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Bibliometric Analysis on the Application of IoT in Smart Manufacturing System in Industry 4.0

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ABSTRACT

The rapid integration of Internet of Things (IoT) technologies in smart manufacturing systems has been a pivotal development within the framework of Industry 4.0. This study conducts a comprehensive bibliometric analysis to examine the evolution, current trends, and emerging research areas related to IoT applications in smart manufacturing. By analyzing data from a decade of scholarly publications, this research identifies key themes, influential authors, and collaborative networks that have shaped the field. The findings reveal that foundational technologies such as the internet, cloud computing, and big data are central to the development of smart manufacturing, while newer innovations like digital twins and blockchain are gaining prominence. The study also emphasizes the importance of strategic collaboration among researchers and industry professionals in advancing IoT adoption. The practical implications suggest that manufacturers should prioritize both foundational digital infrastructure and emerging IoT applications to enhance efficiency, security, and sustainability. This analysis provides a roadmap for future research and practical implementation, highlighting the critical areas where IoT can further revolutionize smart manufacturing systems.

Keywords: *IoT, Smart Manufacturing, Industry 4.0, Bibliometric Analysis, VOSviewer*

1. INTRODUCTION

By fusing cutting-edge technology like the Internet of Things (IoT), artificial intelligence (AI), and big data analytics into established industrial systems, Industry 4.0 has completely transformed the manufacturing sector. These technologies make it possible to create smart manufacturing systems that can increase efficiency, flexibility, and production. In manufacturing environments, the integration of IoT is particularly important as it facilitates smooth data interchange and real-time decision-making by linking machines, sensors, and devices [1]. Adoption of IoT technologies has become a strategic advantage for companies trying to optimize their manufacturing processes, as well as a requirement as industries compete to stay competitive.

The expansion of the Internet of Things within the framework of smart manufacturing is consistent with Industry 4.0's overarching objectives, which prioritize automation, decentralization, and real-time data processing [2]. In this context, IoT facilitates communication between machines and devices as well as between central systems, allowing for adaptive production systems, real-time monitoring, and predictive maintenance [3]. As a result, industrial organizations can increase overall operating efficiency, improve product quality, and decrease downtime. Increasing levels of agility and responsiveness to market needs has been facilitated by the industry's critical shift from traditional manufacturing processes to smart technologies.

Research in this field has increased as IoT use keeps rising, underscoring the crucial role that technology will play in determining the direction of manufacturing in the future. Numerous IoT applications in smart manufacturing systems, including inventory management, process optimization, and quality control, have been studied [4]v. The wide range of study subjects emphasizes how complex IoT is in the industrial industry. Moreover, manufacturers are now able to take advantage of big data analytics and machine learning algorithms, which offer deeper insights into their operations and facilitate data-driven decision-making, thanks to the Internet of Things' capacity to create enormous amounts of data.

Though interest in IoT applications for smart manufacturing is growing, comprehensive literature analysis is still necessary. An organized method for assessing scholarly outputs, trends, and important works in the topic is a bibliometric analysis. Through the use of bibliometric tools, researchers are able to evaluate the trajectory of studies connected to the Internet of Things within the framework of Industry 4.0 and smart manufacturing. This allows them to detect gaps in the literature and developing trends. Understanding the ways in which academia is advancing the development and application of IoT in smart industrial systems requires the completion of such a study.

Even though the use of IoT in smart manufacturing systems has been extensively studied, it can be difficult to stay up to date with the latest innovations due to the quick speed at which technology is developing. It is critical to comprehend the state of research and the direction it is taking as Industry 4.0 technologies become more widely used. Prior research has frequently concentrated on particular case studies, technology frameworks, or the advantages of IoT deployment; but, there hasn't been much effort put into employing bibliometric analysis to thoroughly analyze the larger academic environment. It is challenging to pinpoint prominent research themes, significant writers, and important topics for further investigation in the absence of a thorough evaluation of the literature.

The aim of this study is to perform a bibliometric analysis on the use of IoT in Industry 4.0 context-based smart manufacturing systems. The objective of this study is to analyze scholarly outputs from the last ten years in order to identify research gaps, important publications, and trends. Using bibliometric methods like co-occurrence of keywords and citation analysis, the study aims to give a thorough summary of the literature on IoT and smart manufacturing. Furthermore, this study will identify areas that need more research and provide insightful information about how IoT applications have evolved in the manufacturing sector. In the end, this analysis will provide a baseline for subsequent research and educate scholars, industry professionals, and decision-makers regarding the advancement and possibilities of IoT in Smart Manufacturing.

2. LITERATURE REVIEW

2.1 Evolution of IoT in Smart Manufacturing

A lot of study has been done on the integration of IoT in manufacturing processes, especially in relation to Industry 4.0. The industrial sector has undergone a significant transformation thanks to the Internet of Things (IoT) concept, which entails the network of physical items integrated with sensors, software, and other technologies to link and exchange data with other devices and systems [5]. The development of IoT in smart manufacturing began in the early 2000s, when basic device connectivity was the main focus. IoT applications have grown over time to include increasingly complex functions including autonomous operations, predictive maintenance, and real-time monitoring [6].

IoT is used by smart manufacturing systems to build a more responsive and networked industrial environment. The progress in sensor technology, wireless connectivity, and data analytics has propelled this progression. Manufacturers can now gather massive volumes of data from several sources, evaluate it in real-time, and make well-informed decisions to optimize production processes thanks to the integration of IoT. An important turning point in the industrial sector has been reached with the adoption of smart systems in place of conventional manufacturing techniques [7]. According to the literature, IoT adoption in manufacturing is a fundamental shift that will probably continue to shape the sector for years to come, not just a passing fad.

2.2 *Key Applications of IoT in Smart Manufacturing*

Numerous important IoT applications for smart manufacturing are identified in the literature; these applications all help to increase the overall efficacy and efficiency of production operations. Predictive maintenance, which employs IoT-enabled sensors to track the state of machinery and equipment in real-time, is one of the most important applications. Manufacturers can reduce downtime and maintenance costs by scheduling repair before a breakdown occurs and predicting probable failures through the analysis of data obtained from these sensors [8]v. This proactive maintenance strategy, which differs from conventional reactive approaches, is one of the most important advantages of IoT in manufacturing.

Real-time monitoring and control, which enables manufacturers to follow production processes as they take place, is another crucial application. IoT devices can keep an eye on a number of characteristics, including pressure, temperature, and humidity, to make sure they stay within ideal bounds. Manufacturers can cut waste and maintain consistent product quality thanks to this capability [9]. Moreover, real-time monitoring makes it easier to spot and fix any deviations from regular operating procedures quickly, which boosts overall operational effectiveness.

Within smart manufacturing systems, supply chain management is another area where IoT is vital. Through the integration of IoT technology throughout the supply chain, manufacturers can attain enhanced operational visibility and control. To improve demand forecasting and inventory management, IoT-enabled tracking devices, for instance, can offer real-time information on the location and condition of raw materials and completed goods [10]. Manufacturers can better manage their supply chains and react to fluctuations in demand thanks to this increased insight.

2.3 *Challenges and Limitations in IoT Adoption*

IoT in smart manufacturing offers several advantages, but the literature also points out a number of obstacles and restrictions that need to be overcome. The problem of data privacy and security is one of the main obstacles. Because IoT devices are interconnected, there are weaknesses that fraudsters can take advantage of. Manufacturers are therefore very concerned about guaranteeing the security of data sent between devices and systems [11]. Furthermore, there are difficulties with data management, storage, and analysis because of the growing volume of data produced by IoT devices. To properly handle the massive volumes of data, manufacturers need to invest in strong data management systems and analytics technologies.

Another challenge is the integration of IoT with existing legacy systems. Many manufacturing companies have invested heavily in traditional manufacturing infrastructure, and the transition to IoT-enabled systems can be complex and costly [12]. The integration process often requires significant changes to existing processes and workflows, which can be disruptive to operations. Additionally, there is a need for skilled personnel who are capable of managing and maintaining IoT systems. The shortage of such expertise is a barrier to widespread IoT adoption in the manufacturing industry.

One such restriction that has been noted in the literature is the expense of putting IoT technologies into practice. IoT has many long-term advantages, but it can also come with a hefty upfront cost for systems, devices, and infrastructure—especially for small and medium-sized businesses (SMEs) [13]. The unpredictability of return on investment coupled with the high implementation costs may discourage certain manufacturers from implementing IoT technologies. This financial difficulty is made worse by the speed at which technology is developing, which can quickly make current IoT systems outdated.

2.4 Emerging Trends in IoT Research for Smart Manufacturing

The literature review reveals several emerging trends in the research on IoT for smart manufacturing. One of the most notable trends is the increasing focus on the integration of artificial intelligence (AI) with IoT to create more intelligent and autonomous manufacturing systems. The combination of AI and IoT, often referred to as the Artificial Intelligence of Things (AIoT), enables machines to not only collect and analyze data but also to make decisions and take actions based on that data [7]. This capability has the potential to further enhance the efficiency and effectiveness of smart manufacturing systems.

Another emerging trend is the exploration of IoT in the context of sustainability and green manufacturing. Researchers are increasingly examining how IoT can be used to reduce the environmental impact of manufacturing processes by optimizing resource use and minimizing waste [14]. The concept of sustainable manufacturing is gaining traction as companies seek to balance economic performance with environmental responsibility. IoT plays a crucial role in this effort by providing the data and insights needed to implement more sustainable practices.

The literature also points to the growing interest in the use of IoT for mass customization in manufacturing. Mass customization refers to the ability to produce customized products at scale, which is becoming increasingly important as consumer demand for personalized products rises [15]. IoT technologies enable manufacturers to quickly and efficiently adjust production processes to meet individual customer preferences, making mass customization a viable strategy in the era of smart manufacturing.

3. METHODS

In order to thoroughly examine the academic literature on the use of IoT in smart manufacturing systems within the framework of Industry 4.0, this study uses bibliometric analysis. The Google Scholar database provided the data for the analysis, which was limited to works published during the previous three decades. Articles, conference papers, and reviews that particularly addressed Internet of Things applications in smart manufacturing were included in the selection criteria. VOSviewer software was used to do the bibliometric study, enabling the visualization of co-authorship networks, citation patterns, and co-occurrence of keywords. The most significant writers, organizations, and journals were determined using descriptive statistics, and the field's prevailing research themes and trends were made visible through the use of cluster analysis.

4. RESULTS AND DISCUSSION

4.1 Research Data Matriks

Table 1. Research Data Metrics

Publication years	: 1992-2024
Citation years	: 32 (1992-2024)
Paper	: 980
Citations	: 87789
Cites/year	: 2743.41
Cites/paper	: 89.58
Cites/author	: 33056.05
Papers/author	: 417.00
Author/paper	: 3.01
h-index	: 145
g-index	: 277
hI,norm	: 86
hI,annual	: 2.69
hA-index	: 67
Papers with ACC	: 1,2,5,10,20:765,677,519,375,239

Source: Publish or Perish Output, 2024

The research data metrics for publications about the use of IoT in smart manufacturing systems from 1992 to 2024 are shown in Table 1. The dataset consists of 980 papers with a total of 87,789 citations. This translates to an average of 89.58 citations per paper and 2,743.41 citations annually. A strong impact in the field is indicated by the h-index of 145, which shows that 145 of these papers have earned at least 145 citations apiece. The highly significant influence of the top-cited papers is further highlighted by the 277 g-index. A collaborative research environment is indicated by the average number of papers per author, which is 417, while the average number of authors per paper is 3.01. Additionally, the hI,norm and hI,annual indices of 86 and 2.69, respectively, suggest sustained research productivity and impact over time. The hA-index of 67 reflects the consistent contribution of highly cited articles. The "Papers with ACC" metric highlights that a significant portion of the citations is concentrated among the top five most-cited papers, with 765, 677, 519, 375, and 239 citations each, underscoring the substantial influence of these key publications in advancing the field.

4.2 Network Visualization

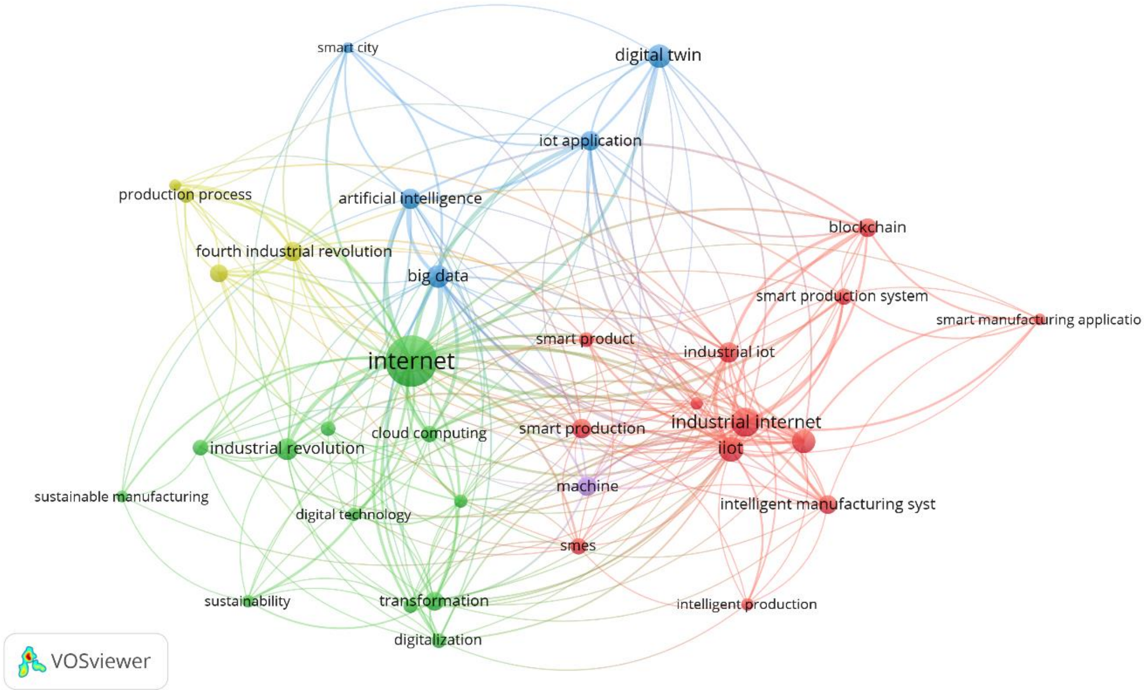

Figure 1. Network Visualization
Source: Data Analysis Result, 2024

The figure above represents the keyword co-occurrence network for research related to the application of IoT in smart manufacturing systems within the context of Industry 4.0. The different colored clusters in the network indicate distinct research themes or areas that are closely related based on the frequency of their co-occurrence in the literature. Each node in the network represents a specific keyword, and the size of the node reflects the frequency of its appearance in the dataset. Larger nodes indicate keywords that are more frequently discussed in the literature. The lines connecting the nodes represent the co-occurrences of these keywords, with thicker lines indicating stronger relationships between the terms.

The green cluster, which is the most prominent in terms of node size and connectivity, centers around the keyword "internet." This cluster is strongly associated with terms such as "cloud computing," "industrial revolution," "sustainable manufacturing," and "digital technology." The prominence of "internet" suggests that discussions related to the foundational role of internet technologies, particularly in the context of cloud computing and the broader industrial revolution, are central to the literature. This cluster highlights the critical role that internet and digitalization technologies play in enabling smart manufacturing, particularly in the transformation towards more sustainable and efficient production processes.

The red cluster focuses on the "Industrial Internet," "IoT," and "industrial IoT" (IIoT), which are closely linked to other terms such as "intelligent manufacturing system," "smart production," and "blockchain." The presence of this cluster underscores the emphasis in the literature on the integration of IoT and IIoT technologies within smart manufacturing environments. This cluster reflects the interest in how IoT technologies are being leveraged to create more intelligent, interconnected production systems that can adapt to real-time data inputs, enhance production efficiency, and integrate with emerging technologies like blockchain for improved supply chain transparency and security.

The blue cluster highlights keywords such as "digital twin," "IoT application," and "artificial intelligence." This cluster is indicative of a growing interest in advanced digital technologies, particularly in the development and application of digital twins—virtual replicas of physical systems that enable predictive analytics and real-time monitoring. The association with "IoT application" and "artificial intelligence" suggests that the literature is increasingly focusing on how these technologies can be combined to create more robust and autonomous manufacturing systems. The "digital twin" concept, in particular, is becoming a focal point in discussions about the future of smart manufacturing, as it enables more accurate simulations, optimizations, and the overall digital transformation of manufacturing processes.

Lastly, the yellow cluster includes keywords such as "production process," "fourth industrial revolution," and "sustainable manufacturing." This cluster is associated with discussions on the broader implications of the fourth industrial revolution, particularly in terms of enhancing production processes and advancing sustainable manufacturing practices. The connection between "production process" and "sustainable manufacturing" indicates that there is significant interest in how Industry 4.0 technologies, including IoT, can be utilized to not only improve efficiency but also to reduce the environmental impact of manufacturing. This cluster highlights the importance of sustainability in the ongoing evolution of manufacturing systems and suggests that future research may increasingly focus on developing IoT-enabled solutions for achieving both economic and environmental goals.

4.3 Overlay Visualization

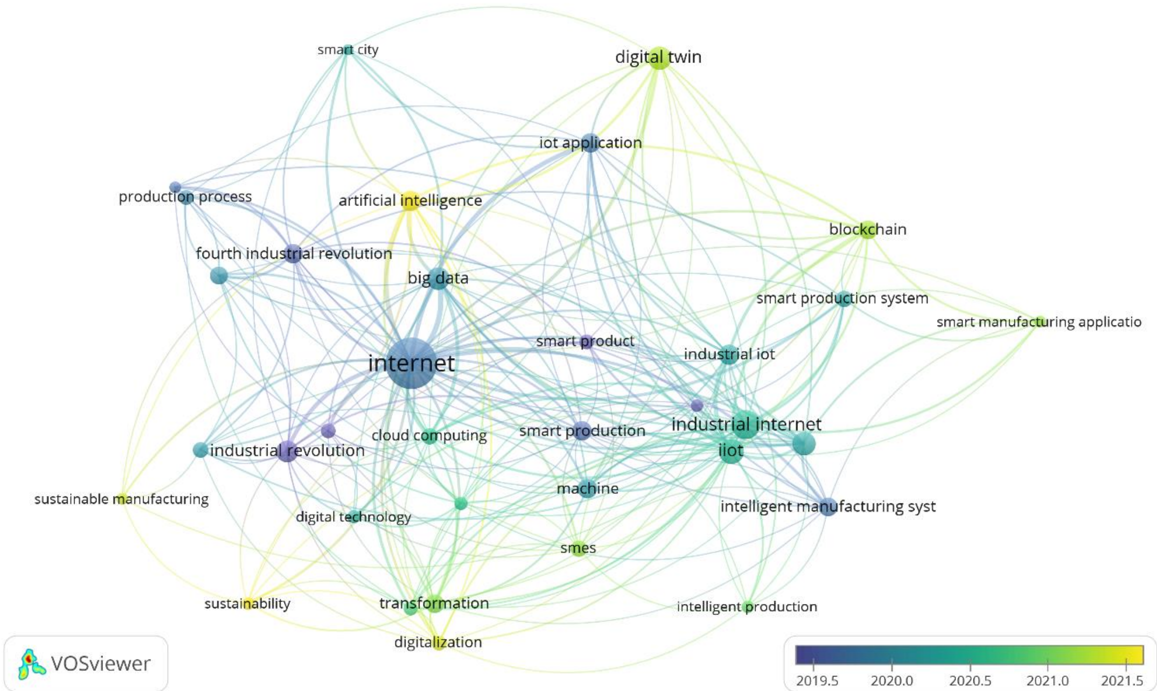

Figure 2. Overlay Visualization

Source: Data Analysis Result, 2024

This VOSviewer visualization represents a keyword co-occurrence network related to IoT applications in smart manufacturing systems, with a color gradient indicating the average publication year for the related research. The gradient ranges from blue (indicating earlier publications, around 2019) to yellow (indicating more recent publications, around 2021.5). This temporal aspect provides insights into how research topics have evolved over time, with the color distribution revealing emerging trends and established areas of study within the field.

The central node, "internet," is colored in blue, indicating that it has been a foundational topic since the earlier stages of research in this area, around 2019. Similarly, other key terms like "cloud computing," "industrial revolution," and "big data" are also shown in shades of blue, suggesting that these topics were among the earlier focus areas in the development of smart manufacturing systems. These terms have played a critical role in establishing the conceptual and technological foundation of smart manufacturing, particularly as the industry transitioned into Industry 4.0.

In contrast, terms such as "blockchain," "digital twin," "IoT application," and "smart production system" are colored in shades of green to yellow, indicating that these are relatively more recent areas of focus, with research peaking around 2021. These terms suggest a shift towards more advanced and specialized applications of IoT in manufacturing. The prominence of "blockchain" and "digital twin" reflects growing interest in integrating these cutting-edge technologies with IoT to enhance data security, transparency, and real-time monitoring in smart manufacturing environments. This shift towards newer technologies signals a move from establishing foundational frameworks to exploring more innovative and complex applications within the Industry 4.0 paradigm.

4.4 Citation Analysis

Table 2. The Most Impactful Literatures

Citations	Authors and year	Title	Findings
3490	[16]	Industry 4.0: state of the art and future trends	This paper provides a comprehensive overview of Industry 4.0, discussing its key technologies, including IoT, and identifying future research trends and challenges in the field.
2331	[17]	Industry 4.0 and the current status as well as future prospects on logistics	The study explores the impact of Industry 4.0 on logistics, analyzing current trends and potential future developments, with a focus on IoT's role in enhancing logistics processes.
2187	[18]	A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises	The paper introduces a maturity model to assess the readiness and maturity levels of manufacturing enterprises for adopting Industry 4.0 technologies, including IoT.
1795	[19]	A review of the roles of digital twin in CPS-based production systems	This review examines the concept of digital twins in Cyber-Physical Systems (CPS) for production, highlighting their applications and potential in smart manufacturing systems.
1683	[20]	The industrial internet of things (IIoT): An analysis framework	The authors propose an analytical framework for the Industrial Internet of Things (IIoT), focusing on its components, challenges, and security concerns in industrial environments.

Citations	Authors and year	Title	Findings
1556	[21]	The future of manufacturing industry: a strategic roadmap toward Industry 4.0	This paper presents a strategic roadmap for the future of the manufacturing industry, emphasizing the transformative role of IoT in achieving Industry 4.0 goals.
1508	[22]	"Industrie 4.0" and smart manufacturing-a review of research issues and application examples	The review addresses key research issues in smart manufacturing, providing examples of IoT applications and discussing the challenges and opportunities presented by Industry 4.0.
1409	[23]	Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives	The paper proposes a sustainable Industry 4.0 framework, identifying current research trends and future perspectives, particularly in the context of IoT and sustainability.
1311	[24]	Review of digital twin about concepts, technologies, and industrial applications	This review focuses on the concept of digital twins, discussing their underlying technologies and applications in Industry 4.0, particularly within smart manufacturing systems.
1306	[25]	Smart factories in Industry 4.0: A review of the concept and of energy management approached in production based on the Internet of Things paradigm	The paper reviews the concept of smart factories within Industry 4.0, with a specific focus on energy management approaches enabled by IoT technologies.

Source: Publish or Perish Output, 2024

4.5 Author Visualization

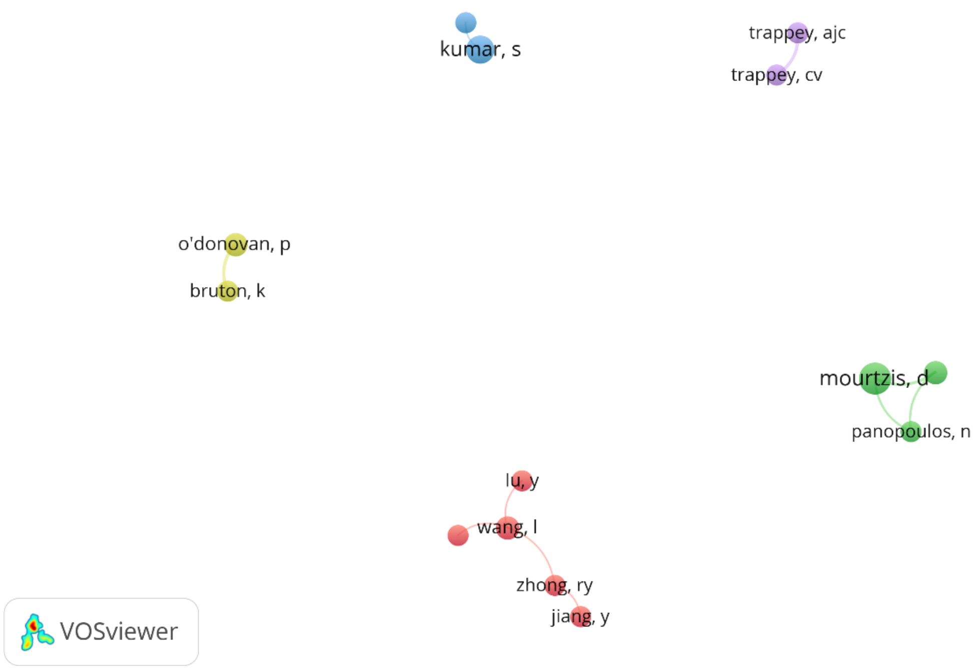

Figure 3. Author Visualization
Source: Data Analysis Result, 2024

The figure shows distinct clusters, each representing a group of authors who collaborate more closely with each other. For example, the green cluster centers around "Mourtzis, D" and "Panopoulos, N," indicating that these researchers have a strong collaborative relationship and likely contribute significantly to the same body of research. Similarly, the red cluster shows a close collaboration between "Zhong, RY," "Wang, L," "Liu, Y," and "Jiang, Y," suggesting that these researchers work together on related topics. Other authors, such as "Kumar, S," "O'Donovan, P," and "Trappey, AJC," appear more isolated or part of smaller clusters, indicating that while they contribute to the field, their collaborative networks are less dense or they may work independently. This figure highlights the collaborative nature of research in this field, with certain groups of researchers working closely together to advance the understanding and application of IoT in smart manufacturing.

4.6 Density Visualization

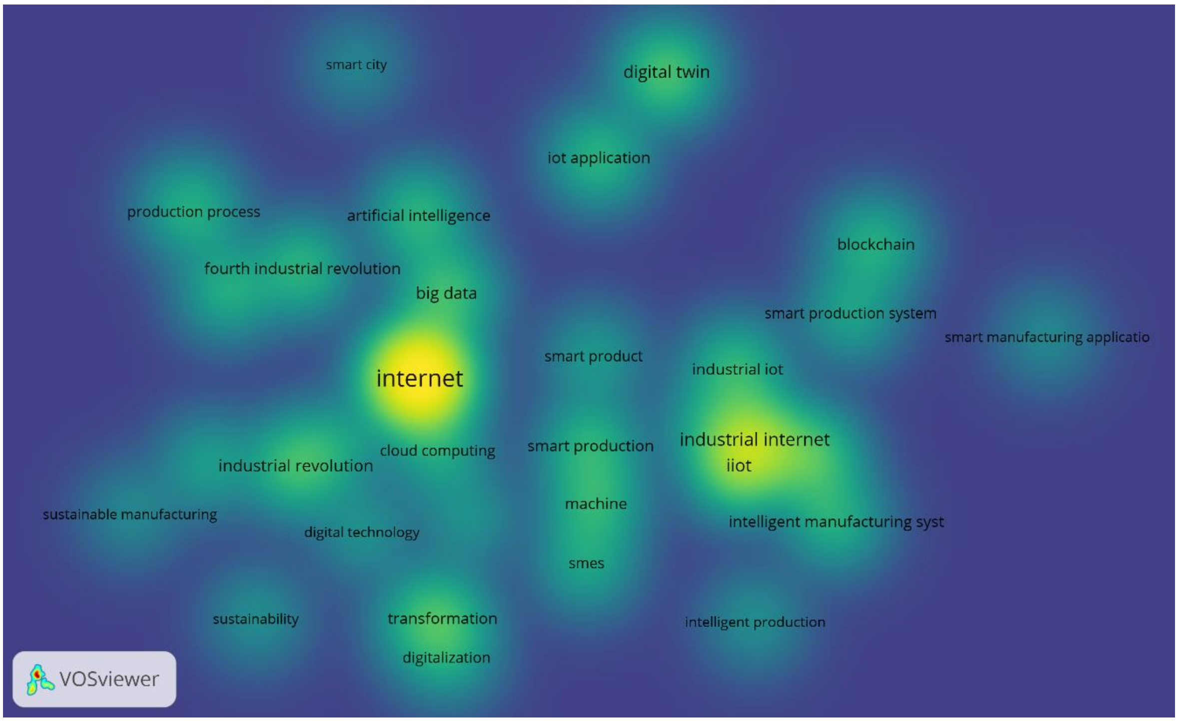

Figure 4. Density Visualization

Source: Data Analysis Result, 2024

The heatmap generated by VOSviewer displays the density of research activity surrounding various keywords related to IoT applications in smart manufacturing systems. In this visualization, the brighter and warmer areas (yellow to green) indicate higher concentrations of research focus and a greater frequency of keyword occurrences in the literature, while the darker areas (blue) signify lower concentrations. The central keyword "internet" is shown in the brightest yellow, indicating that it is the most prominent term in this field, reflecting its fundamental role in discussions about IoT and smart manufacturing. Similarly, "industrial internet" and "IIoT" also appear prominently, emphasizing their importance in the current research landscape. The heatmap also reveals other significant clusters of research activity. For example, keywords such as "digital twin," "IoT application," and "blockchain" have moderately bright regions, indicating substantial but more specialized areas of focus. These terms represent emerging and increasingly important topics in the smart manufacturing domain. On the other hand, keywords related to broader Industry 4.0 concepts, such as "industrial revolution" and "sustainable manufacturing," have a lower density, reflecting their foundational but less focused nature in current research trends.

Practical Implication

The central role of the "internet" and related foundational technologies like "cloud computing" and "big data" in smart manufacturing, as highlighted in the first analysis, underscores the need for manufacturing companies to prioritize investments in digital infrastructure. Companies aiming to implement IoT in their operations should focus on developing robust and scalable internet-based systems that can handle large volumes of data and facilitate real-time communication between devices. This foundational step is critical for enabling the broader adoption of smart manufacturing technologies and ensuring that the transition to Industry 4.0 is both efficient and effective.

The emphasis on newer technologies like "digital twin," "blockchain," and "IoT application," as seen in the temporal analysis, suggests that manufacturing firms should consider adopting these innovations to stay competitive. Digital twin technology, for instance, can be used to create virtual replicas of physical assets, allowing for advanced simulations, predictive maintenance, and real-time monitoring. Implementing blockchain can enhance transparency and security across supply chains, while IoT applications can optimize production processes and improve product quality. These emerging technologies offer significant opportunities for manufacturers to increase efficiency, reduce costs, and improve their overall operational performance.

The co-authorship analysis highlights the importance of collaboration among researchers and industry professionals in advancing the field of IoT in smart manufacturing. For practitioners, this suggests the value of forming strategic partnerships with academic institutions and technology experts to stay at the forefront of technological advancements. Collaborative research and development (R&D) initiatives can lead to innovative solutions that address the specific challenges faced by manufacturers, such as integrating IoT with existing systems or ensuring data security. By engaging in collaborative networks, companies can also benefit from shared knowledge and resources, accelerating their journey toward Industry 4.0 adoption.

Finally, the heatmap analysis of research density indicates that while foundational technologies like the internet remain critical, there is also significant interest in specialized applications of IoT in manufacturing. For practitioners, this implies a dual approach: investing in the development of core digital infrastructure while simultaneously exploring specialized IoT applications that can provide a competitive edge. Companies should assess their specific needs and capabilities to determine which emerging technologies—such as digital twins for predictive maintenance or blockchain for supply chain management—are most relevant to their operations. This strategic focus will enable manufacturers to leverage the latest advancements in IoT technology, driving innovation and sustainability in their manufacturing processes.

CONCLUSION

This bibliometric analysis provides a comprehensive overview of the current state and evolution of IoT applications in smart manufacturing within the context of Industry 4.0. The study highlights the foundational importance of internet-based technologies and the growing significance of advanced innovations such as digital twins and blockchain in enhancing manufacturing processes. Collaborative efforts among researchers and industry practitioners emerge as a critical factor in driving technological advancements and successful implementation of IoT solutions. The insights derived from this analysis offer valuable guidance for manufacturers, policymakers, and researchers by identifying prevailing trends, key areas of focus, and potential directions for future research to further advance the integration of IoT in smart manufacturing systems.

REFERENCES

[1] R. Y. Zhong, L. Wang, and X. Xu, "An IoT-enabled real-time machine status monitoring approach for cloud manufacturing," *Procedia Cirp*, vol. 63, pp. 709–714, 2017.

[2] M. Hermann, T. Pentek, and B. Otto, "Design principles for industrie 4.0 scenarios," in *2016 49th Hawaii international conference on system sciences (HICSS)*, IEEE, 2016, pp. 3928–3937.

[3] A. Gilchrist, *Industry 4.0: the industrial internet of things*. Springer, 2016.

[4] A. Kusiak, "Smart manufacturing," *Int. J. Prod. Res.*, vol. 56, no. 1–2, pp. 508–517, 2018.

[5] T. Xu, J. B. Wendt, and M. Potkonjak, "Security of IoT systems: Design challenges and opportunities," in *2014 IEEE/ACM International Conference on Computer-Aided Design (ICCAD)*, IEEE, 2014, pp. 417–423.

[6] F. Wortmann and K. Flüchter, "Internet of things: technology and value added," *Bus. Inf. Syst. Eng.*, vol. 57, pp. 221–224, 2015.

[7] L. Zhou, X. Li, K.-H. Yeh, C. Su, and W. Chiu, "Lightweight IoT-based authentication scheme in cloud computing circumstance," *Futur. Gener. Comput. Syst.*, vol. 91, pp. 244–251, 2019.

[8] D. Mourtzis, E. Vlachou, and N. Milas, "Industrial big data as a result of IoT adoption in manufacturing," *Procedia cirp*, vol. 55, pp. 290–295, 2016.

[9] C. Yin, J. Xi, R. Sun, and J. Wang, "Location privacy protection based on differential privacy strategy for big data in industrial internet of things," *IEEE Trans. Ind. Informatics*, vol. 14, no. 8, pp. 3628–3636, 2017.

[10] F. Wu *et al.*, "An efficient authentication and key agreement scheme for multi-gateway wireless sensor networks in

IoT deployment," *J. Netw. Comput. Appl.*, vol. 89, pp. 72–85, 2017.
[11] A. Sadeghi-Niaraki, "Internet of Thing (IoT) review of review: Bibliometric overview since its foundation," *Futur. Gener. Comput. Syst.*, vol. 143, pp. 361–377, 2023.
[12] J. S. Raj, "A novel information processing in IoT based real time health care monitoring system," *J. Electron.*, vol. 2, no. 03, pp. 188–196, 2020.
[13] M. A. Khan and K. Salah, "IoT security: Review, blockchain solutions, and open challenges," *Futur. Gener. Comput. Syst.*, vol. 82, pp. 395–411, 2018.
[14] N. I. Jabbouri, R. Siron, I. Zahari, and M. Khalid, "Impact of information technology infrastructure on innovation performance: An empirical study on private universities in Iraq," *Procedia Econ. Financ.*, vol. 39, pp. 861–869, 2016.
[15] M. Tu, M. K. Lim, and M.-F. Yang, "IoT-based production logistics and supply chain system–Part 1: Modeling IoT-based manufacturing supply chain," *Ind. Manag. Data Syst.*, vol. 118, no. 1, pp. 65–95, 2018.
[16] L. Da Xu, E. L. Xu, and L. Li, "Industry 4.0: state of the art and future trends," *Int. J. Prod. Res.*, vol. 56, no. 8, pp. 2941–2962, 2018.
[17] E. Hofmann and M. Rüsch, "Industry 4.0 and the current status as well as future prospects on logistics," *Comput. Ind.*, vol. 89, pp. 23–34, 2017.
[18] A. Schumacher, S. Erol, and W. Sihn, "A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises," *Procedia Cirp*, vol. 52, pp. 161–166, 2016.
[19] E. Negri, L. Fumagalli, and M. Macchi, "A review of the roles of digital twin in CPS-based production systems," *Procedia Manuf.*, vol. 11, pp. 939–948, 2017.
[20] H. Boyes, B. Hallaq, J. Cunningham, and T. Watson, "The industrial internet of things (IIoT): An analysis framework," *Comput. Ind.*, vol. 101, pp. 1–12, 2018.
[21] M. Ghobakhloo, "The future of manufacturing industry: a strategic roadmap toward Industry 4.0," *J. Manuf. Technol. Manag.*, vol. 29, no. 6, pp. 910–936, 2018.
[22] K.-D. Thoben, S. Wiesner, and T. Wuest, "'Industrie 4.0' and smart manufacturing-a review of research issues and application examples," *Int. J. Autom. Technol.*, vol. 11, no. 1, pp. 4–16, 2017.
[23] S. S. Kamble, A. Gunasekaran, and S. A. Gawankar, "Sustainable Industry 4.0 framework: A systematic literature review identifying the current trends and future perspectives," *Process Saf. Environ. Prot.*, vol. 117, pp. 408–425, 2018.
[24] M. Liu, S. Fang, H. Dong, and C. Xu, "Review of digital twin about concepts, technologies, and industrial applications," *J. Manuf. Syst.*, vol. 58, pp. 346–361, 2021.
[25] F. Shrouf, J. Ordieres, and G. Miragliotta, "Smart factories in Industry 4.0: A review of the concept and of energy management approached in production based on the Internet of Things paradigm," in *2014 IEEE international conference on industrial engineering and engineering management*, IEEE, 2014, pp. 697–701.