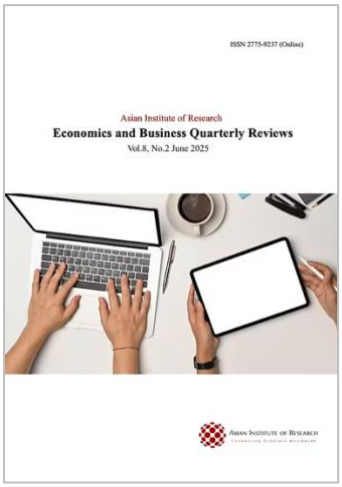

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Mapping Research on Digital Transformation in the Pharmaceutical Supply Chain in Indonesia: A Bibliometric Review

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Abstract
In this era, digital transformation become a key driver in enhancing the efficiency of the pharmaceutical supply chain. This study conducts a bibliometric literature review on digital transformation and pharmaceutical supply chains to identify research trends, literature gaps, and further development opportunities. The data are taken from Google Scholar and Scopus up to 2025, this research analyzes publications with the keywords "digital transformation" and "pharmaceutical supply chain" utilizing VOSviewer software. The findings indicate the adoption of technologies such as the Internet of Things (IoT), artificial intelligence (AI), and supply chain resilience. Furthermore, while there is extensive global research on digital transformation in supply chains, studies focusing on the pharmaceutical industry are limited in Indonesia. However, this study provides insights into the importance of digitalizati on in the pharmaceutical supply chain. It also encourages further research to understand the gap, regulatory implications, and collaborations, especially in the Indonesian context.

Keywords: Digital Transformation, Pharmaceutical Supply Chain, Bibliometric, Industry 4.0, Technology

1. Introduction

In the era of Industry 4.0, Indonesia has experienced significant technological advancements. Industry players are leveraging digital transformation to enhance the quality and competitiveness of their businesses. Digital transformation and Industry 4.0 are closely related, both fundamentally reshaping business models and organizational structures (Büyüközkan & Göçer, 2018). How does this apply to the pharmaceutical industry? Pharmaceutical companies are striving to produce high-quality products to meet increasingly complex and dynamic market demands. They are required to continually innovate and improve performance to respond promptly and effectively to market changes (Damle & Krishnamoorthy, 2022).

Data shows that Indonesia is one of the largest pharmaceutical markets in ASEAN, with 73% of the market share dominated by local pharmaceutical companies (A. F. Mubarok & Syafruddin, 2016). However, Indonesians still spend approximately USD 1.4 billion on healthcare and medication abroad (Thomas, 2022). It indicates that the

quality of the domestic pharmaceutical industry needs improvement. To address this, technological capabilities and research & development are critical factors for producing high-quality products and expanding market share (Sampurno, 2007). The government has prioritized accelerating digital transformation as a key driver of Indonesia's economic growth, aligning with the Digital Indonesia Roadmap 2021–2024 (Catur Purbaya et al., 2024). According to this roadmap, the pharmaceutical industry plays an active role in digital transformation (Kementrian Perindustrian Republik Indonesia, 2018). In 2022, 31 companies received the INDI 4.0 (Indonesia Industry 4.0 Readiness Index) award, including PT Bintang Toedjo and PT Paragon Technology and Innovation (Agatha & Aprian, 2022).

Supply chain efficiency is a crucial aspect driven by digital transformation (Preindl et al., 2020). In the context of the pharmaceutical industry, digital transformation plays a strategic role in enhancing operational efficiency and competitiveness (Pravin Ullagaddi, 2024). By adopting technologies such as the Internet of Things (IoT), big data analytics, and artificial intelligence (AI) (K. Mubarok & Arriaga, 2020), pharmaceutical companies can optimize supply chain management comprehensively, from raw material procurement to product distribution to end consumers (Stroumpoulis & Kopanaki, 2022). The used of technologies also enables real-time tracking of product movements, it is also improves market demands forecasting as consumer needs and minimizes the especially for the stock shortages or surpluses. The application of AI technology in company also for analyzing and responding the market conditions, so it can align production with the demand (Wang et al., 2019), thereby reducing costs and logistics costs.

Furthermore, the digitalization fosters are closer to the collaboration among the stakeholders within the supply chain (Mohammed & Farooqui, 2024). The integrated of digital systems, such as enterprise resource planning (ERP) and blockchain, it can ensure the transparency and accuracy data, minimizing risks of errors or fraud in the procurement and distribution processes (Ullagaddi, 2024). It is quietly critical, as known the pharmaceutical industry operates under strict regulations to ensure product safety and efficacy (Ding, 2018).

Research on digital transformation in supply chains has been extensively conducted; however, most studies lack specificity to objects or contexts. Some studies discuss digitalization in the pharmaceutical industry, but their focus and direction are often undefined(Hole et al., 2021). This study focuses on digital transformation in the pharmaceutical supply chain and pharmaceutical industry, specifically in Indonesia.

2. Theoretical And Empirical Review of Related Literature

2.1 Bibliometric Analysis

In the late 20th century, bibliometric analysis became a foundation in academic research study trends; it also offers valuable insights across multiple disciplines (Moed, 2009). Involves quantitative evaluation of publications through metrics such as the number of citations, authorship networks, journal rankings, and keyword frequencies (Boyack & Klavans, 2010). These tools enable researchers to map the structure of a field, identify influential contributors, and discover emerging research topics and collaborations (Cobo et al., 2011). The science mapping and clustering analysis also define the correlations between the studies, revealing the critical nodes within the citation networks and thematic connections (Rodrigues et al., 2014).

Bibliometric methods are particularly valuable for monitoring research dynamics over time, providing an evidence-based framework to evaluate scientific impact and productivity (Waltman, 2016). For instance, analysis of highly cited papers or journals highlights the pioneer contributions, while keyword co-occurrence analyses clarify the shifts in thematic focus within a domain (Aria & Cuccurullo, 2017). Furthermore, these insights lead to a research policy by identifying the knowledge gaps, fostering interdisciplinary work, and informing the funding strategies (Donthu et al., 2021).

Even though it has advantages, the bibliometric analysis requires a careful interpretation. As (Rodrigues et al., 2014) emphasize, a number of citations are not inherently measured in quality but reflect various factors, including accessibility, topicality, and network effects. Additionally, bibliometric data may be biased towards

underrepresented or emerging fields where the citations accumulate slowly. Therefore, the bibliometric techniques provide a framework for scoping research landscapes; integrating qualitative perspectives and expert judgment is essential for drawing robust and actionable grounds.

The objective of this research is to identify the gaps in the existing literature, considering the limited focus on digital transformation in improving the supply chain within the pharmaceutical industry. Bibliometric analysis is used to explore opportunities and determine directions for advancing the supply chain through digital transformation. Therefore, this research is not aiming to establish a new standard in research methodologies, bibliometric analysis proves to be a valuable tool when aligned with well-defined research questions (Donthu et al., 2021).

2.2 Theoretical of Technological Advances and the Importance of Digital Tranformation for Pharmaceutical Supply Chain

The technological advancements have provided significant benefits in the industry because they play a pivotal role in improvement, as highlighted by (Jing & Fan, 2024). They emphasize that supply chain management was among the first business functions to undergo substantial technological advancements through applications leveraging data from ERP systems.

Digital technologies are believed to deliver greater improvements in three key areas: simplifying transactional activities, such as end-to-end planning; supporting core operations, including warehouse management; and sharpening the analyses that underpin decision-making processes. Research by (Preindl et al., 2020) underlines the importance of building a digital supply chain network that is highly responsive to changing circumstances and transparent for all stakeholders involved. Digital transformation, supported by technological progress and the implementation of Industry 4.0, serves as a critical factor in creating more efficient and effective supply chains (Khan et al., 2016). Further, assert that integrated information within a company is an asset for reducing supply chain-related costs. One of the main solutions lies in the utilization of the Internet of Things (IoT), which combines cloud-based systems, mobile devices, and artificial intelligence. IoT enables the integration of physical and digital flows, fostering a more responsive and efficient supply chain(Barata et al., 2018).

The application of digital technologies also allows companies to address issues in real time, where integrated information flows enhance supply chain responsiveness (Zhao, Hong, Lau, 2023). Utilizing the exchange of real-time information enables a company to optimize decision-making, improve the supply chain effectiveness, also reduce operational costs (Dweekat et al., 2017).

Furthermore, collaboration among stakeholders within the supply chain is integral to creating an efficient ecosystem. As traditional collaboration platforms are unable to keep up with the demands, cloud-based technologies can improve data sharing and streamline the information flow among stakeholders (David et al., 2015 ; Kohli & Jensen, 2010). Blockchain technology also significantly contributes to ensuring transparency and data accuracy, which are crucial factors for sustaining the supply chain (Azzi et al., 2019).

Research on digital transformation for supply chains holds strategic importance, especially for the pharmaceutical industry in Indonesia. This sector is critical as it directly relates to public health. However, the pharmaceutical industry in Indonesia faces complex challenges. Although Indonesia is the largest pharmaceutical market in ASEAN, with 73% of its market share dominated by local companies (A. F. Mubarok & Syafruddin, 2016), Indonesians still spend approximately USD 1.4 billion annually on healthcare services and medications abroad (Thomas, 2022). . It shows that there is a gap between market needs and the capacity of the domestic pharmaceutical industry to meet them.

As a results, pharmaceutical companies can take advantage of the momentum to increase their competitiveness in domestic and global markets. Digital transformation offers a path to address inefficiencies, improve operational performance, and meet growing market demands more effectively (Jing & Fan, 2024; Soni & Patel, 2024) thereby ensuring the long-term sustainability of Indonesia’s pharmaceutical sector.

2.3 Research Question

Guided by the dearth of literature, the following research questions will be considered in this study.

1. What are the most frequently occurring concepts (keywords) shaping the current drive for digital transformasi and pharmaceutical supply chain?

2. Who are the most cited authors on digital transformasi and pharmaceutical supply chain?

3. Which country is the most productive in terms of publication on digital transformasi and pharmaceutical supply chain?

4. What are the most urgent considerations and developments in research on digital transformation for pharmaceutical supply chain efficiency?

This study aims to analyze the role of digital transformation in the pharmaceutical supply chain through a bibliometric review of articles published up to 2025 in Google Scholar and Scopus. The research will focus on the top ten journals based on the keywords "digital transformation" and "pharmaceutical supply chain", as well as citation counts. To further explore the topic, a keyword map will be created using VOSviewer software.

3. Research Methodology

The present study adopts a mixed-method approach, combining qualitative and quantitative methodologies with a predominant emphasis on quantitative analysis. This approach is utilized to systematically explore the existing literature on digital transformation and its impact on improving the pharmaceutical supply chain.

3.1 Research Design

The study used a bibliometric approach employing quantitative methods will be utilized to analyze the patterns and trends of publications related to digital transformation in the pharmaceutical supply chain from 2011 to 2025. This approach enables a comprehensive assessment of research productivity, collaboration among scholars, as well as the influence and evolution of this topic over time. By applying bibliometric indicators to relevant literature sourced from databases such as Google Scholar and Scopus, this study aims to provide in-depth insights into the development and direction of research in this field.

3.2 Search Keywords

Publications were retrieved from the Scopus database, one of the largest abstract and citation databases of peer-reviewed scientific publications across disciplines. Scopus was chosen over other databases like Web of Science, IEEE Xplore, and PubMed due to its multidisciplinary nature and broad coverage of over 28,000 active titles from approximately 11,678 international publishers. The following keywords (Pharmaceutical supply chain* drug supply chain* medicine supply chain* efficiency* performance* optimization* digital transformation* Industry 4.0* digitalization* technological adoption* smart technology*) were used to examine in the title of a research article, abstract, and keywords.

The preliminary search yielded 137 articles that met the established criteria for further examination. Following this, a rigorous screening and filtering process was conducted to refine the dataset. This process involved assessing the relevance of each publication, removing duplicates, and ensuring that the articles aligned with the study's objectives. Following the guidelines set by (Ranjbari et al., 2021), the final dataset underwent a cleaning process to improve its quality and relevance before applying bibliometric and content analysis techniques. This approach ensured that only the most relevant and high-quality articles were included, providing a solid foundation for subsequent data analysis.

The search results were exported from Scopus and converted into CSV format for further analysis using bibliometric software tools. Bibliometric analysis was conducted using VOSviewer, a software that constructs and visualizes bibliometric networks by extracting information from titles, abstracts, and keywords. VOSviewer allows for the mapping of co-citation networks, co-authorship linkages, and generates overlay visualizations that represent statistical indicators on network structures. It extracts and analyzes text data along with linkages to display conceptual proximity and clustering. VOSviewer also offers advanced text mining and overlay mapping techniques within an intuitive and user-friendly interface. Among freely available bibliometric software, VOSviewer strikes a balance between analytical depth and ease of use. For these reasons, VOSviewer was selected, as its technical capabilities align with the analytical objectives of this study.

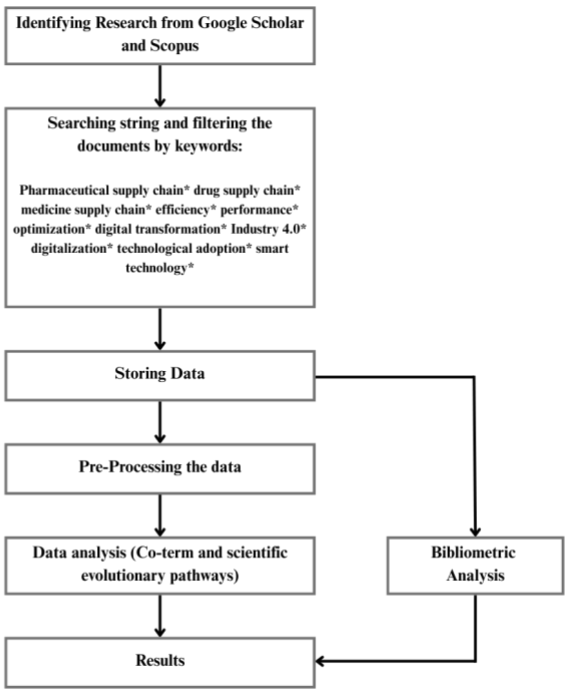

Figure 1. Research Design

4. Results

4.1 Data Analysis

To thoroughly examine the structure and evolution of the current research domain, a comprehensive approach has been employed, integrating three distinct but complementary analytical techniques: bibliometric analysis, content analysis, and text mining. This combination enables a detailed exploration of the trends, patterns, and key themes within the field, offering valuable insights into the progression and focus areas of research. By utilizing these methods, the study aims to provide a nuanced understanding of how the topic has developed over time, identify emerging research directions, and uncover underlying relationships between various elements of the literature.

Similarly, previous studies such as those by (Govindan et al., 2018) utilized a combination of bibliometric and qualitative content analysis to enhance the depth of their investigations into supply chain innovations. In line with this approach, this research also integrates a qualitative technique to complement and validate the quantitative findings derived from bibliometric analysis. Specifically, data clustering methods were applied to selected publications, with clusters being determined through co-citation and keyword co-occurrence analysis.

Once the clusters were established, qualitative content analysis was conducted on the top 5 publications from each cluster. This approach allowed for a closer examination of theoretical and practical orientations related to the digital transformation of pharmaceutical supply chains. By analyzing the content in-depth, the study not only

identifies thematic patterns but also verifies how digital technologies contribute to achieving operational efficiency and strategic advancements in supply chain management. This method ensures a balanced and comprehensive understanding of the interplay between bibliometric insights and qualitative narratives within the field.

4.1.1 Evolution of Publications: a descriptive study

The objective is to evaluate the progress of research on digital transformation for supply chain efficiency in the pharmaceutical industry. Between 2011 and 2024, a total of 1,261 studies were published, with the peak occurring in 2024, during which 422 papers addressed digital transformation for supply chain efficiency, both in general and specifically for the pharmaceutical sector. However, there were gaps in publication in 2012, 2014, and 2015, which is one of the reasons this study was undertaken.

Additionally, this research is considered crucial because the focus is on Indonesia's pharmaceutical industry, where digital transformation plays a significant role in improving time efficiency, the accuracy of analysis results, and other enhancements in the pharmaceutical supply chain. This study is also expected to contribute to advancing the pharmaceutical industry in Indonesia by optimizing manufacturing processes and enabling companies to respond more effectively to rapidly changing market trends. Figure 2 will illustrate the trends in research publications related to digital transformation in the pharmaceutical supply chain.

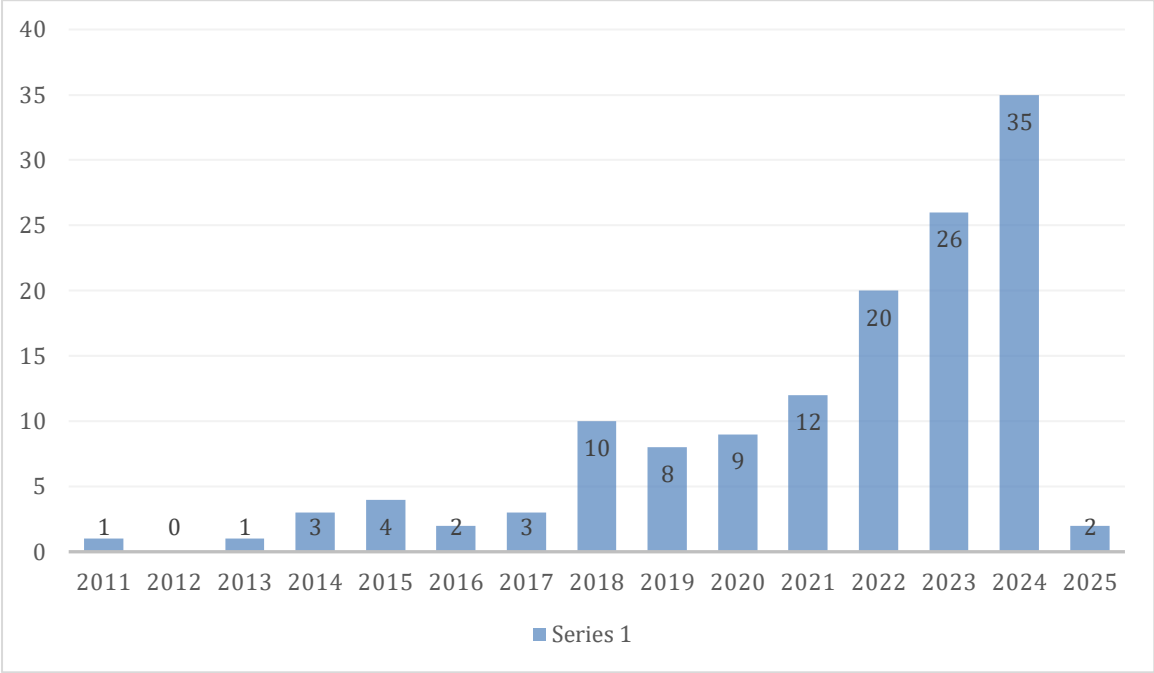

Figure 2: Publications evolution over time from 2011 – 2025

4.1.2 Analysis of Citations

The number of citations an article receives can indicate its significance in the research community. Table 1 presenets the twenty most cited articles in our database on digital transformation and pharmaceutical supply chains (PSC).

Process Safety and Environtmental Protection and the International Journal of Production Research have a strong influence on the technological innovation movement. According to the data, (Ding, 2018), in *Pharma Industry 4.0: Literature Review and Research Opportunities in Sustainable Pharmaceutical Supply Chains*, received 241 citations. Ding stated that Industry 4.0-based technologies and innovations can address several challenges in Pharmaceutical Supply Chain. Meanwhile, (Qader et al., 2022) suggest that adopting Industry 4.0 technologies

can enhance supply chain resilience and performance. Furthermore, the implementation of these technologies enables a more effective response to crises. Others have also emphasized that traceability is a crucial aspect of supply chains, including PSC.

Table 1: The top 20 most cited articles in Pharmaceutical Supply Chain research pertaining to the Digital Transformation

No.	Authors	Year	title	Journal	Cited by
1	Ding B.	2018	Pharma Industry 4.0: Literature review and research opportunities in sustainable pharmaceutical supply chains	Process Safety and Environmental Protection	241
2	Casino F.; Kanakaris V.; Dasaklis T.K.; Moschuris S.; Stachtiaris S.; Pagoni M.; Rachaniotis N.P.	2020	Blockchain-based food supply chain traceability: a case study in the dairy sector	International Journal of Production Research	194
3	Singh R.K.; Gunasekaran A.; Kumar P.	2018	Third party logistics (3PL) selection for cold chain management: a fuzzy AHP and fuzzy TOPSIS approach	Annals of Operations Research	167
4	Qader G.; Junaid M.; Abbas Q.; Mubarik M.S.	2022	Industry 4.0 enables supply chain resilience and supply chain performance	Technological Forecasting and Social Change	135
5	Indumathi J.; Shankar A.; Ghalib M.R.; Gitanjali J.; Hua Q.; Wen Z.; Qi X.	2020	Block Chain Based Internet of Medical Things for Uninterrupted, Ubiquitous, User-Friendly, Unflappable, Unblemished, Unlimited Health Care Services (BC IoMT U6HCS)	IEEEAccess	85
6	Visconti R.M.; Morea D.	2020	Healthcare digitalization and pay-for-performance incentives in smart hospital project financing	International Journal of Environtmental Research and Public Health	83
7	Bag S.; Dhamija P.; Singh R.K.; Rahman M.S.; Sreedharan V.R.	2023	Big data analytics and artificial intelligence technologies based collaborative platform empowering absorptive capacity in health care supply chain: An empirical study	Journal of Business Research	76
8	Villegas M.A.; Pedregal D.J.; Trapero J.R.	2018	A support vector machine for model selection in demand forecasting applications	Computers & Industrial Engineering	67
9	Panda S.K.; Satapathy S.C.	2024	Drug traceability and transparency in medical supply chain using blockchain for easing the process and creating trust between stakeholders and consumers	Personal and Ubiquitous Computing	53
10	Chiacchio F.; D'urso D.; Oliveri L.M.; Spitaleri A.; Spampinato C.; Giordano D.	2022	A Non-Fungible Token Solution for the Track and Trace of Pharmaceutical Supply Chain	Applied Science	52
11	Vanany I.; Ali M.H.; Tan K.H.; Kumar A.; Siswanto N.	2024	A Supply Chain Resilience Capability Framework and Process for Mitigating the COVID-19 Pandemic Disruption	IEEE Transactions on Engineering Management	46

12	Martini P.; Boschi A.; Cicoria G.; Zagni F.; Corazza A.; Uccelli L.; Pasquali M.; Pupillo G.; Marengo M.; Loriggiola M.; Skliarova H.; Mou L.; Cisternino S.; Carturan S.; Melendez-Alafort L.; Uzunov N.M.; Bello M.; Alvarez C.R.; Esposito J.; Duatti A.	2018	In-house cyclotron production of high-purity Tc-99m and Tc-99m radiopharmaceuticals	Applied Radiation and Isotopes	40
13	Sarkis M.; Bernardi A.; Shah N.; Papathanasiou M.M.	2021	Emerging challenges and opportunities in pharmaceutical manufacturing and distribution	Processes	35
14	Datta S.; Namasudra S.	2024	Blockchain-Based Smart Contract Model for Securing Healthcare Transactions by Using Consumer Electronics and Mobile-Edge Computing	IEEE Transactions on Consumer Electronics	33
15	Lewin J.J., III; Choi E.J.; Ling G.	2016	Pharmacy on demand: New technologies to enable miniaturized and mobile drug manufacturing	American Journal of Health-System Pharmacy	26
16	Azad M.A.; Osorio J.G.; Brancazio D.; Hammersmith G.; Klee D.M.; Rapp K.; Myerson A.	2018	A compact, portable, re-configurable, and automated system for on-demand pharmaceutical tablet manufacturing	International Journal of Pharmaceutics	26
17	Joseph Jerome J.J.; Saxena D.; Sonwaney V.; Foropon C.	2022	Procurement 4.0 to the rescue: catalysing its adoption by modelling the challenges	Benchmarking: An International Journal	26
18	Debnath B.; Shakur M.S.; Mainul Bari A.B.M.; Saha J.; Porna W.A.; Mishu M.J.; Islam A.R.M.T.; Rahman M.A.	2023	Assessing the critical success factors for implementing industry 4.0 in the pharmaceutical industry: Implications for supply chain sustainability in emerging economies	PLOSOne	26
19	Al-Khatib A.W.	2023	The impact of industrial Internet of things on sustainable performance: the indirect effect of supply chain visibility	Business Process Management Journal	24
20	Ntamo D.; Lopez-Montero E.; Mack J.; Omar C.; Highett M.I.; Moss D.; Mitchell N.; Soulatintork P.; Moghadam P.Z.; Zandi M.	2022	Industry 4.0 in Action: Digitalisation of a Continuous Process Manufacturing for Formulated Products	Digital Chemical Engineering	18

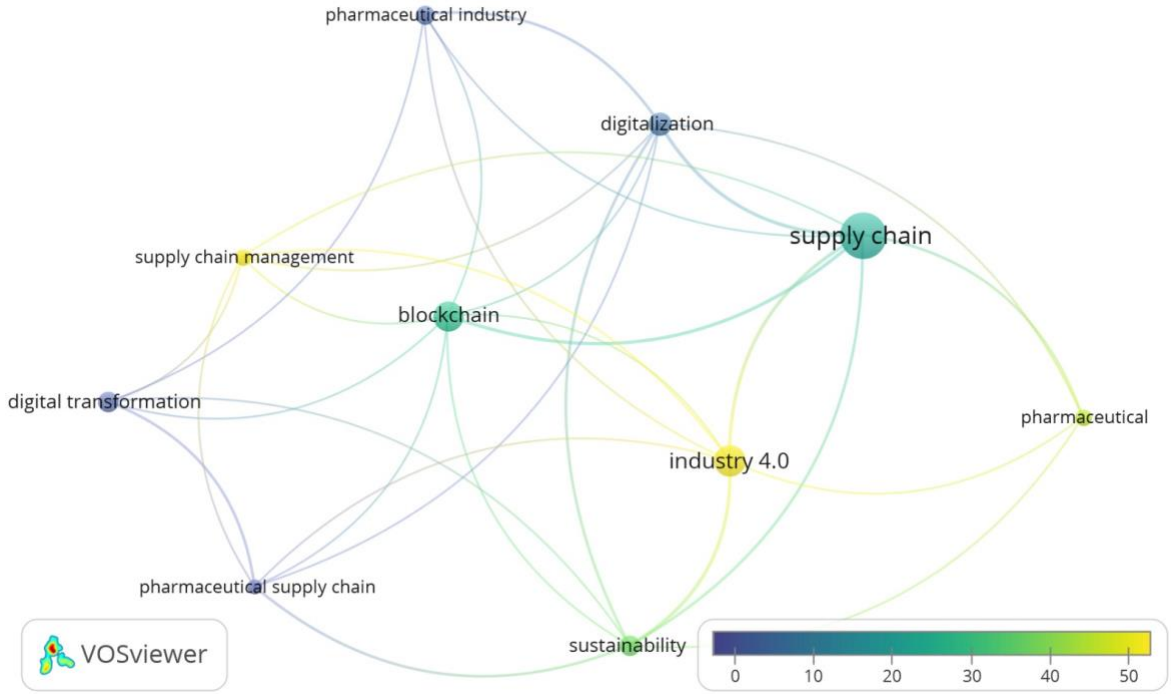

Figure 3: Keyword density based on the number of occurrences

The bibliometric visualization in figure 3, highlights the most frequently occurring keywords and their interconnections, illustrating the relationships among key concepts in this research area. The connections between keywords represent their co-occurrence in research articles. For example, "blockchain" is closely linked to "supply chain" and "digital transformation," reflecting its increasing significance in enhancing supply chain transparency and efficiency. Meanwhile, "Industry 4.0" is strongly associated with "supply chain" and "sustainability," emphasizing its role in optimizing sustainable supply chain management. In contrast, while "digitalization" and "pharmaceutical supply chains" are present in the visualization, they have not shown a significant increase in research focus.

These findings reinforce the growing academic interest in technological innovation within pharmaceutical supply chains and highlight the importance of Industry 4.0, blockchain, and digital transformation in shaping the future of Pharmaceutical Supply Chain research and practice.

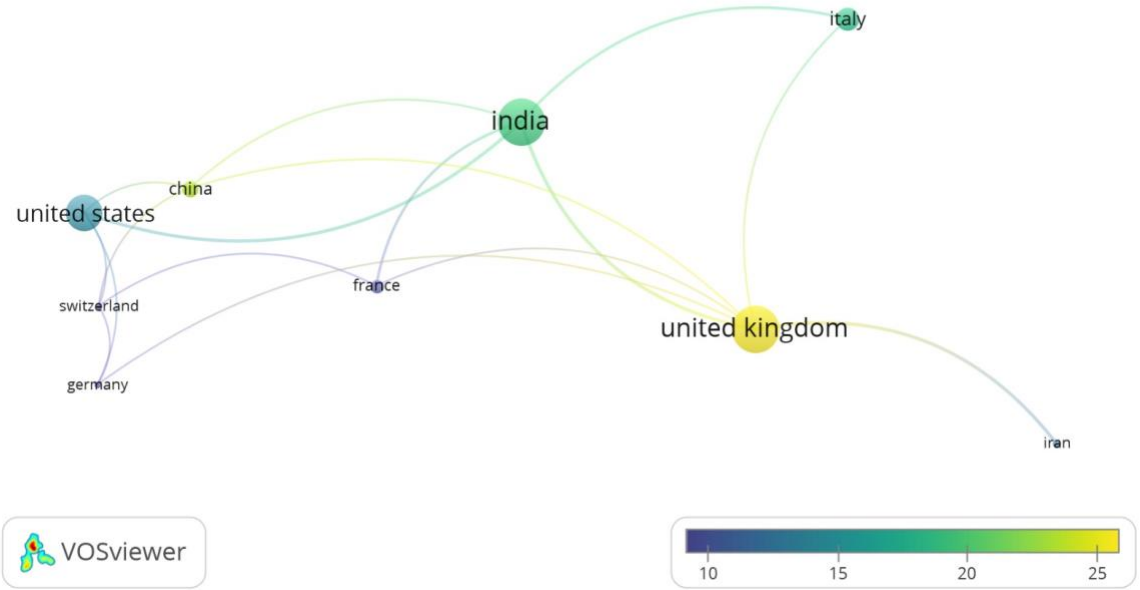

Figure 4: Country based on citation

The figure above illustrates the contribution of various countries to this research. The most significant contributions are observed from the United Kingdom, India, and the United States. However, no specific studies related to this research have been identified in Southeast Asian countries. Therefore, this study aims to explore the development of the pharmaceutical supply chain in the context of digitalization within the industry 4.0 era, particularly in South Asian countries, with a specific focus on Indonesia.

The figure below also illustrates the distribution of research publications on the same theme across various journals or conferences. From the data below, it is evident that Hospitals & Health Networks/AHA has the highest number of publications with approximately eight publications on consistent themes compared to other journals.

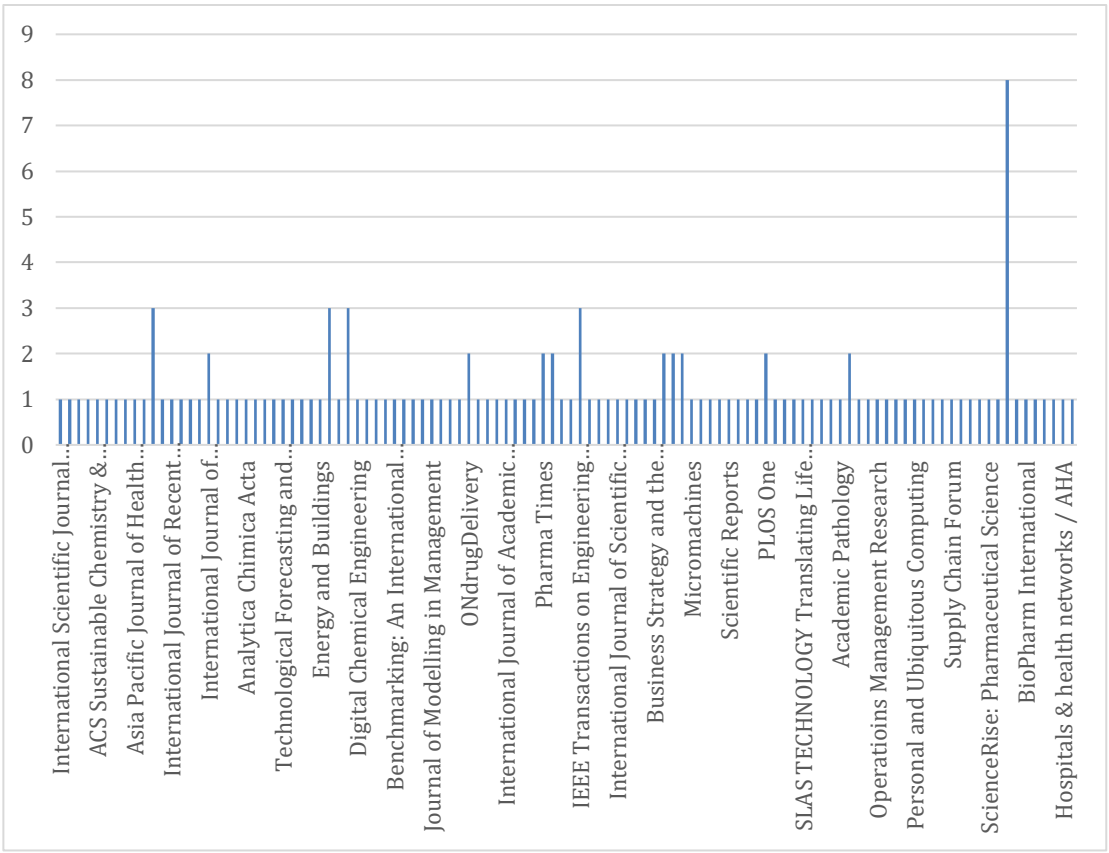

Figure 5: The most cited publication journal in Pharmaceutical Supply Chain or Digital Transformation

5. Conclusion and Recommendation

The study titled "Mapping Research on Digital Transformation in the Pharmaceutical Supply Chain in Indonesia: A Bibliometric Review" highlights the scholarly developments in the field of pharmaceutical supply chains. The number of publications from 2011 shows significant progress until 2025. This development became particularly evident in 2019, with numerous articles discussing Industry 4.0 and digital transformation. This is reflected in the use of keywords such as Industry 4.0, Technologies (IoT, AI, Big Data), Blockchain, and others. In addition, global research on digital transformation in the supply chain is extensive, but there is a gap in research specifically focused on the pharmaceutical context in Indonesia. Therefore, this study addresses digitalization in the pharmaceutical industry, with Southeast Asia as its primary focus.

Bibliometric analysis was employed as a tool to examine the digital transformation in the pharmaceutical supply chain, showing a clear trend toward integrating Industry 4.0 technologies. The use of keywords such as "Industry

4.0," "Blockchain," and "Digitalization" formed the foundation of the study search. Citation analysis revealed influential papers focusing on the impact of Industry 4.0 on sustainable pharmaceutical supply chains, emphasizing the interconnectedness of these concepts. Geographical analysis showed a concentration of research outputs in the UK, India, and the US, highlighting the need for more regionally focused studies, particularly in emerging economies like Indonesia.

A significant gap in research on digitalization in the pharmaceutical industry presents an opportunity. Many articles directly address specific topics but lack a broader scope. However, further research is necessary to understand the challenges and opportunities specific to the Indonesian context. This includes the role of regulations, collaboration, facilities, and more. Future research should also consider the unique social, economic, and regulatory factors that influence the adoption and implementation of digital technologies in Indonesia. By addressing these research gaps, this study contributes to a more nuanced understanding of the potential benefits and challenges of digital transformation in the Indonesian pharmaceutical supply chain, providing valuable insights for both academics and industry practitioners.

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Informed Consent Statement/Ethics approval: Not applicable.

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