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PAPER

Revolutionizing Manufacturing with Blockchain Technology: Opportunities and Challenges

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ABSTRACT

A decentralised, tamper-proof ledger offered by blockchain technology has the potential to revolutionise the manufacturing sector by enhancing digital rights management, supply chain management, and product monitoring and tracking. Industrial supply chains may be made more transparent, secure, and efficient with the use of blockchain technology. This will save costs, boost quality control, and raise consumer confidence that the goods they buy are genuine and high calibre. However, there is a research gap in the implications of blockchain technology in the manufacturing sector. The aim of this research was to investigate the challenges and opportunities of blockchain technologies in the manufacturing sector. In order to accomplish the study's goal, a two-stage systematic literature review technique was used, with the PRISMA framework being used to gather pertinent data from reliable sources like Scopus. The study contained 117 research papers, which were analysed using descriptive and scientometric methods and lysis to synthesise the literature and investigate important research clusters using the centrality and co-occurrence of keywords. The study's conclusions point to the potential of blockchain technology to support decentralised manufacturing systems that provide risk-free and trustworthy cooperation among multiple stakeholders. The report also discusses the advantages and drawbacks of using blockchain in manufacturing and offers information on recent developments in the field of digital manufacturing that are related to blockchain technology. This study emphasises the value of blockchain technology for the industrial sector and the need for more research to fully understand its potential. Blockchain technology may help the manufacturing industry become more effective, transparent, and quality assured while also reducing costs and fostering better confidence among supply chain actors.

KEYWORDS

blockchain technologies, manufacturing, supply chain management, RStudio, PRISMA, digital technologies

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1 INTRODUCTION

Blockchain technology is gaining traction as a potential answer to some of the industrial industry's problems [1]. Blockchain can alter the sector in various ways, including improved supply-chain management, product monitoring and tracking, and digital rights management [2]. According to [3], it is worth noting that blockchain technology has the potential to improve several aspects of production, including inventory management, quality control, and intellectual property protection. Blockchain can help maintain the validity and transparency of data throughout the manufacturing process by providing a decentralised, tamper-proof ledger [4]. In addition, the benefits are improved data security, lower transaction costs, and more confidence and transparency among supply chain participants [5]. They contend that blockchain technology might assist manufacturers in overcoming some of the long-standing issues connected with supply chain management, such as a lack of transparency and collaboration [6]. According to [7], blockchain technology can also be used in digital manufacturing. It may be used, for example, to securely store and exchange manufacturing data across a distributed network of stakeholders. Blockchain technology is notable because it removes transaction intermediaries, potentially resulting in a more efficient and cost-effective flow of products and services [8].

Furthermore, once recorded, the data is permanently connected to the previous block and cannot be changed or altered in the future [9]. Non-permissioned blockchains enable anybody to read and write transactions in a decentralised forum, whereas permissioned blockchains allow only selected users to view and write transactions within a closed network [10]. This fundamental distinction impacts the incentives and functions of customers inside the system. The supply chain is a dynamic system comprising several firms that work together to add value to products, from raw materials to finished goods, thereby meeting client demands [11]. In addition, each supply chain participant may track the status of items, shipments, and deliveries and the success of each supply chain activity [12]. They can also efficiently track product quality throughout shipping [13]. As a result, deploying a blockchain-based supply chain decreases effort while improving traceability, efficiency, and quality assurance, resulting in cost savings and greater trust that items are authentic and of high quality [14]. Also, the conventional supply chain was primarily concerned with the location and delivery time of the physical product [14]. But increasingly, the supply chain also manages bundled data, services, and goods solutions [15]. Although blockchain technology cannot answer all supply chain concerns, it can efficiently handle various data-related issues in industrial supply chains [16]. The obstacles include needing product traceability methods, identifying counterfeit or grey-market items, boosting product visibility, and decreasing paperwork and administrative issues across the product life cycle [17].

However, there is a considerable study deficit concerning the consequences of blockchain technology in the manufacturing sector [18]. While prior research has investigated the implications of blockchain technology in fields such as digital currency and healthcare [19], [20], there still needs to be a need to look into the possible uses of blockchain in manufacturing. Recent research has shown that blockchain has the potential to improve transparency, security, and efficiency in industrial supply chains [21], [22]. Furthermore, blockchain can help create decentralised manufacturing systems that allow for safe and trustless collaboration among various stakeholders [23]. By studying the possibilities of blockchain technology in the manufacturing business, this study intends to address a research gap. This research will precisely map current advances in the digital manufacturing environment connected to blockchain technology, offering insights into the potential and problems of deploying blockchain in manufacturing.

2 MATERIALS AND METHODS

In this study, a two-stage systematic literature review methodology was employed. The first stage involved utilizing the preferred reporting items for systematic reviews and meta-analyses (PRISMA) framework to extract relevant records. Descriptive and scientometric analyses were then conducted to assess the reliability and validity of the extracted records. Additionally, the R package was employed to investigate the key clusters of research through the use of centrality and co-occurrence of keywords. In the second stage, content analysis was conducted on the extracted records in each cluster to synthesize the literature. The current study encompasses literature from reputable databases, including Scopus, and a comprehensive search strategy was implemented to access relevant literature. The search strategy involved using the keywords “digital manufacturing” and “"blockchain,” resulting in the retrieval of 225 documents. The document search was limited to research articles to refine the search, resulting in 122 research articles after removing duplicates and irrelevant articles. Ultimately, 117 research articles were included in the systematic literature review, as illustrated in Figure 1.

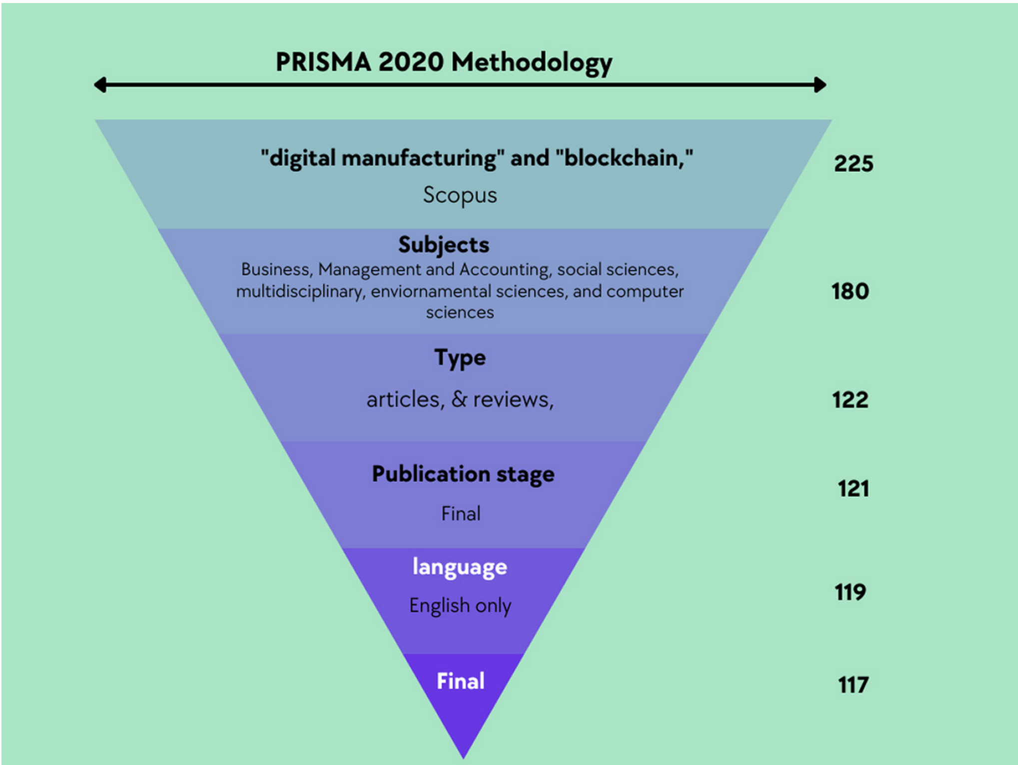

Fig. 1. Preferred reporting items for systematic reviews and meta-analyses (PRISMA) 2020

To follow the methodology suggested by Page et al. (2021), we utilized the PRISMA framework for initial record screening, as illustrated in Figure 1. We also conducted a comprehensive content analysis of the selected articles to classify them based on keyword frequency and co-occurrence, using R software to generate research clusters. The documents were scrutinized multiple times to avoid duplication, and irrelevant studies were eliminated to achieve the desired results.

After the screening process, only 117 articles were deemed relevant for exploring the implications of blockchain technology in manufacturing. These records were imported into Microsoft Excel for detailed analysis. The R package was used to extract preliminary results, as shown in Table 1, to gain insight into the literature included in this systematic review.

Table 1. General information about records extracted

Description	Results
MAIN INFORMATION ABOUT THE DATA	
Timespan	2019–2023
Sources (Journals, Books, etc)	82
Documents	137
Annual Growth Rate %	23.59
Document Average Age	1.55
Average citations per doc	28.26
References	11,312
DOCUMENT CONTENTS	
Keywords Plus (ID)	984
Author's Keywords (DE)	487
AUTHORS	
Authors	507
Authors of single-authored docs	10
AUTHORS COLLABORATION	
Single-authored docs	11
Co-authors per doc	3.94
International co-authorships %	43.07
DOCUMENT TYPES	
Articles	117
Reviews	20

3 RESULTS

3.1 Descriptive and scientometric analysis of records

The time period, sources, number of documents, yearly growth rate, average document age, average number of citations per document, and total number of references are all listed in Table 1. With an annual growth rate of 23.59%, the study examined 137 documents from 82 sources (journals, books, etc.) that were published between 2019 and 2023. The documents had an average age of 1.55 years and an average of 28.26 citations per document. The texts were written by 507 different people and had a total of 984 Keywords Plus (ID) and 487 Author's Keywords (DE). Of them, 10 were documents with a single author and 11, or 43.07 percent of all co-authorships, were documents with international authors. Many of the document types examined were articles(117) and reviews (20).

In addition, the citation metrics for the top 10 articles on blockchain technology in manufacturing are displayed in Figure 2. The title of the work and its overall number of citations are listed in the first column. The last column displays the normalised citation score, which considers the average citation rate for papers in its field and publication year. The third column displays the average number of citations each year since its publication.

With a total of 712 citations and a normalised citation score of 142.4, the most-cited work is "Blockchain-based distributed manufacturing: A case study of 3D printing" by Ivanov et al., published in the *International Journal of Production Research* in 2019.

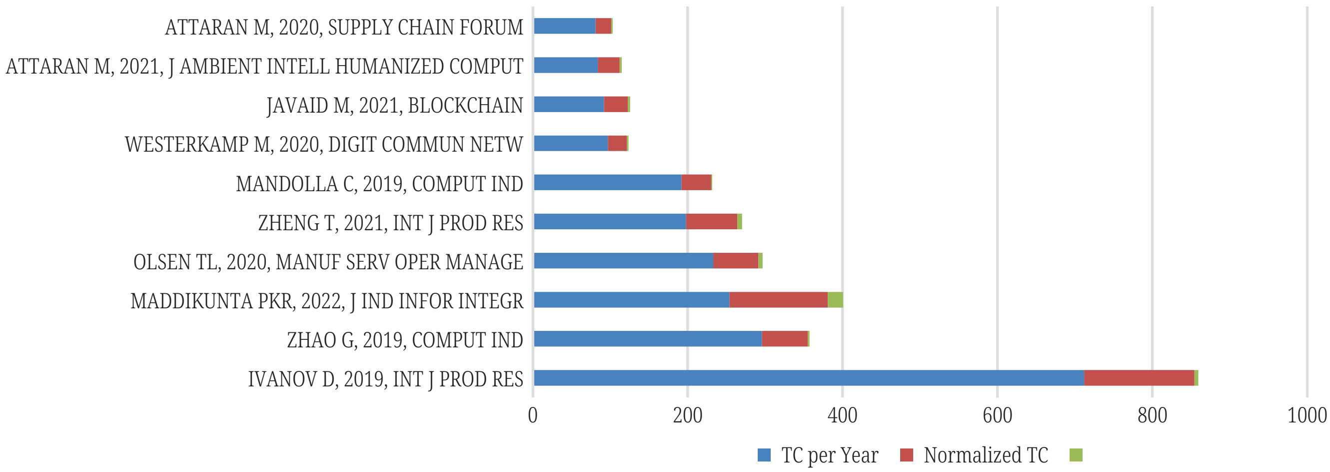

Fig. 2. Most-cited articles

This table provides a ranking of journals based on their frequency of occurrence in a particular zone. The table comprises columns indicating the source title or journal name (SO), the ranking of the journal based on its frequency of occurrence (Rank), the number of times the journal appeared in the list (Freq), the cumulative frequency of the journal in the list up to that point (cumFreq), and the zone in which the journal falls (Zone). The zone classification system is used to categorize journals based on their impact factor, with Zone 1 encompassing the most prestigious and high-impact journals and Zone 4 comprising lower-impact journals. The table shows that *IEEE Access* and the *International Journal of Production Research* are the top two journals on this list, both located in Zone 1. The table also displays the frequency of appearance for each journal on the list, with *IEEE Access* appearing the most frequently, at 8 times.

In the current systematic literature review, which has no time constraints, we considered all studies that satisfied the quality standards. You can better understand the development of the field's research by being aware of the number of publications each year. Figure 3 displays the literary output by year from 2019 through 2023. Most publications were published in 2022.

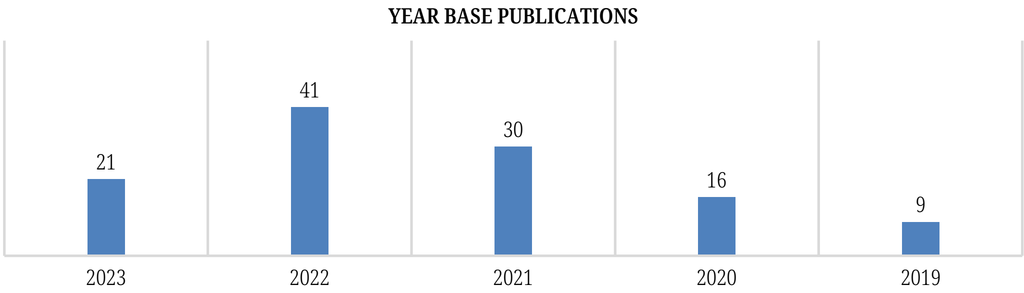

Fig. 3. Number of articles published by year (2019–2023)

Furthermore, the number of publications relating to the study's topic that have been published in various journals or other sources is shown in this table. The source title and the number of articles published in each source are displayed in Figure 4. As an illustration, *IEEE Access* includes eight papers, and the *International Journal of Production Research* has eight articles as well. Both are the sources with the most content. A variety of materials, including scientific journals, books on computer standards and interfaces, and books on sustainability, are included in Figure 4.

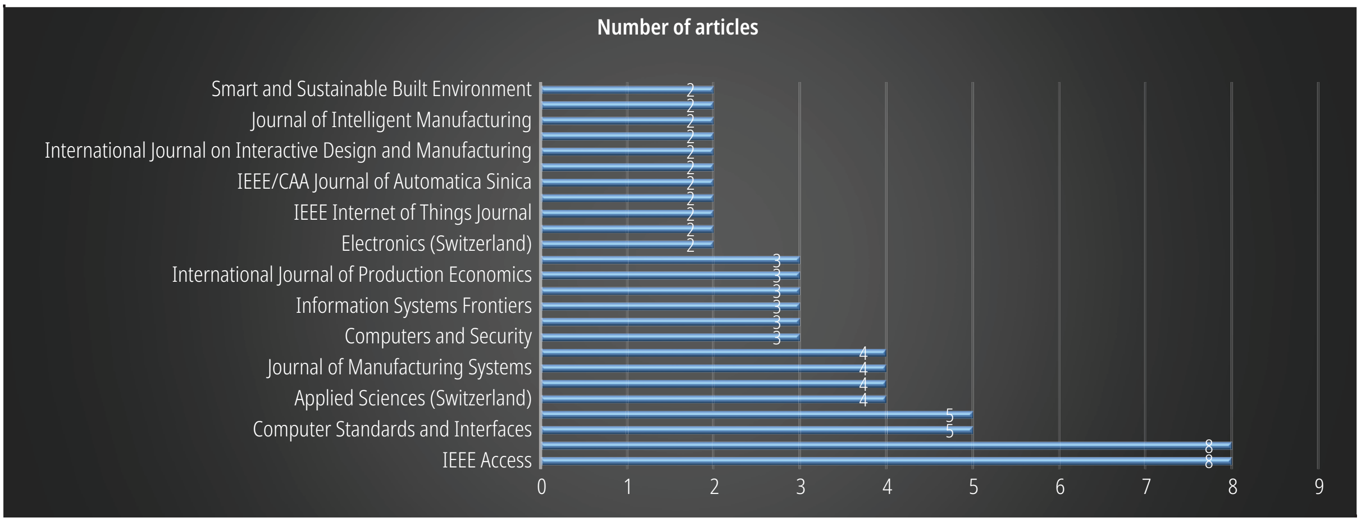

Fig. 4. Most frequent sources

In addition, globally this table shows the sources with the most locally cited articles. The sources are listed in the first column, and the number of local citations for the most cited articles from each source is listed in the second column. "Locally cited" means that the citations were made within the same database or search platform where the original articles were found.

Figure 5 indicates that the source with the most locally cited articles is *IEEE ACCESS*, with a total of 305 citations. The second most cited source is the *International Journal of Production Research*, with 254 citations, followed by *Int J Prod Res*, with 118 citations. Other sources with a significant number of locally cited articles include *Sustainability*, *IEEE Internet of Things Journal*, *International Journal of Production Economics*, *Procedia CIRP*, *Journal of Manufacturing Systems*, and *Journal of Clean Production*.

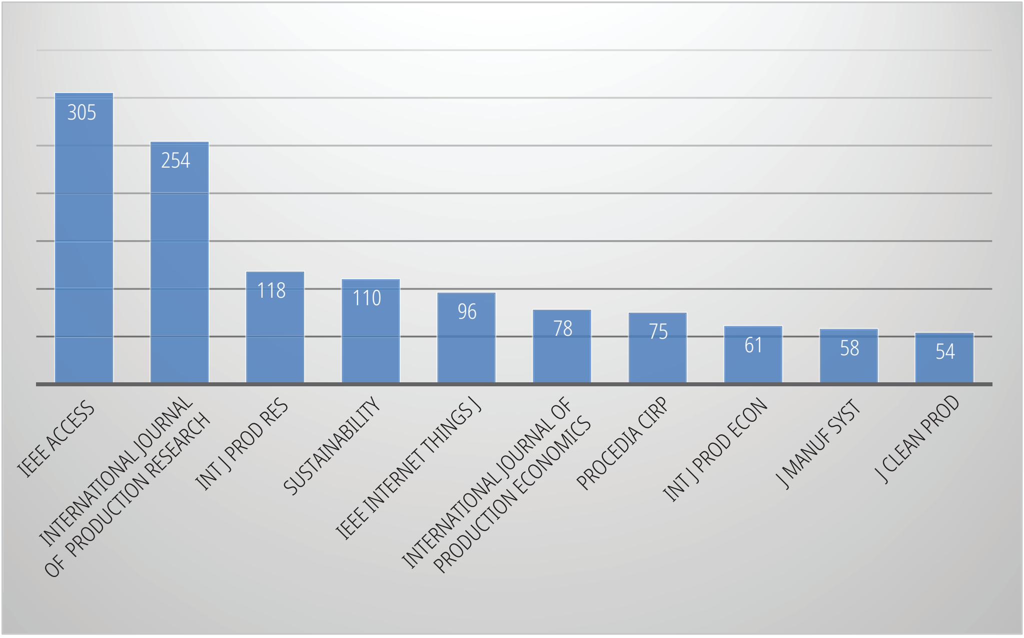

Fig. 5. Most frequently cited articles by source

4 LITERATURE CLUSTERING

To understand the evolution of the themes in the literature, the author's keywords were used to generate the thematic maps. Figure 6 shows a cluster map based on the author's keywords. We used text processing and the mapping tool in the bibliophily program, using the R package to generate themes. Some settings were used to preserve the readability of the maps and provide helpful information. For example, there were 200 words, a minimum of 5 clusters per word, and 2 labels per cluster, and all other variables were set to the defaults.

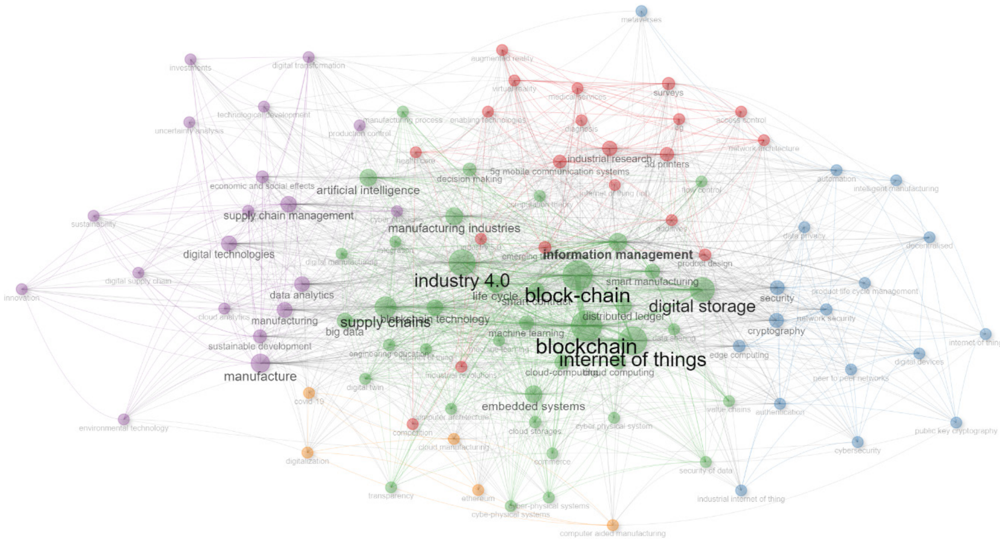

Fig. 6. Cluster map

Using the two criteria of *density* and *centrality*, which are relevant to all study topics, a set of keywords can be seen as a succinct description of a specific research theme [24]. Density determines how closely related all keywords are, while centrality determines how closely related one topic is to another [25]. The density and prominence of the issues determine the division into four sections of a thematic map, also known as a strategic diagram. Several aspects are present in each of the four quadrants, as seen in Figure 7.

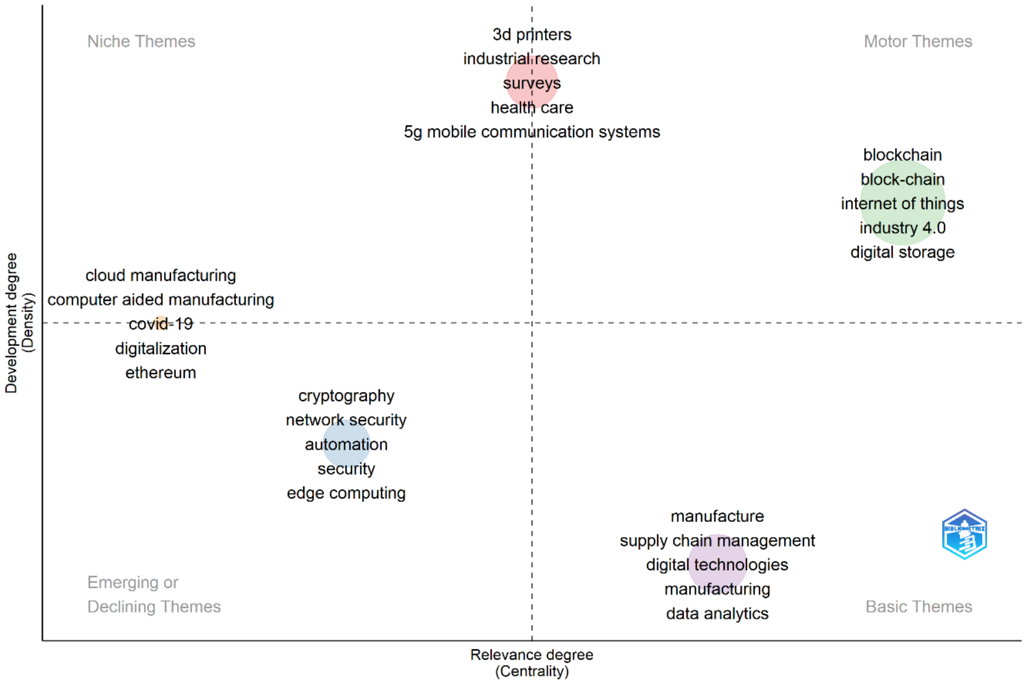

Fig. 7. Thematic map

Figure 7 highlights the thematic evolution of the literature based on the keywords. For example, the theme of "cloud manufacturing" In the Niche Theme quadrant has low centrality (0.48) but a higher density (50.66), as displayed in Table 2.

Table 2. Thematic evolution

Cluster	Callon Centrality	Callon Density	Rank Centrality	Rank Density	Cluster Frequency
3d printers	3.503829365	51.66597222	3	5	99
cryptography	3.05811319	41.94977158	2	2	81
blockchain	12.05615439	51.11070547	5	4	456
manufacturing	4.532579472	37.00519901	4	1	136
cloud manufacturing	0.484444444	50.66666667	1	3	17

Table 2 indicates whether a theme is emerging or declining due to increasing of decreasing incidence in the literature.

Table 3 highlights the key terms used in the theme and occurrence, centrality, and rank of each key term. There are 6 instances of "edge computing" in the data, and its strong betweenness centrality score of 54.32 indicates that it connects other terms in the network. Since it has a closeness centrality score of 0.005, it is close to other words in the network. Its PageRank centrality score of 0.008 indicates that, while it is significant, it is not as significant as other terms in the network.

The term "cryptography," appears eight times and performs well on all three criteria, so it is a key term in the network. Despite appearing six times, the word "decentralised" has a low centrality score, which suggests that it is not as significant in the network as other words.

Table 3. Cryptography cluster

Keywords	Occurrences	Betweenness Centrality	Closeness Centrality	Page Rank Centrality
edge computing	6	54.32319	0.005682	0.008466225
cryptography	8	75.48285	0.005917	0.010569345
network security	8	63.09514	0.005747	0.008267339
automation	7	39.43045	0.005495	0.008170382
security	7	77.01806	0.005917	0.010257583
decentralised	6	6.198384	0.005076	0.006843643
authentication	5	34.92675	0.005525	0.006991284
digital devices	5	23.92153	0.005155	0.006390522
intelligent manufacturing	4	18.8162	0.005102	0.004715522
peer-to-peer networks	4	13.5476	0.005236	0.00488542
cybersecurity	3	10.82616	0.005076	0.004869231
data privacy	3	3.589486	0.004926	0.004966842
industrial internet of thing	3	8.704766	0.005128	0.00436534
internet of things (iot)	3	4.006124	0.00463	0.004193738
metaverses	3	9.631889	0.004831	0.003140776
product life-cycle management	3	5.774019	0.005025	0.005292043
public key cryptography	3	18.56827	0.004831	0.003876307

Table 4 indicates the manufacturing second theme, with the centrality value of 4.53257947244554 and density value of 37.0051990094283 and exists in the basic themes of the thematic map. Manufacturing is the concept that appears the most frequently, with 20 occurrences, followed by "supply chain management" (16 occurrences) and "digital technologies" (14 occurrences). These three ideas are likewise placed in cluster 4, indicating that they are interconnected within the subject matter. With a betweenness centrality score of 73.54, "supply chain management" is rated as having the highest betweenness, indicating that it is located between other concepts in the domain. The word "manufacture" had the greatest proximity centrality score in the domain, 0.005714, indicating that it is tightly linked to other terms in the field. The concept "manufacture" has the greatest number of connections to other significant concepts in the domain, as indicated by its highest Page Rank centrality score of 0.0193.

Table 4. Manufacturing theme

Words	Occurrences	Betweenness Centrality	Closeness Centrality	Page Rank Centrality
manufacture	20	62.93344	0.005714	0.019347
supply chain management	16	73.54366	0.005747	0.014848
digital technologies	14	64.34534	0.005587	0.014768
data analytics	10	31.03683	0.005464	0.013568
manufacturing	12	51.30084	0.00578	0.014142
sustainable development	9	51.62543	0.005556	0.011311
economic and social effects	7	41.00006	0.00565	0.008833
current	5	28.76883	0.005587	0.007112
digital transformation	5	33.0892	0.005525	0.005731
cloud analytics	4	36.51353	0.005464	0.00566
cyber physicals	4	42.30291	0.005618	0.00555
digital supply chain	4	11.22458	0.005181	0.005114
environmental technology	4	6.783848	0.004902	0.004694
innovation	4	6.405759	0.005051	0.004503
sustainability	4	17.99393	0.005181	0.005273
technological development	4	16.53016	0.005405	0.005105
uncertainty analysis	4	6.7127	0.005	0.003847
investments	3	10.13443	0.005236	0.00379
production control	3	26.09024	0.005376	0.004273

Moreover, Blockchain, has a centrality of 12.05615439 and a density of 51.11070547 and exists above the middle region of the thematic evolution; it has the highest cluster frequency of 456 of key terms. The centrality and density values indicate the theme is in the Motor Themes quadrant due to high density and low centrality. These themes can be considered highly developed and mature but are usually isolated and have weak links with other themes. Table 4 shows the significant key terms and their centrality.

The data reveals that the term "blockchain" itself, followed by "block-chain" and "internet of things" is the most frequent cluster associated with blockchain. The data also reveals that "industry 4.0" and "digital storage" are two other blockchain-related clusters that are shown frequently. Different clusters have different centrality measures, with some clusters having higher centrality scores than others. For instance, the "Internet of Things" typically travels along the network's shortest path because of its high betweenness centrality score.

Table 5. Blockchain theme

Keywords	Occurrences	Betweenness Centrality	Closeness Centrality	Page Rank Centrality
blockchain	73	21.1574	0.004901961	0.073813555
block-chain	55	33.3194	0.005154639	0.062530885
internet of things	39	75.1454	0.005586592	0.047316011
industry 4.0	32	147.0315	0.005988024	0.037383069
digital storage	31	106.3806	0.005714286	0.033811934
supply chains	25	117.5286	0.005952381	0.025765317
artificial intelligence	12	63.88624	0.005813953	0.014097415
manufacturing industries	14	143.4605	0.006134969	0.013997462
information management	12	118.7594	0.006097561	0.016270297
smart manufacturing	11	62.07357	0.005617978	0.013263948
distributed ledger	10	100.5193	0.005952381	0.013105192
embedded systems	10	84.10969	0.006097561	0.013456018
life cycle	10	89.84576	0.00591716	0.014535487
big data	8	66.57625	0.005882353	0.012266414
decision making	8	55.9538	0.005714286	0.009073261
smart contract	8	115.2336	0.006024096	0.012308225
blockchain technology	7	114.0677	0.006024096	0.011853277
cloud computing	5	77.26793	0.005952381	0.009693037
machine learning	6	62.29564	0.005747126	0.010920697
digital twin	6	44.81375	0.005780347	0.007021184
flow control	6	52.21796	0.005617978	0.007509552
cloud-computing	5	56.3203	0.00591716	0.009972948
manufacturing process	5	30.48828	0.005405405	0.006400018
security of data	5	46.54714	0.005524862	0.006303471
cloud storages	4	42.46969	0.005714286	0.007326083
commerce	4	39.32189	0.005555556	0.005394017
data sharing	4	29.90118	0.005586592	0.006582922
engineering education	4	20.90251	0.005524862	0.007603719
integration	4	29.73675	0.005524862	0.006384644
machine-learning	4	32.70499	0.005555556	0.007343349
transparency	4	10.42506	0.005291005	0.004844551
value chains	4	30.98565	0.005494505	0.005801324
computation theory	3	45.06802	0.005649718	0.004822616
computer architecture	3	14.58838	0.005464481	0.006344838

(Continued)

Table 5. Blockchain theme *(Continued)*

Keywords	Occurrences	Betweenness Centrality	Closeness Centrality	Page Rank Centrality
cyber-physical systems	3	9.895238	0.005181347	0.005668831
cyber-physical systems	3	9.895238	0.005181347	0.005668831
Cyber-physical system	3	17.27635	0.005263158	0.005290214
digital manufacturing	3	28.14159	0.005714286	0.005877372
internet of thing	3	19.15784	0.005434783	0.007270762

Furthermore, cloud manufacturing is the fourth theme with a centrality value of 0.4844444444444444 and a density of 50.6666666666667 in the thematic map. The themes exist in the Niche Themes at the lower left corner. "Cloud manufacturing" is the first term in the table and it appears five times in the context of cluster 5. The fact that it has a high betweenness centrality of 28.09359631 means that it is crucial in tying together other keywords in the context. Its closeness centrality of 0.005347594 indicates that other keywords in the context are relatively close to it. In the network of keywords in the context, it is also a relatively important keyword, as shown by its PageRank centrality of 0.00676046.

"Computer-aided manufacturing" is the second keyword, which is used three times in the same sentence. Compared to "cloud manufacturing," it has a somewhat lower betweenness centrality of 21.14310794, but it still demonstrates that it is crucial for linking other keywords in the context. The keyword before it has a proximity centrality of 0.005235602, which is comparable. Although "cloud manufacturing" has a higher PageRank centrality, this keyword is less significant in the network of keywords that make up the context.

Table 6. Blockchain theme

Keywords	Occurrences	Betweenness Centrality	Closeness Centrality	Page Rank Centrality
cloud manufacturing	5	28.0936	0.005348	0.00676
computer aided manufacturing	3	21.14311	0.005236	0.003935
covid-19	3	19.40816	0.005263	0.004171
digitalization	3	10.69636	0.005076	0.00509
ethereum	3	13.54812	0.005263	0.004759

Finally, the fourth theme is 3d printers and exists in Table 2 of the thematic map with a centrality value of 3.50382936507937 and density of 51.6659722222222 in the centre of the Niche Themes. With a high betweenness centrality of 47.84 and 12 occurrences in this cluster, the term "3d printers" is significant for tying together various nodes in the network. However, the term "diagnosis" only appears four times and has a betweenness centrality of 10.38, indicating that it is not as crucial in tying together various nodes in the network.

The phrase "industrial research" appears 10 times and has a high proximity centrality of 0.00585, suggesting that it is placed close to many other nodes in the network. With just 3 occurrences and a closeness centrality of 0.00535, the term "access control" is not in close proximity to many other network nodes.

Table 7. Blockchain theme

Keywords	Occurrences	Betweenness Centrality	Closeness Centrality	Page Rank Centrality
3d printers	12	47.83532	0.005747	0.011223
industrial research	10	74.8539	0.005848	0.011046
surveys	8	43.77793	0.005682	0.008966
health care	5	33.91901	0.005556	0.006289
5g mobile communication systems	5	45.06714	0.005747	0.008656
additives	5	28.2877	0.005556	0.006667
emerging technologies	5	57.61696	0.005814	0.007546
enabling technologies	5	24.15661	0.005525	0.006037
industrial revolutions	5	29.48928	0.005525	0.007496
product design	5	51.077	0.005747	0.007807
virtual reality	5	42.46463	0.005682	0.00652
diagnosis	4	10.38302	0.005263	0.004811
network architecture	4	26.14775	0.005618	0.006772
6g	3	28.73749	0.005618	0.006106
access control	3	9.596869	0.005348	0.005443
augmented reality	3	24.97234	0.005495	0.00536
competition	3	19.04711	0.005376	0.005045
industry 5.0	3	26.98395	0.005525	0.005342
Internet of thing (iot)	3	10.65476	0.005025	0.00405
medical services	3	17.94138	0.005319	0.005478

5 DISCUSSION

The aim of this investigation was to identify the advancement in the manufacturing industry due to the large-scale involvement of blockchain technologies. We used the PRISMA statement 2020 for the inclusion and exclusion of records from the Scopus database. Results show that most of the research work was done in recent years from 2019 to 2023. In addition, the final 117 records were analysed for the final discussion. All the records were published, and only articles, reviews, and book chapters were selected. In the next step, duplication, irrelevant records, and missing documents were deleted from the list. We used the RStudio and Biblioshiny software for the analysis part. We analysed the year base, sources base, and citation base. In the next step, we investigated the key terms occurrences, thematic map and thematic evolution of the records to identify the area of research on blockchain and manufacturing.

Results show that the manufacturing industry is using blockchain technologies in the supply chain processes of manufacturing [26], [27]. The manufacturing industry has seen a significant contribution from digital technologies, particularly blockchain technologies [28]. While some researchers are exploring cloud manufacturing and computer-aided manufacturing, the majority of research work in recent years has focused on blockchain technologies, the Internet of Things, and Industry 4.0 in the context of the manufacturing industry [29]. Notably, some researchers are investigating cryptography, security, and edge computing in the relationship between blockchain and manufacturing [30], [31].

Overall, the research shows that blockchain technologies are increasingly influencing supply chain processes in the manufacturing industry [32]. Many researchers have reported on the developments and identified gaps in the literature, indicating a growing interest in this area. As such, blockchain technologies have the potential to revolutionize the manufacturing industry and contribute significantly to improving its efficiency, security, and transparency.

6 CONCLUSION

The findings of this study show that blockchain technology is gaining popularity in the industrial sector as a potential solution to a variety of issues. The potential advantages of blockchain technology have been researched by a few academics. These advantages include enhanced supply chain management, product monitoring and tracking, digital rights management, inventory management, quality control, and intellectual property protection. Increased data security, cheaper transactions, and greater trust among supply chain participants are all advantages of using blockchain technology. Manufacturing companies may be able to use blockchain technology to solve long-standing supply chain management problems such as a lack of openness and cooperation. In order to securely store and share manufacturing data across a dispersed network of stakeholders, blockchain technology may also be utilised in digital manufacturing. This might lead to a more effective and economical flow of goods and services.

One of the fundamental benefits of employing blockchain technology is the capacity to construct a decentralised, tamper-proof ledger that upholds the authenticity and integrity of data throughout the manufacturing process. After being recorded, the information is inextricably linked to the previous block and cannot be changed or modified again. But there are important distinctions between permission and non-permissioned blockchains that influence the incentives and capabilities of users within the system. Blockchain technology can effectively handle a variety of data-related issues in industrial supply chains, including product traceability, identifying counterfeit or grey-market items, increasing product visibility, and reducing paperwork and administrative issues throughout the product life cycle, even though it cannot resolve all supply chain concerns.

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