of the documents included in the bibliometric analysis, a substantial presence of Chinese authors (23 articles) can be observed. The following four positions, occupied by

Italy (13 articles), Germany, Spain, and the United States, have almost an equal number of authors (12 articles). Additionally, Figure 1 shows a map of the total results of scientific production by country considering the corresponding authors

Table 3. Scientific production by country of origin.

Country	Corresponding Authors
China	23
Italy	13
Germany	12
Spain	12
USA	12
United Kingdom	9
Romania	8
Saudi Arabia	8
Australia	7

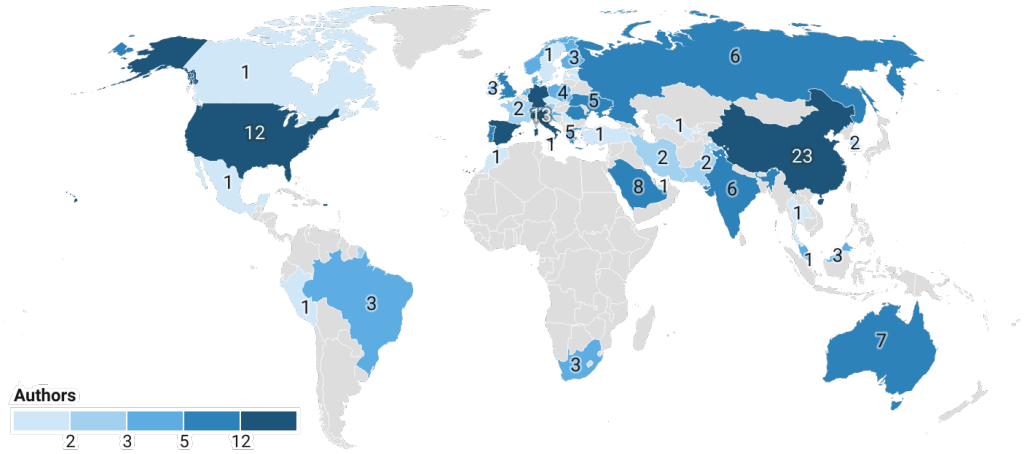

Figure 1. Countries' scientific production of blockchain and digital transformation articles.

A search was conducted to find the countries with the most-significant impact, that is with the highest number of citations of their produced articles (Table 4). From this search, it is possible to highlight the significant impact of the U.K. articles, with 973 total citations. It is also worth mentioning the presence of two other European countries, Italy with 202 citations and Germany with 165. The participation of Australia representing Oceania had 176 citations and, finally, Brazil with 112 citations, as a leader in the Americas.

Table 4. Countries with the highest number of citations of produced articles.

Country	Total Citations
United Kingdom	973
Italy	202
Australia	176
Germany	165
Brazil	112

Additionally, a citation map was created (Figure 2) to compare the scientific production around the world with the impact of the articles produced, that is with the most number of citations. Table 4 shows that, although the United Kingdom was not among the top five countries in terms of the corresponding authors, it had the highest number of citations with 973. Italy, Australia, Germany, and Brazil trailed behind with 202, 176, 165, and 112 citations, respectively. It is also possible to observe that China was not among the five

countries with the most citations, nor was the USA or Spain, three countries that are in the top five of the corresponding authors.

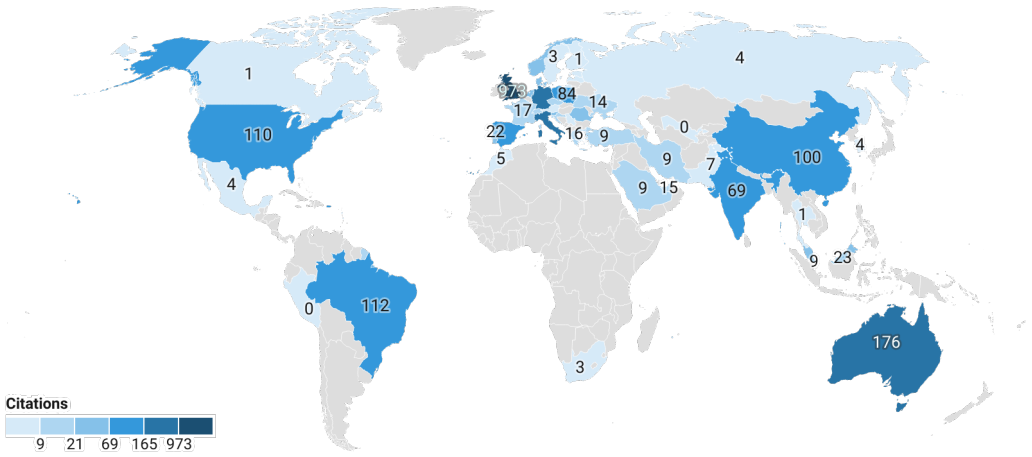

Figure 2. Countries' scientific impact of blockchain and digital transformation articles.

The 10 sources with the most publications on the implementation of blockchain technologies in the context of digital transformation are presented in Table 5. The *Sustainability* journal ranks first with 19 publications, followed by *IEEE Access* with 8, *Sensors* and *Technological Forecasting and Social Change* with 7, and *Applied Sciences-Basel* with 4, and the remaining sources presented only had 3 articles.

Table 5. Sources with the largest number of publications.

Sources	Articles
Sustainability	19
IEEE Access	8
Sensors	7
Technological Forecasting and Social Change	7
Applied Sciences-Basel	4
Automation in Construction	3
Energies	3
Financial and Credit Activity-Problems of Theory and Practice	3
Future Internet	3
International Journal of Computer Science and Network Security	3

Finally, to give an idea of the scientific production of the journals over time, a visualization of annual occurrence was obtained (Figure 3). From this, a trend of increasing scientific production can be observed in the top five journals in this field. In addition, the growth of the *Sustainability* journal is highlighted in comparison with the others and the recent growth experienced by the *Applied Sciences-Basel* journal in recent times.

3.2. Knowledge Base (Co-Citation Analysis)

In this section, a co-citation analysis (Figure 4) was conducted to uncover the knowledge base and intellectual structure of the relationship between blockchain and digital transformation, which shows its beginning. The analysis revealed that the development of this relationship originated from a knowledge base composed of six clusters, which compromise the terms: digital transformation, Industry 4.0, supply chain, emerging technologies, and blockchain and the relationships between some of them.

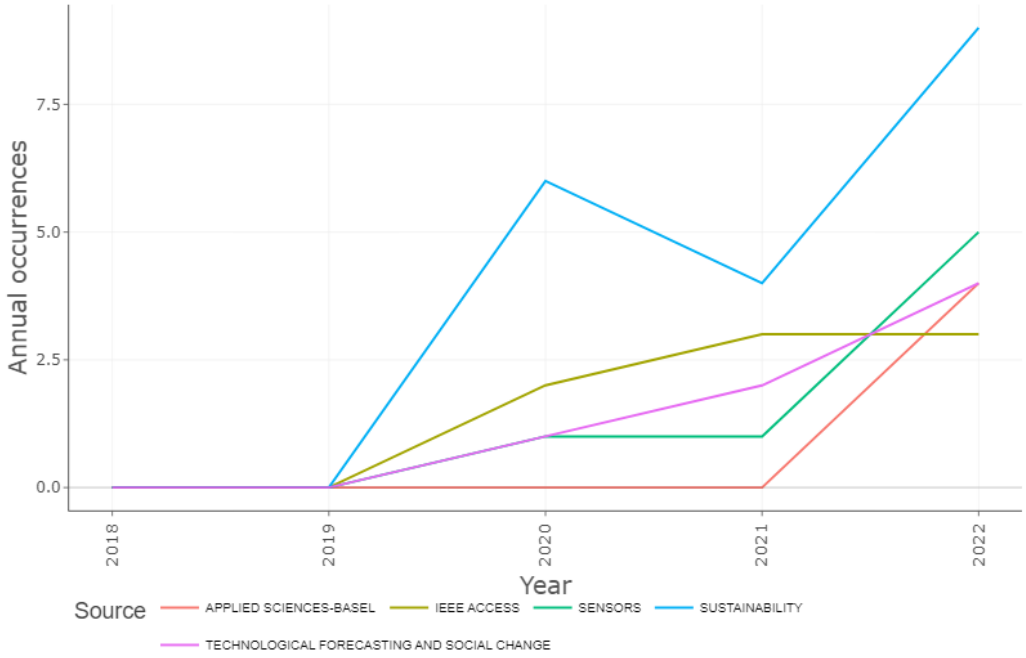

Figure 3. Scientific production of journals.

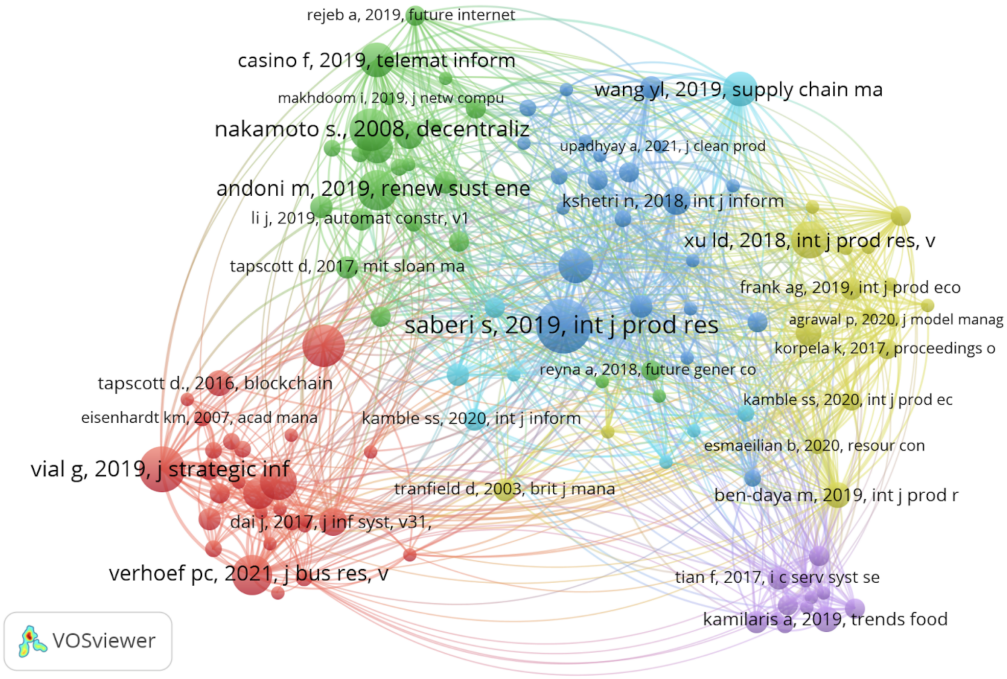

Figure 4. Co-citation visualization.

Three clusters are directly related to the implementation of blockchain technologies: the green, blue, and light blue clusters. The first of these clusters consists of works that explore the application and impact of blockchain technology in business. This cluster also includes the article of Nakamoto [24], which introduced Bitcoin as an electronic cash system based on blockchain. The blue and light-blue clusters contain literature aimed at addressing the adoption of blockchain-based technologies and their contributions to supply chain management, including their potential for sustainable development.

Two of the clusters—the yellow and purple clusters—focus on emerging technologies and Industry 4.0 as their main topics. The yellow cluster addresses the application of

emerging technologies associated with the development of Industry 4.0 to improve supply chain management, specifically in areas such as manufacturing and logistics. Furthermore, the articles that belong to this cluster aim to describe the roles, impacts, and opportunities that the implementation of technologies, such as IoT, blockchain, and big data, among others, could entail, and propose an agenda for future research. The purple cluster comprises papers that focus on the innovation and disruption that Industry 4.0 technologies can provide to the food sector. Specifically, these papers address various issues, such as safety, traceability, reliability, and sustainability. Additionally, they investigate the potential of these technologies to address the challenges currently facing the industry and the need for further research to understand their implementation better.

Finally, the red cluster mainly contains articles on digital transformation that aim to improve the understanding of the nature of this transformation [25–27]. Some of these studies also aim to develop a strategy for its development [26,27]. In addition, this cluster has documents that discuss the possible uses of blockchain technologies [28]. Finally, there is a paper present that discusses the construction of theoretical knowledge from case studies [29].

3.3. Most-Relevant Articles (Bibliographic Coupling and Literature Review)

To land the bibliometric analysis provided, a bibliographic coupling (Figure 5) with a review of the most-relevant articles (Table 6) was conducted, highlighting the contributions that they communicate on the relationship between blockchain and digital transformation. Subsequently, a comparison was carried out, analyzing the similarities and differences of the topics discussed in the articles to be able to conclude why these publications have such an impact.

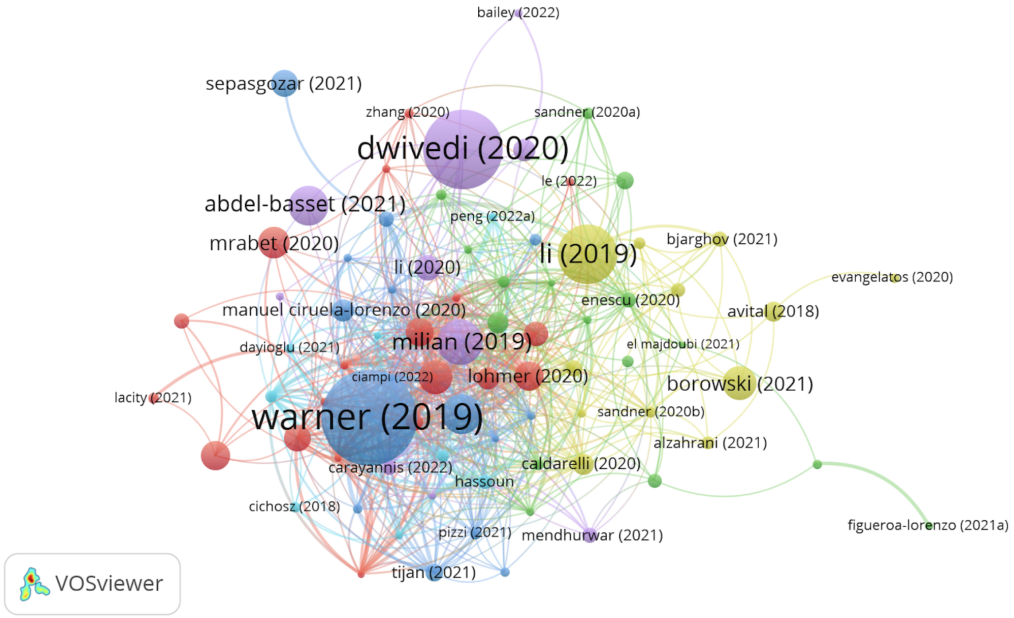

Figure 5. Bibliographic coupling visualization.

As can be seen in the bibliographic coupling visualization in Figure 5, it is not possible to identify the formation of clusters; in the same way, the review of the articles did not allow the establishment of a clear relationship either. However, the impact of some articles stands out, which coincides with being the most-cited (Table 6). A review of these will be carried out below, highlighting the meetings and contributions that they communicate on the relationship between blockchain and digital transformation.

Table 6. Most-cited articles.

Title	Authors	Total Citations
Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal	WARNER KSR, 2019 [30]	368
Impact of COVID-19 pandemic on information management research and practice: Transforming education, work, and life	DWIVEDI YK, 2020 [31]	267
Blockchain in the built environment and construction industry: A systematic review, conceptual models, and practical use cases	LI J, 2020 [32]	163
Fintechs: A literature review and research agenda	MILIAN EZ, 2019 [33]	109
An intelligent framework using disruptive technologies for COVID-19 analysis	ABDEL-BASSET M, 2021 [34]	87

The first article, by the author Warner [30], investigates how firms in traditional industries develop dynamic capabilities for digital transformation. Understanding this as a process that allows the creation of new business models, the improvement of the customer experience, and the optimization of processes. The barrier found for this is that the term digital transformation is commonly used with different meanings and its research does not have the relevance it should as part of the organizational strategy of today's businesses. In addition, the importance of building dynamic capabilities for digital transformation is highlighted, which, unlike operational capabilities, allows firms to adapt to external changes and the rapid development of emerging technologies such as blockchain. Taking this objective into account, the author proposes a process model that identifies triggers, internal and external enablers, and barriers in the construction of dynamic capacities. Additionally, it was found that emerging technologies, including blockchain, are transforming the nature of dynamic capabilities. This allows firms to enhance their operations at a previously unattainable speed. Finally, the finding is also made that more and more organizations are considering the implementation of digital technologies.

The second article, by Dwivedi [31], brings together the perspectives of different professionals on the impact that the COVID-19 pandemic had on information systems research and the transformation that different organizations have experienced. In this context, technologies such as blockchain have been fundamental in this adaptation process, automating the verification of transactions and the development of contracts, which makes it difficult for bottlenecks to form. As in the previous article, the idea that digital transformation allows organizations to create capacities and not remain vulnerable to environmental factors is reinforced. However, it is also necessary to test these technologies due to the concerns that may exist about them; in the case of blockchain, it is its security.

The third article, by Li [35], develops blockchain advances in the context of its implementation in the construction industry and its impact on the development of the digital transformation of this industry, categorizing it as one of those responsible. In addition, it proposes a list of relevant challenges and opportunities that blockchain has in this industry.

The fourth article, by Milian [33], reviews the literature on the development of fintechs. In this context, blockchain appears as an innovative and recurring technology that has allowed the development of new fintechs in the context of digital transformation. In this group, the development that Bitcoin and cryptocurrencies in general have had stands out, being one of the most-researched topics. Once again, the security of this type of system appears as a concern in its development, as well as the loss of control that it could cause to other institutions considering its decentralized nature.

The fifth article, by Abdel-Basset [34], proposes a framework, considering the importance of emerging technologies, also called disruptive, to prevent the spread of COVID-19. This supports the need for this type of technology for the development of Industry 4.0 and its versatility in various industries. In this context, the importance of blockchain-based technologies for the standardization of systems is emphasized.

3.4. Conceptual Structure (Co-Word Analysis)

To identify the relationship between the topics and the formation of clusters, a network visualization was constructed (Figure 6), in which five clusters were identified. The yellow contains almost all the emerging technologies that, together with those based on blockchain, are driving the development of digital transformation and Industry 4.0. It also shows some terms related to applications in information protection. The blue cluster presents the benefits of implementing blockchain technologies in the context of digital transformation as a result of improved management of the supply chain. The green one contains organizational goals that are closely related to digital transformation. The red cluster covers terms related to the implementation of technologies in business, with the financial industry as a leader, and the mention of topics such as performance, innovation, and dynamic capabilities. Finally, the purple one contains topics related to blockchain-based technologies and the beginning of their application in cryptocurrencies.

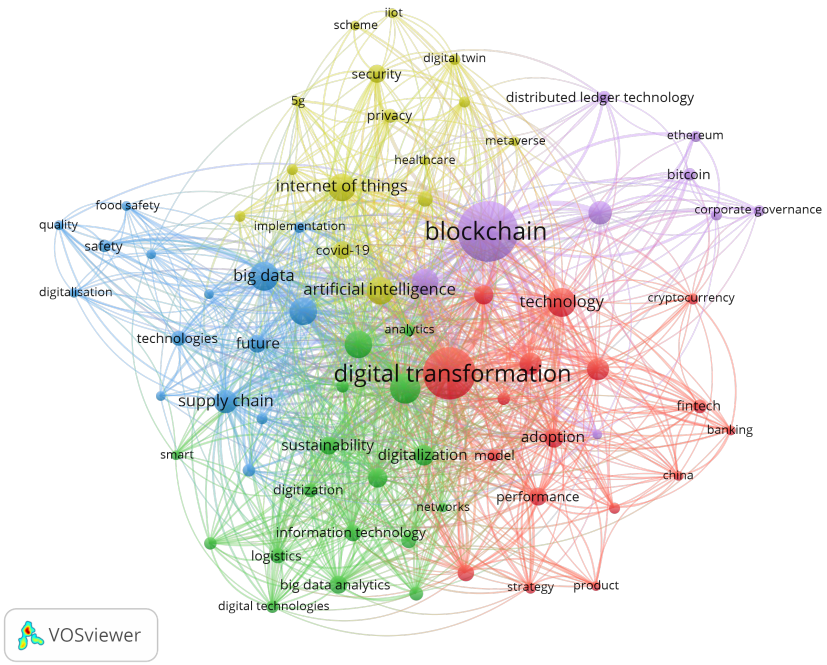

Figure 6. Co-word visualization.

The overlay visualization (Figure 7) confirmed that the application and development of blockchain technologies began with the creation of cryptocurrencies, whereas the relationship of blockchain with other technologies occurred later, with the exception that the association with big data was one of the most-recent. Finally, the most-recent terms are related to implementation, quality, and an emerging concept such as the metaverse. Taking into consideration the preceding results, it is possible to realize that the origin of blockchain applications, found in cryptocurrencies, is a topic that has not been further developed. This is compared to others in terms of the evolvement of blockchain technologies in the context of digital transformation.

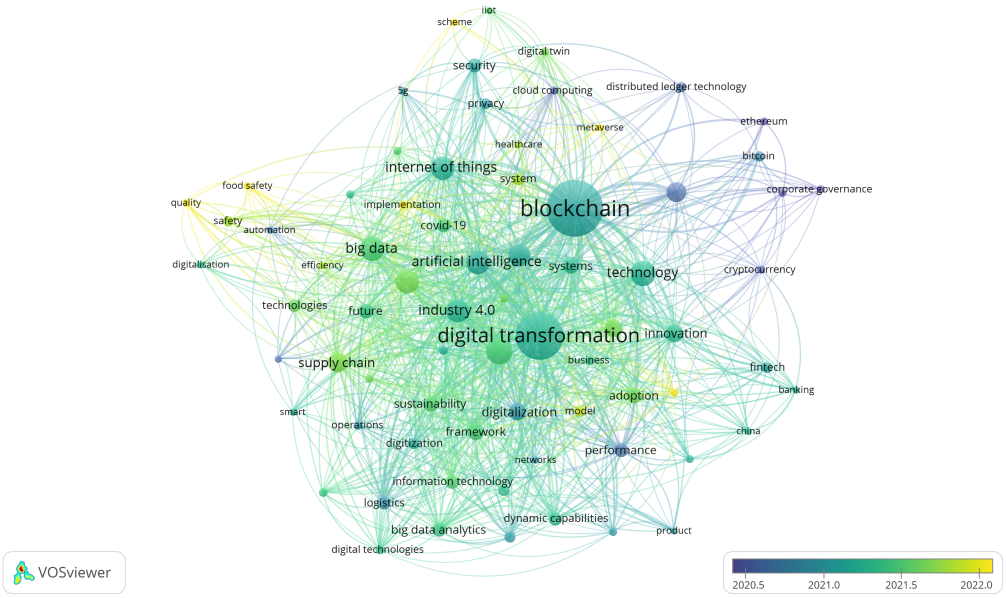

Figure 7. Overlay visualization.

Finally, in a density visualization (Figure 8), it is possible to realize that the most-treated concepts were those related to Industry 4.0, including it. Among the other terms with higher density were artificial intelligence, big data, the Internet of Things, and technology. Although this relationship was also appreciated in previous visualizations, it is now possible to notice that it occurs recurrently. In other words, when we talk about blockchain in the context of digital transformation, we consider the development of Industry 4.0 and the associated technologies and topics.

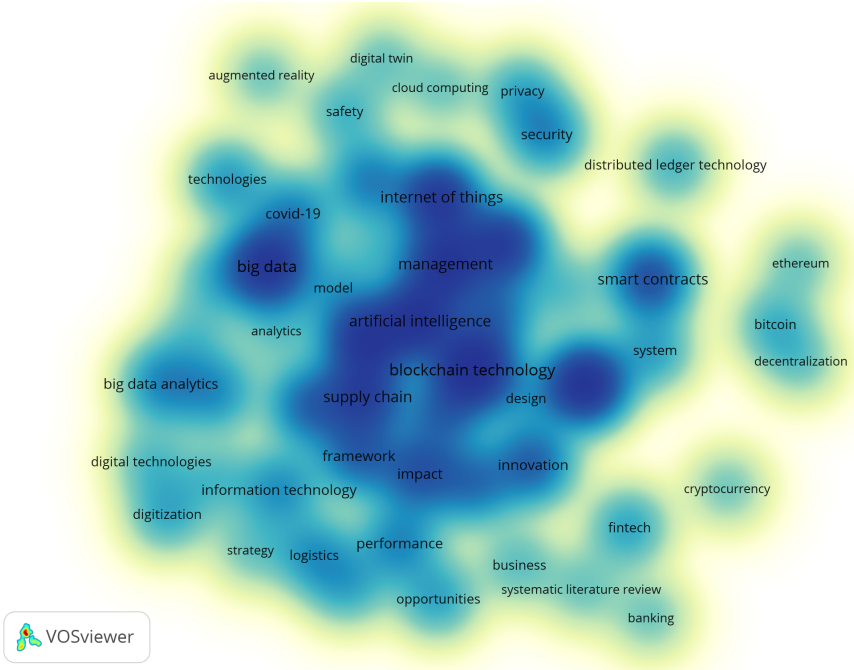

Figure 8. Density visualization.

4. Theoretical Implications

This study aimed to provide a temporal overview of how blockchain has developed in the context of digital transformation. It examined the foundational themes (past), current state (present), and emerging trends (future). The purpose of this study was to contribute to the development of the literature on this subject by identifying the topics that have

facilitated its initial development, the articles that have had the greatest impact, and future research directions. This is necessary considering that more and more industries are implementing blockchain-based technologies, seeking the generation of value, innovation, and the development of new business models. However, for this, it is necessary to recognize, structure, and give temporality to the topics treated in the literature.

In general terms, the recent emergence of the relationship between blockchain and digital transformation has been identified, reflected in a range of publications found between 2018 and 2022. This is even though the literature related to blockchain-based technologies began in 1991 with the solution proposed by Haber and Stornetta [36], which established reliable timestamps in documents. Subsequently, it was in 2008 that Nakamoto presented Bitcoin as a blockchain-based electronic payment system, which marked the beginning of the development of other cryptocurrency applications. However, it was not until 2018 that numerous applications within the context of digital transformation began to emerge, resulting in a growing body of literature on various applications across different industries. In this way, the development of digital transformation changed the course of the application of blockchain-based systems, opening up a great diversity of new possible applications in various industries. Despite the recentness of this change, the related literature presents a great annual growth of 103%. Such a magnitude of growth is a new precedent that reflects an increase in interest in the development of new blockchain technologies and their subsequent implementation at an academic level. This trend could not be captured by previous works, which did not consider the large increase in publications in 2022 [10]. In terms of scientific production by country of origin, there is a large participation of Chinese authors, whose works surprisingly have not generated the same impact. Considering this last aspect, it is the publications from the United Kingdom, followed by the ones from Italy, which, despite not being the majority, have generated a great impact according to the number of citations obtained.

4.1. Foundational Topics

As indicated in the Results Section, the foundational literature on the relationship between blockchain and digital transformation is divided into six clusters. However, these can be grouped into three major themes: implementation of blockchain technologies, Industry 4.0, and digital transformation. Consequently, the emerging literature on this topic is almost necessarily supported by articles that provide some experience on the implementation of blockchain-based systems in various application areas. The following two groups aim to contextualize and give guidelines on the context in which these applications are developed, this being that of Industry 4.0 and digital transformation. In terms of Industry 4.0, the contributions come from works that associate blockchain with other technologies such as the IoT, the cloud, and big data for the development of integrated systems that provide reliability, transparency, and traceability to the supply chain. Finally, in terms of digital transformation, the articles used mainly seek to provide definitions on the nature of this transformation [25–27]. This is essential considering that there are various perceptions about what digital transformation consists of [30], which has led to wrongly recognizing and evaluating this process.

4.2. Valuable Lessons and Findings in the Current Literature

As a result of a bibliographic coupling analysis that allowed us to identify the most-relevant articles in the development of the literature, relevant ideas were extracted that justify their impact. The first of these is the low degree of agreement regarding the meaning of digital transformation and the few efforts dedicated by organizations to make digital transformation part of their strategy, taking into account the relevance of this process [30]. Additionally, it is argued that emerging technologies, including blockchain, are changing the nature of dynamic capabilities [30]. Despite this, the need to test the security of these systems is also emphasized [31]. Finally, another prevalent idea is the impetus brought about by the COVID-19 pandemic in the development of technologies associated with

digital transformation, such as blockchain. This was a response to the change in lifestyle that we had to adopt. The discussion of these topics in the future could help to cover those problems that afflict the literature and researchers today. This allows the reduction of gaps in those topics that are generating a greater impact on the relationship between blockchain and digital transformation, accelerating the development of the literature.

4.3. Conceptual Structure

From the co-word analysis, it was possible to establish a distinction of five research lines within the relationship between blockchain and digital transformation: integration with other technologies, supply chain management, strategic objectives, implementation, and cryptocurrencies. Until now, this had not been possible, since even old papers investigating blockchain without a specific context had not been able to clearly distinguish the formation of clusters in the literature [37]. However, an additional structure of the literature is proposed (Figure 9) based on a rearrangement of these clusters that did not evaluate their treatment relationship in the literature, but their belonging to proposed categories. This was in order to define and group the existing relationships between the discovered topics. The construction of these relationships was made from the consideration of the discovered topics and their subsequent classification into one of the four recognized categories that encompass almost all of these. In this way, it is proposed that the terms developed in the literature related to blockchain development in the context of digital transformation belong to a structure with two axes of scope. The first aspect, vertical in nature, shapes the implementation progress. It begins with an initial emphasis on integrating blockchain with other technologies and industries where it has been developed, gradually extending to encompass objectives at both the operational and strategic levels. These objectives, in turn, entail the implications arising from the implementation of these systems. On the other hand, the horizontal axis orders the categories from a narrower scope with technologies and operational objectives to a larger scope with industries and objectives at a strategic level. In the following, each of these sections will be analyzed from the point of view of its position in the literature on blockchain and digital transformation.

In terms of the integration with other technologies, it can be extracted that the study of blockchain-based technologies in the context of digital transformation requires a bibliography related to both these and other emerging technologies. The latter includes artificial intelligence, cloud computing, the Internet of Things, big data, digital twins, 5G, augmented reality, and the metaverse. However, the current literature is not only fed by works that deal with the development of other technologies, but also develops research that integrates blockchain with other digital transformation technologies. A sample of this can be observed in the analysis of co-words. Due to the presence of these technologies and a review of the existing literature, it can be extracted that the creation of integrated systems using them has high potential concerning digital transformation [16–18]. Thus, it appears that research on blockchain research as a technology that enables digital transformation is inseparable from other technologies, either to increase its potential or due to the need for integration with existing systems.

With regard to operational objectives, it will be interesting to see in the future how a greater number of benefits are recognized and defined, which will be evaluated and confirmed in practice through the development of further research. The above work provides expectations and assurances about what can be expected from blockchain-based technologies in a specific context, as well as possible uncertainties to consider. Likewise, once these benefits are recognized, it is possible to move on to quantitative research that can provide some numerical reference for measuring these benefits offered by blockchain.

As for the strategic objectives, although the current literature has already studied and recognized a large part of them, until now, they have not been collected and linked as a whole to the development of blockchain in the context of digital transformation. This is essential and one of the concerns in the literature, the definition of the main objectives, as the main perceived benefit of the application of blockchain-based technologies. This

finding allows maximizing the potential of blockchain applications, but it also brings with it the difficulty of concretizing good management at all levels of an organization to achieve it.

Finally, considering the industries, it is interesting to note the ones that are the most frequently repeated. However, although blockchain applications started in the financial industry, they are currently being developed in other diverse areas. It will be interesting in the future to see how more and more industries join the use of blockchain and how its applications are used according to their needs.

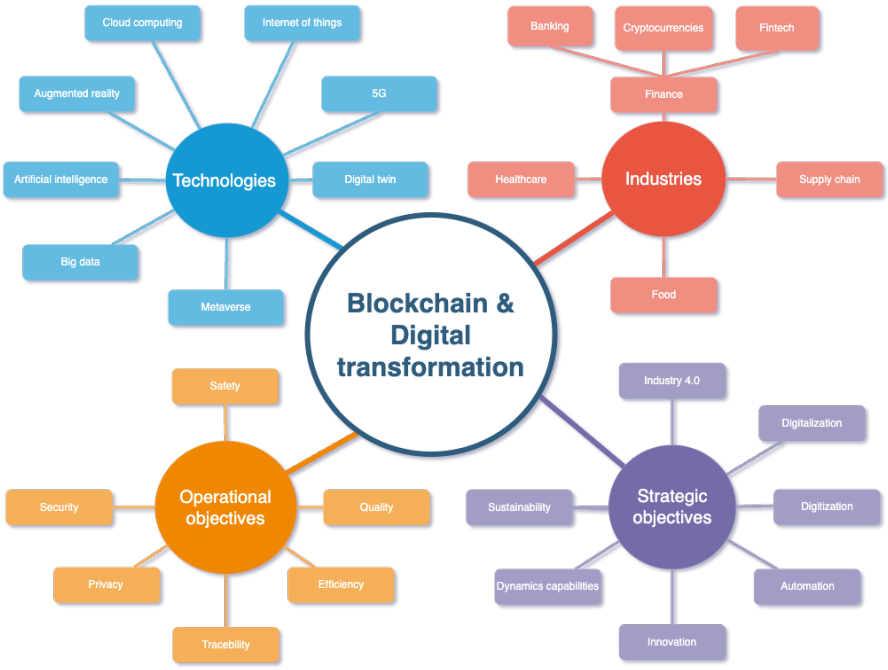

Figure 9. Structure of the blockchain literature in the context of digital transformation.

The structure of Figure 9 was used to carry out an analysis of the practical implications concerning the topics recognized, which are these operational objectives, strategic objectives, technologies, and industries. Subsequently, the challenges posed by digital transformation are recognized, and it was extracted from the literature how blockchain contributes to solving these challenges. Finally, the problems that arise as a result of the implementation of blockchain are presented, highlighting some approaches proposed by some works to solve them.

5. Practical Implications

This section aims to draw practical implications from the review of the articles related to the topics recognized from the structure of the proposed literature. In this way, an analysis was made of how blockchain is present in different industries, how it is achieving the recognized objectives, and how it is being integrated with other technologies.

5.1. Industries

This category is made up of blockchain applications in business together with the evaluation of their results from these in various industries, with the supply chain topic leading. Each of these industries/sectors are presented below:

- Supply chain:

Supply chain management represents a topic that feeds on and also constitutes a line of research in the relationship between blockchain and digital transformation. This is because blockchain features are highly compatible and have multiple benefits to overcome the challenges that supply chains have today. Among these is the need for integrated information systems with partners that improve the credibility and transparency of cargo

information [11,14]. Similarly, the implementation of blockchain in this context has potential for automation, monitoring, and security, among others [14]. In this way, this technology allows the secure storage of information, the transmission of information in real-time between the participants of a supply chain, and with this, a fluid communication that allows reaching consensus efficiently [14]. However, there are also some difficulties facing the digital transformation of these processes. Among these are the lack of the application of these systems, which makes it impossible to have a good understanding of how to manage them, and the lack of confidence of regulators and consumers in these systems [14]. Finally, it is essential to highlight that many of the challenges related to this topic became a concern once the COVID-19 pandemic arrived, this being the situation that prompted the study and implementation of blockchain in these activities.

- Finance:

As for the financial industry, it can be divided into banking, fintech, and cryptocurrency sectors. Although cryptocurrencies were initially essential for the development of blockchain, in the context of digital transformation, this topic is not one of the most-developed currently. This can be confirmed by comparing the publication dates of the topics, with those related to cryptocurrencies being the ones with the oldest average publication time. Meanwhile, the topics of banking and fintech arise as a result of the development of blockchain in the context of digital transformation, expanding the uses of this technology to an entire industry. In terms of applications, the financial industry is using this technology to replace existing systems. It is also making disruptive changes, in terms of the decentralization of control and power and the creation of new forms of property rights [11]. Despite this, in terms of digital transformation, this industry does not have a large presence.

- Healthcare:

The health industry is currently benefiting from the quality, efficiency, and cost reduction provided by the implementation of blockchain-based systems [38]. This is based on the creation of blockchain-based systems for electronic healthcare records, which allow the decentralization of information management by sharing it with all stakeholders, which is expected to improve health research and generally improve health services [38]. These systems provide controlled access to information, providing a secure environment that takes into account the patients' willingness to share their data. In this way, a secure repository of information is created, which can even give patients the possibility to remove access to their information from the service provider [39]. These service features are in line with the objectives of digital transformation, as they allow for the increased security, privacy, integrity, and confidentiality of healthcare organizations' information systems. However, it is an interesting point to consider that the possible private or public nature of healthcare organizations changes the dynamics of implementing blockchain-based systems for digital transformation and the outcomes it could have [40].

- Food:

On the other hand, the food industry sees this technology as an opportunity to, in the same way, achieve shared information systems with stakeholders that provide transparency and trust [41]. In this way, the safety and quality of the food can be ensured when it reaches the consumer, once it has gone through a large part of the stages of the supply chain [42]. On the other hand, there are more-ambitious goals in the digital transformation of this industry, such as achieving zero hunger by reducing food waste and leveraging the other benefits already mentioned [42]. However, these are not all the benefits, given the nature and quality dependence of the food industry on supply chain processes; it also benefits greatly from the value generated in the implementation of blockchain for these processes.

5.2. Operational Objectives

Within this category is included the mention of the operational objectives that are expected as a direct effect of the implementation of systems based on blockchain and that

are considered inherent to their technologies. Among these are safety, privacy, traceability, efficiency, quality, and security. These are benefits or objectives that have been supported by numerous works [43,44] and are repeated to the point of appearing within works as keywords. Other operational objectives include the elimination of information silos [16], the reduction of communication latency [14], and the automation of processes [45]. Most of the benefits mentioned above are the result of the characteristics of this technology and how it allows information to be stored and control over it to be decentralized. However, there are specific objectives that are pursued by some industries. For example, the petrochemical industry seeks to achieve savings and optimization of production by regulating production based on available price and demand information shared among industry participants [46]. However, we believe that this objective could be achieved by other industries. On the other hand, there are educational systems that plan to promote the generation of educational content through a global platform that pursues this purpose [12]. However, some aspects of these are continuously questioned in new research, due to the lack of the implementation and evaluation of results that exist [31].

5.3. Strategic Objectives

In the same way as other emerging technologies that are driving digital transformation, blockchain aims to achieve certain objectives at a strategic level. This is accompanied by changes at the organizational level necessary for the above [30]. These objectives correspond to the greatest benefit that can be perceived from the implementation of technologies, these being sustainable development [10], the acquisition of dynamic capabilities [15,35,47], the digitization of data, the digitalization of processes, the innovation in various aspects [16], and the incorporation into the Fourth Industrial Revolution. As for these, essential conclusions can be drawn. In terms of sustainability, blockchain allows the control of products through the supply chain and the emissions caused, the reduction of waste, and the communication to the customer about the good treatment of these [15]. In terms of dynamic capabilities, the capacity of blockchain and other technologies is highlighted, reducing the costs and difficulties of acquiring them compared to those acquired from non-digital resources [30]. For its part, digitization is not new; blockchain allows maintaining information systems and process automation through the development of smart contracts that can involve any stakeholder. Finally, in terms of innovation, blockchain is enabling this in its greatest form, by creating value with new business models, being able to change the way organizations carry out their processes [18].

5.4. Integration with Other Technologies

There are numerous testimonials in the literature, from different industries, on the need to integrate blockchain with other technologies. In the field of metrology, it is noted that, although blockchain offers certain benefits, incorporating IoT devices is crucial for ensuring reliable information reception and storage [48]. In the oil and gas industry, ensuring the veracity and accuracy of data in a blockchain-based system is dependent on the automation of the data-collection process, according to suggestions [16]. Similarly, for healthcare, the integration of data from multiple IoT devices necessitates the use of diverse resources to form an intelligent system for digital transformation [39]. Similar examples exist in the rice industry and its supply chain, where the focus is on enhancing the interaction between these two technologies to ensure barrier-free collaboration with stakeholders. Another significant discovery is that such systems can facilitate the digital transformation of the supply chain in any industry. In the digital economy, it has been asserted that blockchain plays a secondary role. Instead, the IoT and machine learning are identified as the leading technologies driving transformation [49]. In conclusion, several articles exploring the implementation of blockchain, AI, cloud computing, and data analytics validate the aforementioned benefits. These technologies each offer distinct advantages, but the greatest value can be achieved by utilizing them in combination [18].

Whatever the reason, the benefits of integrating multiple technologies that are driving the digital transformation process are undeniable. Focusing on the interaction of blockchain with other technologies, the latter is automating processes that other technologies cannot. Blockchain-based systems and, specifically, the use of smart contracts are replacing intermediaries, unlike, for example, artificial intelligence, which automates operational tasks. However, more than defining the superiority of one technology over another, the relevant discovery is that the improvements that these provide, according to their characteristics, fit better in certain processes. This idea is manifested in integration proposals among emerging technologies, wherein the IoT serves as a valuable data collector, blockchain acts as an information infrastructure and rule-setter, and artificial intelligence optimizes processes and constructs solutions [17]. In addition to these technologies, blockchain is being integrated with other newer technologies like the metaverse. It will be worth seeing new interactions that emerge in the future and the construction of integrated systems that make use of multiple technologies converge.

5.5. Challenges and Possible Solutions

The development of digital transformation in recent years has driven innovation and even disruption in various industries [26,50]. The context of this transformation, coupled with the lessons learned from the COVID-19 pandemic, has raised new concerns in organizations. One of these concerns is the vulnerability of our operations and the information systems that support them, highlighting the need for a resilient, secure, and reliable supply chain to meet our daily needs [51]. With the emergence of these new issues has come the application of new technologies to address these challenges. Now, in a post-pandemic era, the development and application of new digital technologies have resulted in significant changes in organizations [52]. This context has led to an increase in the value of products and services offered by different industries as a result of the ability to innovate and restructure the business models that these technologies possess [16]. Thus, the status quo of organizations has changed, as they are now under increasing pressure to innovate, reduce costs, meet customer expectations, and increase the value delivered to customers to remain competitive. Based on these challenges, we used the articles in the bibliometric analysis to see how blockchain can help overcome these existing challenges in the context of digital transformation. As a result, we obtained the following Table 7, which seeks to answer how blockchain technologies are addressing the aforementioned challenges of digital transformation in various industries.

Table 7. Challenges for organizations in the context of digital transformation and the contribution of blockchain to overcome them.

Challenges of Digital Transformation	Blockchain Contribution
Innovation [10,25]	Blockchain disruptively changes how organizations offer their products or services to achieve customer satisfaction. This is through innovation in their business strategies by taking advantage of the reliability and security of the information stored in these systems and the possibility of sharing it [53]. In the field of information commons, blockchain-based technologies allow innovation in the governance of this type of good by protecting it from the free-rider problem. This makes it possible to make business models with these characteristics sustainable [54].

Table 7. *Cont.*

Challenges of Digital Transformation	Blockchain Contribution
Automation [25,26]	In the metrology industry, the use of smart contracts allows the automation of decision-making. This is through the verification of parameters that do not require intermediaries, but only the prior consensus of the participants [48]. In the pension industry, the use of smart contracts automates the processes required for the delivery of benefits once they are requested. The execution of this process in an optimal and error-free manner allows for an increase in business revenue and customer pension [13]. In the tourism industry, blockchain enables the automation of a series of processes in both hotel and airline companies. This includes the processes of identity verification, ticket purchase from a set of offers from which the most-convenient one is chosen, and reimbursement. However, the characteristics of this technology allow the programming of various other operations in other industries that facilitate the processes of the organizations [45].
Information management [25,26]	In healthcare, blockchain provides a secure environment for the creation of EHR systems by storing reliable and tamper-proof information. In addition, the use of smart contracts can give the possibility to make the patients' access to their healthcare information revocable [39]. In the petrochemical industry, blockchain is an ideal technology to establish a shared system with stakeholders that allows the sharing of information and the execution of monetary transactions. This system would allow transactions to be carried out with real-time information on the price of raw materials, additives, and packaging related to production [46]. In the rice supply chain, blockchain enables traceability and monitoring of products based on reliable information. It also enables seamless communication between the participants in the chain, leading to efficient consensus. It should be noted that other industries could also benefit from these features of this technology [14].
Value creation [25,55]	By creating shared systems that are secure, reliable, and transparent, blockchain creates value by increasing the efficiency of processes involving multiple stakeholders. In this way, working with information with these characteristics allows avoiding fraud. In addition, it facilitates the achievement of proposed objectives, cost reduction, the development of shared services, and better overall management [55]. By creating a blockchain-based network, the oil and gas industry can generate more value by adjusting plant performance depending on product prices and the perceived profit from it. In addition, this network would allow the tracking of any kind of information related to production such as quantity, sales, value, etc. In this way, these systems can act as a global master optimizer to achieve an efficient, integrated, and robust industry [46].

As seen in the table above, blockchain has the potential to address some of the challenges that digital transformation has brought to organizations. These include the need to innovate, automate processes, manage large amounts of information, and create value. These challenges have emerged as a result of the change in expectations that digital transformation has brought to the way organizations run their processes and deliver their services. This context has led to increased existential risk for some organizations in certain industries, where the adoption of new technologies is becoming necessary to remain competitive. However, it is essential to remember that the use of technology is not the only requirement for digital transformation. Its implementation must be accompanied by a clear strategy, as well as organizational, structural, and cultural changes [30]. This is why the need for disruption has forced traditional centralized organizations to restructure, giving rise to

decentralized organizations that are still evolving and maturing [3,56,57]. Thus, it is clear that both the acquisition of blockchain-based technologies and the efforts to make the most of them require a great amount of effort. From the review of some articles in the literature, it was possible to extract some problems that arise in the implementation of blockchain. Among these are the investment and maintenance costs, the consensus among stakeholders necessary for the operation of these systems, the still undefined legal regulations, and the lack of knowledge about this technology. Table 8 below provides a brief description of these problems and some of the solutions that have been proposed to address them.

Table 8. Blockchain implementation issues and possible solutions.

Issue	Description	Solution
Costs [3,45,58–60]	There is a large investment and maintenance cost related to the human and technological capital required for blockchain implementation.	New blockchain architectures are being developed in search of achieving the development of decentralized systems with lower operational costs by storing metadata, which avoids needing an entire blockchain to carry out verifications [61].
Legal regulations [3,45,59,60]	There are no legal framework and standards regulating the use of blockchain.	The lack of legal regulation is not something that organizations can address. However, it is expected that the rapid growth of blockchain will require regulatory frameworks to change and adapt to these types of technologies in the coming years [3]. Other authors recommend including people with legal expertise to assess the legal feasibility of developing or implementing blockchain-based systems [62].
Consensus and trust [3,14,45,58,59]	The implementation of a blockchain-based system that enables communication and execution of smart contracts across a network of stakeholders requires stakeholder consensus and trust for its success, which is difficult to achieve.	It is believed that the root cause of this issue is the immaturity of the technology and the excessive hype surrounding Bitcoin [58]. Over time and as people gain more experience using this technology and generate more knowledge about it, it is expected that more-realistic expectations and greater trust will be built around it. Other perspectives claim that, while the provision of knowledge about the operation and purpose of blockchain is necessary to generate greater confidence in blockchain, the effectiveness of the methodology in which this knowledge is delivered is equally important [63]. Another aspect that helps generate greater trust in blockchain is the support of institutions that people already trust, so a good perception of an institution can increase trust in this technology [63].
Lack of knowledge [14,45,46,59]	Due to the lack of knowledge of this technology, still immature in its implementation, there is a lack of awareness and acceptance of it in the personnel in charge of operating these systems in their routine.	From a technical point of view, it is necessary to train existing personnel or hire specialized experts to take full advantage of this technology and prevent the lack of knowledge from leading to poor acceptance of the technology [11].

From the above results, it is possible to conclude that the application of blockchain, while seeking to solve some current problems of organizations in this digital world, opens the way to the resolution of new challenges. In addition, it is possible to observe that, in its great majority, the resolution of these requires its development and implementation over time and the generation of new knowledge that these generate. Particular emphasis is

placed on education for this technology, which could be considered of great help for the partial development of solutions to most of these problems. In this way, the generation of knowledge is not enough, but an effective delivery of this knowledge both to technical personnel who interact with this technology and to decision-makers who must decide on its implementation. Finally, it is essential to emphasize that the adoption of blockchain should be evaluated taking into account both its benefits and its challenges. Regarding the benefits, we recommend not falling into the hype generated by the development of Bitcoin and other cryptocurrencies, which can create unrealistic expectations about the results of blockchain. On the challenges side, we recommend a careful evaluation of this type of technology, given the existing legal uncertainty, the investment risks involved, and the additional effort required to integrate this technology into an organization's culture.

6. Conclusions

To clarify the current status of the application of blockchain technology in the context of digital transformation, an in-depth bibliometric study of the existing literature so far was carried out. The objective of this was to clarify the confusion that exists around blockchain, trying to make the process of digital transformation provide purpose to a technology that carries several confusions. To this end, multiple analyses were carried out to showcase various perspectives in the literature to establish its origin, temporality, and structure. Based on these, the results showed the following.

Regarding the origin, the literature is mainly fed by cases of blockchain application in various industries, which are given purpose and context based on articles on digital transformation and Industry 4.0. This is fundamental, given that the lack of knowledge about these contexts that surround us today can lead either to not taking advantage of the full potential of emerging technologies such as blockchain or to misrecognizing their purpose. In this sense, we believe it is fundamental to provide a clear theoretical framework in application case studies to give purpose and context to the implementation of technologies so that they are not just seen as digital assets.

Reviewing the development of the literature, we were able to realize that, despite the recent emerging relationship between blockchain and digital transformation, the surrounding literature is growing at a rate of 103%, suggesting interest. This quantification is important because, while it is claimed that there is a growing interest in the relationship, we had no numerical reference on this. Another general appreciation is that the context of digital transformation has changed the course of blockchain applications and even its purpose. The academic production around cryptocurrencies is positioned at the beginning of this relationship; however, the current generation of knowledge is more interested in the application of blockchain-based systems in various industries. In addition, it is also exploring how these applications can pursue major objectives such as sustainability, the creation of dynamic capabilities, or business model innovation.

From the bibliometric analysis, a clear structure of the literature on blockchain and digital transformation is provided. The generation of this structure considers the repetition of the visualized keywords and the ordering of these from the understanding of the literature that involves them. In this way, it is possible to recognize that there are four subgroups of topics that represent the main concerns in the field. These are industries, integration with other technologies, strategic objectives, and operational objectives. From these and the literature review, it is possible to draw several conclusions. First, blockchain applications starting in cryptocurrencies have come to encompass numerous industries, including supply chain logistics, healthcare, financial, and food processes. Thus, it is important to keep track of the next applications where this technology can be leveraged, and that could mean solving new challenges. Secondly, the integration of blockchain with other technologies is fundamental in the context of digital transformation, either because of the need for integration or to take advantage of the maximum potential of this technology. In this sense, it is essential to recognize that, depending on the industry and process to be digitized, it could be the most-appropriate technology or not. Similarly, it may be sufficient

on its own, or it may require interaction with other emerging technologies. Thirdly, it is necessary to emphasize that, among the benefits of blockchain such as safety, privacy, traceability, efficiency, quality, and security, despite being recurrently mentioned, the quantified expression of these benefits in the articles is almost nonexistent. Thus, it would be interesting to measure these benefits and compare them with the performance of existing systems to quantify the results of blockchain implementation. Finally, it is essential not to forget what is on top ofthe implementation of technologies such as blockchain. This is sustainable development, the acquisition of dynamic capabilities, the digitization of data, the digitization of processes, innovation in various aspects, and the incorporation into the Fourth Industrial Revolution. These objectives correspond to the greatest benefit that can be perceived from the implementation of blockchain-based technologies, so it is essential to consider them to assess their impact.

It would be interesting for future research to delve deeper into the nature and results of blockchain's interaction with other technologies to identify its applicability and compatibility with certain system configurations. Another intriguing aspect to investigate is the generalization of the applicability of systems that are replicated in varied industries. The realization of this approach could be possible considering that the contribution of blockchain is mainly based on its benefits for the support of information systems, present in all organizations. Finally, it could be a great contribution to quantify the results that the implementation of blockchain-based systems has had in terms of effectiveness, improvement against current systems, evaluation, investment benefit, etc.

On a practitioner level, decision-makers must understand the interaction of blockchain with other technologies, either to consider its integration into existing systems or to evaluate the implementation of blockchain systems that interact with the Internet of Things, artificial intelligence, the cloud, and others. In addition, it is necessary to be aware of the purpose of implementing a technology such as blockchain. Beyond its contribution to digital transformation in innovation, automation, information management, and value creation in organizations, several challenges need to be addressed in its implementation. These include the high cost of investment, implementation, and training, the lack of clear legal regulation, the lack of consensus and trust in the technology, and finally, the lack of knowledge. On the one hand, the lack of the recognition of the benefits of this technology can complicate the full exploitation of its application; among others, we highlight the boost that blockchain can provide in terms of acquiring dynamic capabilities, improving in terms of sustainability and processes before digital transformation, such as digitalization and digitization. For a better understanding of how blockchain contributes to these objectives, we highlight the need to focus not only on the generation of knowledge, but also on seeking effective methods of its emission, either to technical staff or decision-makers. This as a remedy to the lack of knowledge and trust in this technology, which can sabotage attempts to take advantage of its benefits. In conclusion, the development of blockchain in different industries, in the integration with other technologies and with the need to resolve some difficulties, makes the decision of its implementation a non-trivial problem. Likewise, it confirms that its use with the objective of digital transformation requires several aspects more than just its acquisition, but that it requires integration with existing systems, organizational culture, and the legal and social context in which the organization is located.

As a limitation of the study, it is important to mention that the number of articles to which the bibliometric techniques were applied is not optimal in this type of study. However, given the recent emergence of the relationship between blockchain and digital transformation, there is not a greater volume of articles. Nevertheless, these techniques were used in this study to obtain a structure of the literature that was analyzed from the review of the articles involved in it. Future work will be able to apply these techniques to a more-robust literature that will allow visualization of the changes that have occurred over time in this field of study.

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