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Leveraging AI and Blockchain Technologies for Optimizing Healthcare Supply Chain Management

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In order to drive the digitization process in the context of the healthcare business, it is crucial to understand fundamentals of the blockchain and its applications in the healthcare industry. Blockchain has the potential for addressing major challenges in healthcare because of its characteristics as security enhancement, traceability, transparency, and cost reduction. These qualities can improve transparent supply chain, EHR, and medicine authentication and can make a positive impact in healthcare industry. Popularly believed to be a kind of revolutionary advancement in computing science, there is so much that blockchain might bring about positive change in the health facilities. This paper's objectives are to evaluate the current state of blockchain technology research in healthcare supply chains, discuss implications, and identify potential future themes. The approach used in this paper was the use of systematic literature review or SLR which has two phases. At first, only related articles were identified based on relevance to selected keywords through database search and an extensive process that led to bibliographic coupling which divided 124 papers into relevant categories. In the second phase, these documents underwent elaborate descriptive and content analysis. In the results, it is evident that literature in the application of blockchain in healthcare is still emerging, though there is a steady upward trend over the last five years. Asian countries are leading in this aspect of production and *IEEE Access* emerging as the most productive journal in the blockchain healthcare research. The principal application domains identified include medical insurance, remote patient monitoring, medication supply chain management, EHR management, and inventory control; among them, EHR management is the largest use case. However, the study points out that many of the findings obtained tend to be limited in terms of applicability because the reviewed samples mainly include theoretical or non-sufficiently empirical studies. The knowledge acquired is expected to help the stakeholders,

policy makers, scholars, and managers in order to make tactical choices pertaining to implementation and adaptation of blockchain technology in health care. Excluding such other emerging technologies and sectors as well, the focus of this study on blockchain solutions in the healthcare context may also limit the studies' external validity. This research can be ranked as one of the few recent comprehensive attempts to offer a systematic literature review and bibliometric analysis of blockchain application in healthcare. This paper reviews the existing literature, identifies emerging trends, and provides specific recommendations for future research to improve existing knowledge and planning regarding the application of blockchain in the healthcare industry.

Keywords: Healthcare Supply Chain, Blockchain, Blockchain Technology, Healthcare, Supply Chain.

1. Introduction

The healthcare supply chain (HSCM) is a complex network involving various parties and stakeholders with varying interests, like suppliers are interested in maximizing their profits, whereas healthcare workers are concerned about patient healthcare and safety [1]. These conflicting goals reduce the coordination among the stakeholders and make the work challenging. Further, healthcare sector has been facing challenges of rising healthcare services costs, fragmented patient records which are not interoperable, medical data security, control of medical data, counterfeit drugs, frauds related to insurance claims and prescription management, and complexity and expensiveness of healthcare supply chains[2],[3],[4].

The healthcare sector has still not seen digital transformation and has not transformed in the same way as other sectors.To provide patients with better treatment, the healthcare sector must adapt technologically. Incorporating technologieslike blockchain can prove its significance in the healthcareindustry [5]. By tackling the present issues in healthcare, blockchain can completely transform the industry. It storesand shares sensitive healthcare data in a secure, private, andtrustworthy way using decentralized consensus mechanismsand cryptographic algorithms. In addition to seamless dataexchange, it can help connect different healthcare systemsand provide real time access to patient's past data, reducingthe tendency of redundant tests [6]. Patients can securely control their healthcare data through blockchain while maintaining consent and privacy. Thanks to blockchain-enabled rights and permissions, patients can exchange their data withauthorized parties. The technology can help improve thetraceability and transparency of drug supply chains, reducingthe risk of counterfeit drugs [7]. Technology's security andtransparency can reduce fraud by enhancing the validity of medical insurance claims and enhancing the trustworthinessof clinical trial results.

Previously, different studies tried to explore blockchain research in healthcare. Ali et al. [7] classify the blockchain related articles into challenges, benefits and functionalities in healthcare, manufacturing, financial and government sectors. Alrahbi et al. [8] suggest a paradigm for assessing preparedness that considers the intricate interactions between various underlying causes, institutional mechanisms, and social structures, as well as all significant stakeholders. The framework's relevance and utility are established by applying it to the healthcare industry in the United Arab Emirates, based on a comprehensive literature review.

Latif et al. [9] conduct a SLR regarding the state of-the-art in healthcare digital transformation. The authors divide the previous research into four clusters: workforce practices, organizational elements and management consequences, patient-centered approaches, workforce efficiency by healthcare providers, and socioeconomic issues. These clusters are connected to create a model that illustrates how different technology implementation strategies improve service providers' operational efficiency [10]. Attaran [10] summarize health-related blockchain products and major players providing solutions across various applications, as well as identifying potential and difficulties for integrating blockchain technology (BCT) in healthcare.

Attaran et al. [12] conduct a bibliometric review to understand blockchain trends in healthcare. The authors conduct co-occurrence analysis and identify productive academic institutions, countries, and well-known writers in addition to the scholarly output and the annual total number of authors' developmental trend. Balasubramanian et al. [13] provide a framework for categorizing both existing and forthcoming developments in the access control domain. Theme-based blockchain-based access control taxonomies are also supplied to detect security problems in present systems and underline the security demands for granular access control. Beaulieu and Bentahar [14] describe how blockchain technology (BCT) has been used to solve supply chain (SC) issues in the pharmaceutical, medical device, blood, organ, and tissue industries. The studies discussed are detailed in table A1 of the annex. It is clear from the literature that blockchain technology's potential and uses in healthcare must be understood to help digitize the healthcare sector [15]. Hence, it becomes crucial to comprehend the state of BCT research in the healthcare supply chains (HSCs), about the implications and pathways for possible future developments in this field. So, this led us to take up the following research questions for this study are;

- What is the development status and dynamics of BCT research in the HSCs?
- What are the implications and future research directions regarding BCT use in Indian HSCs?

This article focuses on the literature divided into four different clusters communicating blockchain's evolution, its advantages, adoption status as well as challenges, healthcare issues, emerging areas and blockchain's applications in the healthcare supply chains. Our study adds to and expands upon prior blockchain research in the field of healthcare through descriptive and content analysis. Firstly, articles of BCT, HSCs, healthcare, and supply chain-related, focusing on blockchain work in healthcare applications were identified through a thorough literature search. Then, these articles were divided into clusters through bibliographic coupling [16]. Secondly, an exhaustive investigation of these studies was performed with descriptive and content analysis. The study's findings will benefit healthcare practitioners and researchers, expanding understanding and will help in explaining the current research and future trends [17]. The aim of this study is to enhance blockchain related research, encourage new applications and provide fresh avenues for blockchain knowledge propagation in the healthcare sector. It provides valuable information on this topic in ideas, conclusions, research gaps, and cluster wise directions for future work. This work is a beneficial contribution to the researchers and the healthcare sector as the overview of the technology's impact on this complex and promising field is sincerely presented. The study consists of following sections such as, Section II describes the background of BCT and section III explains the research methodology

adoptedfor the study. Section IV justifies the findings of the study in terms of descriptive and content analysis. Section V presentsthe discussion part in detail and section VI outlines theimplications, limitations, and future research directions. Theconclusion is finally presented in section VII.

2. LITERATURE

This section sheds light on knowledge regarding blockchaintechnology's background and a comparison among the recent literature review studies with the present study is presented.

A. BACKGROUND ON BLOCKCHAIN TECHNOLOGY

BCT is a distributed ledger technology thatcombines two characteristics, i.e., peer-to-peer communication and cryptography [18]. It first came into the picture through Satoshi Nakamoto due to the growing popularity ofthe bitcoin white paper [19], [20]. It is a continuous chainof blocks that gets stored in an extensive computer database,which is formed with the help of various interconnecteddevices like computers, phones, or other systems, connected virtually or manually [21], [22], [23]. Each block contains transaction or communication data whose security and privacy are maintained through cryptography. The driving factors for the technology's implementation include less dependency on massive servers, reduced requirement for trusted parties, redundant work reduction, cost-effective and maintaining data integrity, privacy, and security [24]. Blockchain technology is mainly applied in cryptocurrency and financial transactions, but more industries like healthcare and manufacturing are exploring its applications [25], [26], [27]. Blockchain has various uses like storing medical records, tracking goods, recording, verifying transactional details, concluding binding agreements, etc. It strengthens security and provides privacy protection to the associated system. It isof a distributed nature and allows records to be stored on many connected systems that keep the same information. Hackers need to breach more than 50% of the challenging systems to hack the whole network [28].

There are four types of blockchains named as private, public, consortium and hybrid. A private blockchain or permissioned blockchain, has a single operator who controls who can access and add data to the blockchain network. Public blockchains or permissionless blockchains are of decentralized nature with no individual or organization controlling them [29]. The network is open to everyone, and anyone can joinin on its main activities and at the same time users remain anonymous. The advantages of public blockchains include immutability, easy accessibility, and high security whereas disadvantages include high energy consumption and low throughput. Public blockchains examples include Ethereum,bitcoin, Litecoin etc. [30]. A private blockchain, on the other hand, requires users on the system to be verified whichis not in public blockchains. They are centralized or partially decentralized, and their users can be identified. Privateblockchains process transactions more quickly because theyare speedier, more dependable, and have fewer users. Consortium and hybrid blockchains were proposed to address the drawbacks of private and public blockchains. A permissioned blockchain known as a consortium blockchain is used whenmultiple organizations share data and conduct transactions [31]. It is a kind of federated blockchain. It has a higher levelof decentralized nature as well as security if we compare it with private blockchains. Permissioned and permissionless

blockchains combined to provide a balance between controland freedom are known as hybrid blockchains. It combines public and private blockchain benefits and can execute permissioned or permissionless features depending on the situation [32]. Controlling authorities have the option to make the transactions transparent or to keep them open to the public. These blockchains can function based on the circumstances, such as when data exchange between hospitals or within the hospital is necessary.

B. EXISTING LITERATURE STUDIES

Literature review studies based on blockchain, healthcare and supply chain related have been done before. According to theexisting literature, there has been a lack of case studies and use cases due to technology's novelty and complexity. Thereis a dearth of comparative studies showing the similarities and differences that different healthcare firms faced while adopting blockchain technology. More theoretical studies have been there and there is a lack of empirically validated studies across different geographical locations, especially developing countries. Blockchain applications like EHR management have been explored well while other applications still need exploration. A comparative study of how this study is different from other recent review studies conducted in this field isshown in table A1 in annexure.

3. RESEARCH METHODOLOGY

Ding [33] has explained about eight different types of literature reviews: systematic, conceptual, narrative, realistic, rapid, expert, critical and state of theart. Out of which, Systematic literature review (SLR) is thereview technique that has been adopted for this study. This paper adopted a stringent research protocol tominimize the extent of the researcher's bias. This work hasbeen conducted in two phases. The first phase consists ofsearching for articles from scholarly databases using appropriate keyword pairs, sorting them out based on inclusion andexclusion criteria, and using bibliometric analysis to classifythe articles with the help of VOS viewer software [34],[35]. In the second phase of the study, a quantitative and qualitative analysis of the selected articles is done using content analysis and descriptive analysis as explained under findings. These analyses endeavors to appropriately respond to the research questions and present robust information regarding the study objectives.

This work does not deviate from formulated research process, depicted in Newcomer and Kennedy et al. Figure 1 which outlines the methodical approach used in the study. The details on inclusion and exclusion of pertinent articles are presented in Figure 1 in appendix. These criteria ensure that only studies which are in line with the study objectives are included therefore increasing the reliability and validity of the study. This research fills a gap in the existing literature by offering a systematic and diverse review of content and descriptive research that examines the uses of BCT in HSCs.

KEYWORD SELECTION

The multiple words and keywords were selected during the selection process an exclusion process. In general, each set of keywords included and was surrounded by 'blockchain', 'supply chain', and 'healthcare-variant'. To avoid the problem of false negatives, there might be valuable research that is excluded, the variations of the term of healthcare such as medical, smart healthcare, e-health, pharmaceutical, healthcare management, healthcare service and

healthcare system were entered into the search process. The precise search parameters employed were:

- blockchain and supply chain and intelligent healthcare
- blockchain AND supply chain AND pharmaceutical
- blockchain AND supply chain AND health care management or services
- blockchain AND supply chain AND medical system

This approach aimed at attempting to cover all the necessary information on the use of blockchain technology in the health care supply chain system.

DATABASE SEARCH AND SCREENING PROCESS

Five scholarly databases were utilized to collect relevant articles from the systematic database search: Scopus, Web of Science, Science Direct, IEEE Xplore and EBSCO.

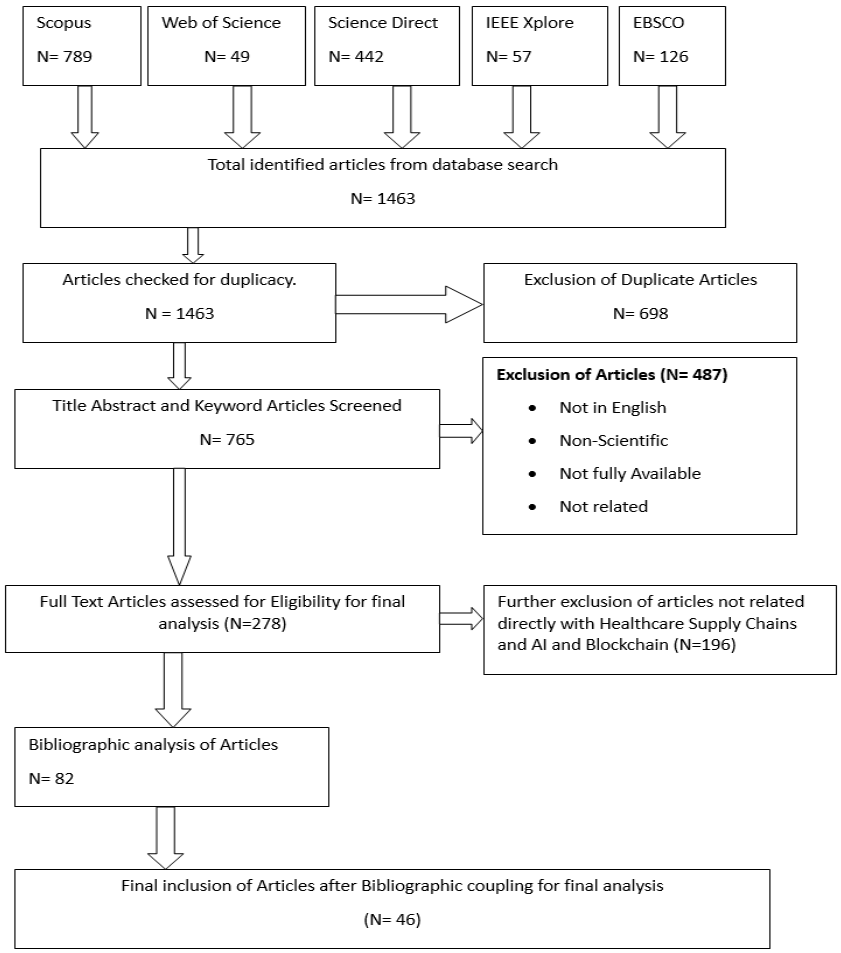

Figure 1 Screeenign of Article for current study

Most of the relevant articles wereobtained from the Scopus database. EBSCO offers access to other twenty-six databases like MEDLINE, Cochrane, and PsycINFO. IEEE Xplore has a strategic inclination towards blockchain and healthcare. Other databases like Web ofScience and Science Direct completed the systematic search and ensured no relevant article was missed.

The keyword pairs were used to find 1463 articles in five academic databases. 698 duplicate articles were then eliminated once these items were de-duplicated. 765 articles that were left were evaluated for their titles, abstracts, and keywords. The further selected articles were then conditioned to inclusion and exclusion criteria, as shown in the annexure table-A1. Only journals as sources and articlesand review papers as documents were considered for the study. Exclusion criteria included studies that were not completely available, too technical, not scientific, or written ina language other than English. Conference papers, bookchapters, white papers, theses, etc. were not included in the study. All these constraints lead to the removal of 487 articles. A full-text assessment of the refined 278 articles from the previous step was made to check whether they were related to blockchain, supply chain, or healthcare domain with 'blockchain in healthcare as the focus of research'. Thisprocess yielded 82 articles which were further subjectedto bibliographic coupling analysis using VOS viewer software version 1.6.15 [50], [52]. Finally, 46 articles were included in our study, grouped into four clusters, through bibliographic coupling analysis. A detailed study of these 46 articles was performed, and the articles were analyzed concerning their respective clusters for identifying status, future avenues, and emerging areas concerning blockchain use in healthcare supply chains with the help of descriptive and content analysis.

4. FINDINGS

This unit presents the outcomes of the study in terms of descriptive analysis as well as content analysis. With descriptive analysis, we aim to show the distribution of articles year-wise, journal wise, country wise and author wise. This will help us to understand the yearly publication trend, journals, countries, and authors with the most no. of publicationsin this field. With content analysis, we portray the interpretation of the content of the 46 research articles extracted through this review. The content analysis has been performed in two ways, firstly, by categorizing these articles into four clusters based on bibliographic analysis and discussing themfurther. Secondly, categorizing these articles based on the type of methodology used. This has been explained well in further detail.

A. DESCRIPTIVE ANALYSIS

It is the use of data to achieve initial insights and describe the main patterns, characteristics, and trends within a dataset. This analysis focus on the data itself and does not present inferences beyond the data. This work showsthe articles' year wise distribution, journal wise distribution, country wise distribution and author wise distribution below. Figure 2 depicts those publications in this domain started in2016. It has been steadily increasing till 2022 with a greater number of publications coming in 2023. This proves that more researchers are becoming interested in healthcare blockchainresearch, leading to an escalating number of publications.

Figure 3 discusses the most relevant sources that has published at least 6 articles in this domain. IEEE Access hasbeen producing the greatest number of journals in this area, followed by Sensors, Journal of Medical Internet Research,Electronics, etc. Figure 4 shows each country's contribution to publications inthis domain. India tops the list, followed by the USA, UK,China, Saudi Arabia etc. Figure 5 indicates the most contributing authors with at least 7 publications in this domain. It presents Jayaraman, Salahand Javaid are the authors with the most no. of publicationsin this area.

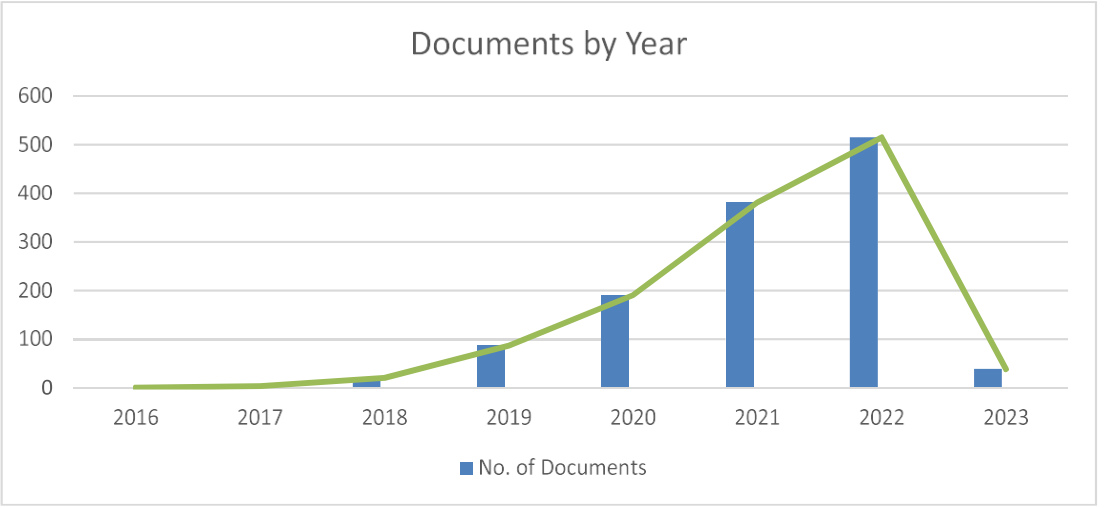

FIGURE 2. Documents by year

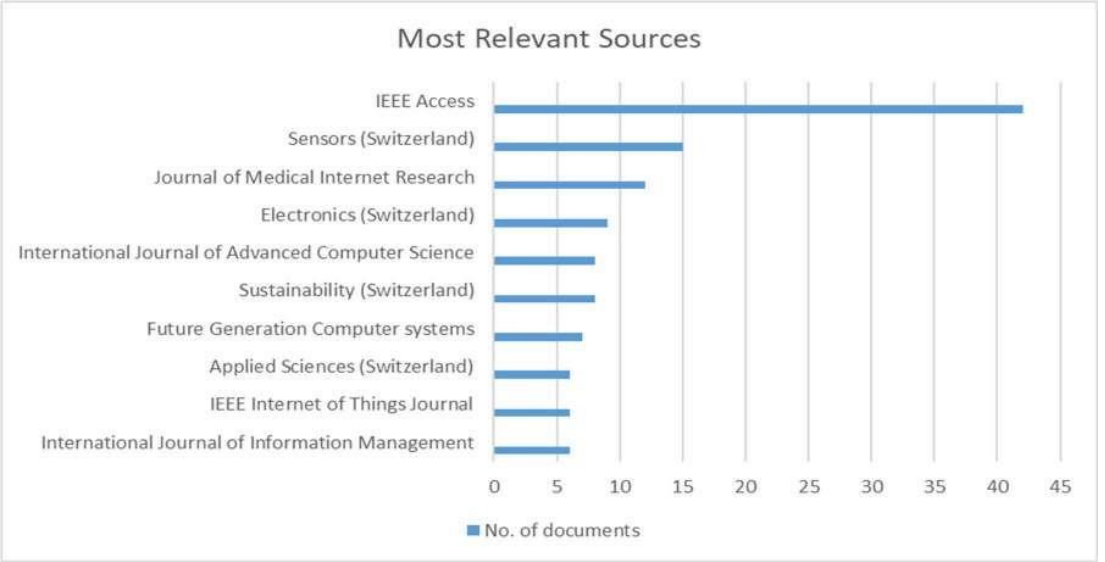

FIGURE 3. Most relevant sources.

B. CONTENT ANALYSIS

Under this unit, firstly, we argue the content of the papersdivided into four clusters based

on bibliographic analysis. Cluster 1 discuss about the issues, digitalization, sustainability practices and technology adoption in the HSCs. Cluster 2 looks into the growth and progress of BCT with a particular focus on how it is integrating with other emergent technologies. This cluster highlights the advancements in blockchain research and its capability to incorporate with smart technologies like, AI, IoT, and big data to create new notions and improve the efficacy of cross-industry networks. Cluster 3 identifies healthcare challenges, current decisions on blockchain usage, its possible sectors, and the challenges faced by the sector even in the implementation stage. This paper presents the all-round analysis of how blockchain can solve some significant issues in the healthcare system while showing the weaknesses of acceptance and implementation at the same time.

ANALYSIS OF BIBLIOGRAPHIC COUPLING

Bibliographic coupling of documents with VOS viewer [50] is carried out to analyze the foremost research themes in blockchain, healthcare, and supply chain. This helps in analyzing all the articles regardless of the number of citations they possess. It prevents the exclusion of uncited articles, especially the recently published ones, which can prove quite relevant for the study. A minimum of two articles per cluster is attributed to this process. A total of 46 articles are grouped into four clusters based on bibliographic coupling, as shown in figure 6. The framework that we achieved after analysing the clusters have been shown in fig. 7.

CLUSTER 1: ISSUES, DIGITALIZATION, SUSTAINABILITY PRACTICES AND TECHNOLOGY ADOPTION IN HEALTHCARE SUPPLY CHAINS

Thirty articles contribute to this group to better understanding of research status in healthcare supply chains. Few studies discuss the issues faced by healthcare supply chains. Some publications argue that the healthcare industry must go digital and adopt Industry 4.0 technologies. Only a few studies address the new developments in pharmaceutical supply chains and the sustainability of technology adoption.

i) Healthcare supply chain issues:

Dong et al. [34] discuss the need to improve the decision-making of healthcare supply chains through simulation and modeling. The authors propose simulation models for various healthcare supply chain issues like optimization of drug inventory, supply chain logistics, sterilization logistics, etc. They discuss adoption challenges such as implementation cost, complexity, and applicability of simulation and modeling techniques to healthcare supply chain problems and suggest which emerging technologies will support simulation and modeling in the healthcare supply chains [35].

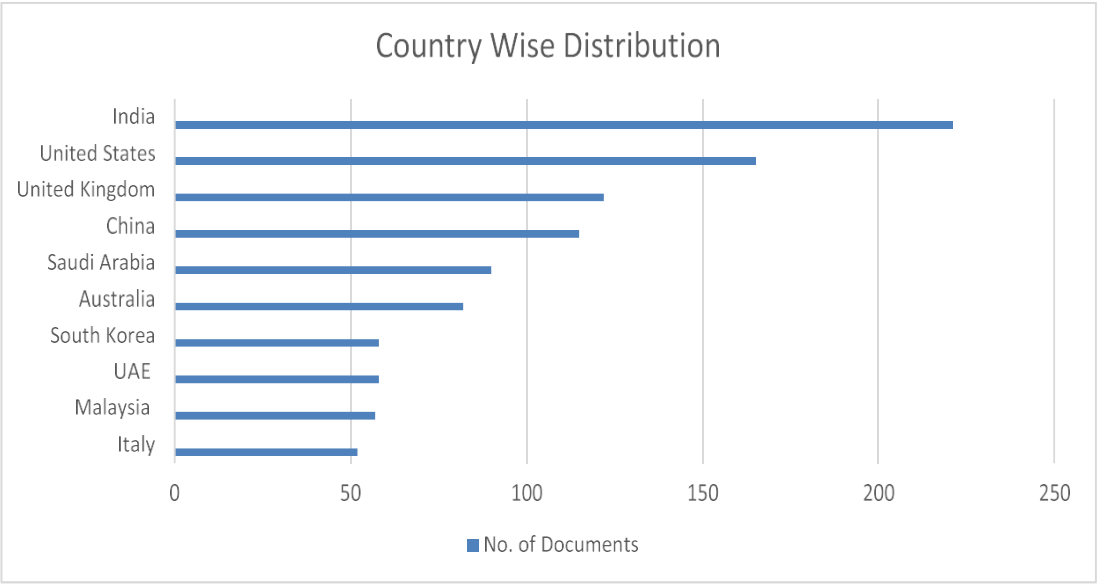

FIGURE 4. Documents produced by countries.

Dong et al. [34] study the potential issues and relevant areas of healthcare supply chains that need improvement. Analysis of areas like inventory management, information technology use, performance analysis, supply chain operations, and leanand agile operations has been done before. More focus should be paid to healthcare-related issues such risk management, cold chain management, employee training, waste management, visibility and tracking of medications, and humanresource practices [36].

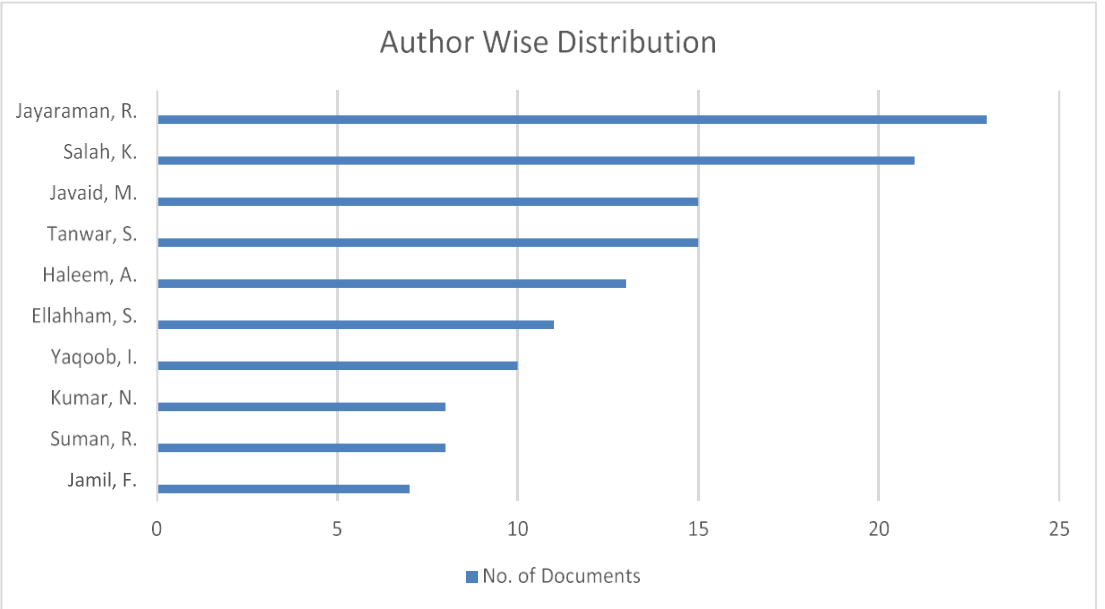

FIGURE 5. Documents published by authors.

Jayaraman et al. [37] discuss healthcare product management challenges like product recalls, counterfeits, expiration,and item shortages and suggest using IoT-blockchain-based solutions to address them. Blockchain and IoT are emerging technologies, but smart contracts applications can help overcome healthcare supply chain issues.

Kritchanchai et al. [38] explore information and material flows across various entities of healthcare supply chainsat macro and micro levels. The micro level method is an exploratory case study with the hospital as the focal point, while the literature on supply chain management and logistics in the healthcare sector is assessed via a macro level analysis [39].The authors conclude that both the business and supply chainlayers of the healthcare supply chain can achieve efficiency.The organizations' main concerns are patient safety and process efficiency at both levels. Duque-Uribe et al. [40] identify the main problems with the healthcare supply chains in response to COVID, i.e., low initial supplies, sudden demand rise, low supply from the suppliers' side, and trust breakdown among stakeholders proposea framework to deal with the shortages. The authors report that the lean method of healthcare models is inappropriate and can compromise both public health and national security.In addition to public health measures like travel restrictions,comprehensive testing, and worker protection, a robust supply chain is required to prevent the pandemic. The supply chain becomes more efficient when blockchain technology is used [41].

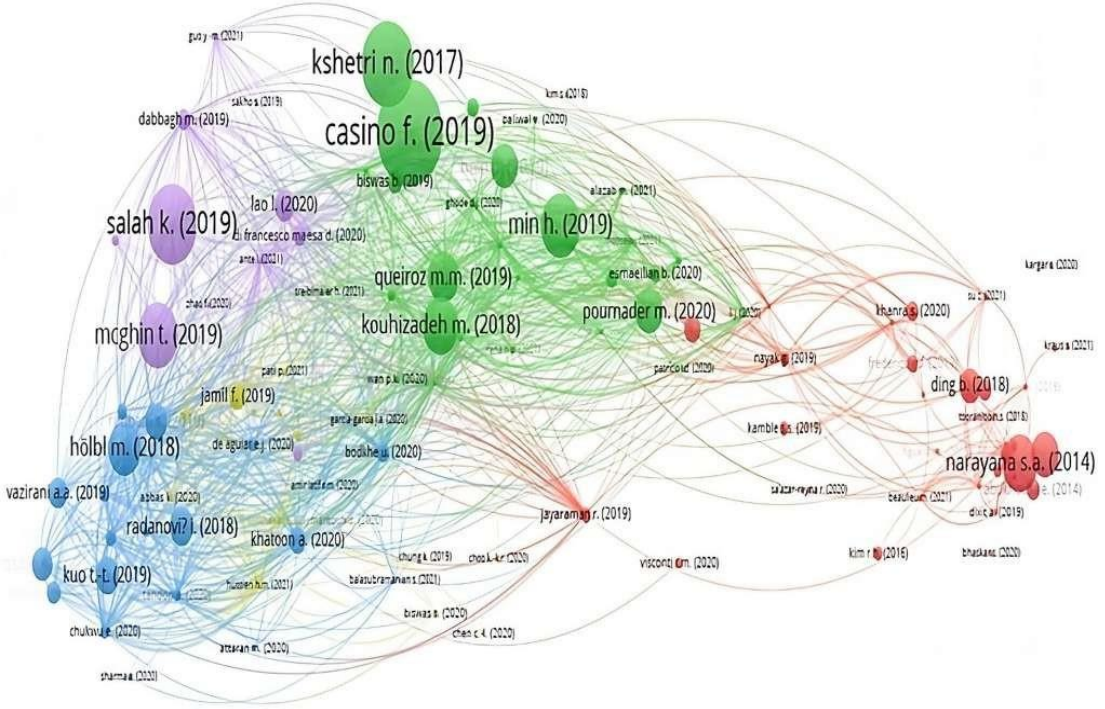

FIGURE 6. Bibliographic coupling analysis of involved documents.

ii) Parameter's influence on performance, technologyadoption and digitization of HCSs:

Kim et al. [42] conducted a review on healthcare quality focusing on technological and managerial innovation. The authors present diverse views of the pharmaceutical industry,

hospitals, health insurance providers, and researchers worldwide on innovation and healthcare quality. The perspectives of healthcare policymakers and the empowerment of healthcare consumers are necessary to manage healthcare quality better and improve healthcare services.

Mandal and Jha [43] explore the importance of the collaborative asset in healthcare supply chains with respect to hospital supplier integration. The resources include group decision-making, planning, and implementation. Hospitalsupplier integration is positively influenced by all three of these dominating forces [44]. Integration of hospital suppliers hasa favorable effect on operational effectiveness.

Yoon et al. [45] examine how supply chain innovation and leadership affect hospital growth and efficiency. Supply chain innovation helps improve healthcare operations management, thus impacting organizational performance for hospitals over 500 beds.Extracting required information from end customers andlinking it through IT systems helps improve supply chain efficiency.

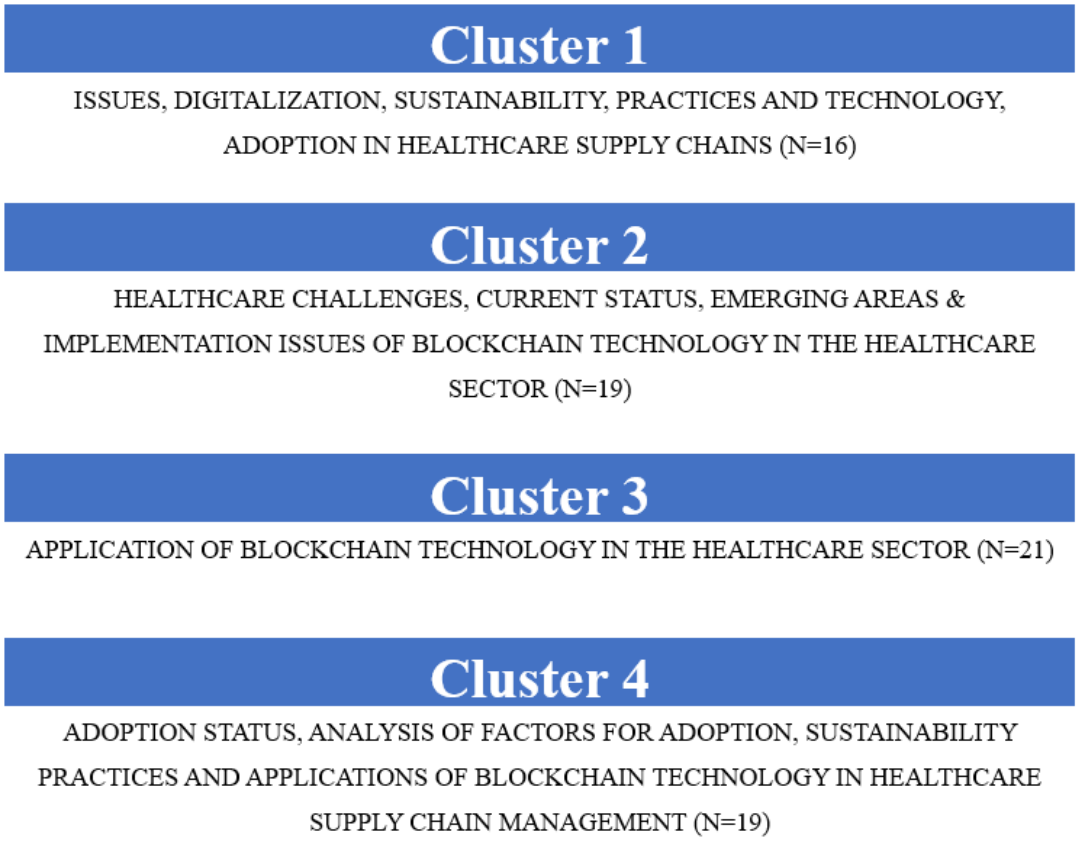

FIGURE 7. Framework for analyzing the systematic literature review (SLR).

Esmaeilian et al. [46] assess the impact of using RFID and EDI jointly on hospital performance. The results show thatthe hospitals using RFID and EDI must bear lower supply costs, thus boosting supply chain cost efficiency. They arealso linked with lower personnel

expenses with time, leadingto a rise in labor efficiency. No significant relationship isfound between RFID-EDI use and hospital readmission rates.Figueroa et al. [47] implement attribute-based access control model in RFID based on blockchain technology inhealthcare. An access control system avoids healthcare assetsentering the wrong area due to external risk or human error.Blockchain solves the financial, technical, privacy and security challenges of RFID, thus acting as an asset for healthcare environment when combined. Frederico et al. [48] explore the drivers for technology adoption in healthcare systems of UAE using AHP. Using stakeholder theory, the authors ascertain what drives patients,staff members, UAE nationals, and foresight specialists to make the necessary adoption. Government assistance, infrastructure, information exchange, lean and green management,the environment both inside and outside the company, and social sustainability rank among the top considerations. Frederico et al. [48] propose a conceptual framework based on four constructs i.e., technology levers, strategic outcomes, performance requirements and managerial andcapability supporters. The proposed framework increases thestakeholders' interest and helps interested businesses in betterexploration of supply chain 4.0 concepts. Tortorella et al. [49] assess the adoption of healthcare technologies on hospitals' performance and identify associated barriers for implementation. The implementation andmaturity level of healthcare 4.0 vary considerably acrossthe hospitals analyzed. The technologies positively impact hospital performance and their interaction with barriers are analyzed to understand the influence on hospitals. Gupta et al. [50] identify supply chain performance driversbased on digitization technologies and prioritize them usingBest Worst Method. The most relevant drivers found in the study are tracking products, appropriate studies for technology selection, and big data adoption. Appropriate technology selection and implementation like industry 4.0, blockchain, etc., help top management bring substantial upgrading in thesupply chain operation.

Visconti and Morea [51] discover that healthcare digitalization influences pay for performance incentives and projectfinancing in smart hospitals. Many healthcare problems likepaper data, last-mile unavailability, performance management, fewer diagnostic services etc. can be dealt with the help of digital investments that help achieve sustainability. Digitaltechnologies help reduce congestion in hospitals, manage big data timely, and even be useful for disease observation in bigpandemics like COVID. Garcia-Garcia et al., [52] stress the importance of the digitalization of healthcare supply chains to bring flexibilityand improve efficiency. The authors propose initiatives fordigitalization that assist managers in improving hospital supply chains. These initiatives' identification is based on foursupports, i.e. (a) healthcare stock management, (b) medicalsupply management in operating rooms, (c) internal supplychain improvement, and (d) creating more dynamic logistic networks. Kraus et al. [53] present the state of digital transformation in the healthcare industry. The study classifies articlesinto five categories – patient-centered approach, healthcare organization's operational efficiency, workforce practiceimpact, organizational factors, and socio-economic aspects.Patient-centric approaches, meaningful use of digitalizationtechnologies, and proper data management help adopt digital healthcare models and improve the whole healthcare process. Hopkins [54] observed that larger organizations are more digitally equipped than smaller enterprises and that small expenditures in specific industry 4.0 technologies increase supply chain performance.

iii) Pharmaceutical supply chains and sustainability improvement in healthcare supply

chains:

Pedroso and Nakano [55] stress the importance of technical information flows in pharmaceutical supply chains and their significance in demand creation. Flows of technical information, financial, material, and order information need a properalignment for the effective working of pharmaceutical supplychains, especially those whose success depends on timelydelivery. Narayana et al. [56] share insights that research interests have also shifted from pharmaceutical supply chains working in the manufacturingenvironment to the healthcare industry and fiscal entities. According to Ding [33], potential hindrances to sustainability adoption in pharmaceutical supply chains includeimproper regulations, high time and cost involvement, less trained manpower, lack of coordination across the supply chain, poor customer awareness, etc [57]. The author concludes that industry 4.0 based solutions can help overcome these barriers by enhancing the flexibility of drug supply chains, proper waste management at various stages, co-ordination improvement, and improving the supply chain managers' decision making.

Hussain et al. [59] share a structure to identify, categorizeand prioritize social sustainability motivators in healthcare supply chains using AHP. The stakeholders' (employees, patients, government, and suppliers) views are taken to accomplish the study. Five categories comprise the motivators: innovation and technology, excellence and awards, attitude, media and reputation, and organizational practices. Kargar et al. [58] develop a tri-integer linear programmingmodel to design medical waste reverse supply chain. Thethree objective functions of the analysis are to minimize totalcost, minimize medical waste and maximize the best wastetreatment technology under sustainability conditions. A real case study is also conducted in the Babol area of Iran to validate the findings. Supply chain managers can act accordinglyand make better strategic decisions with the results obtained.Guo et al. [60] shared insights about blockchain and pharmaceutical supply chains nexus. While it has accelerated since COVID-19, blockchain-related research in pharmaceutical supply chains is still advancing slowly when compared to other industries. Tooranloo et al. [49] study factors impacting sustainableelectronic supply chains in healthcare establishments. Infrastructure and technology management are the two primary factors affecting the sustainability of electronic supply chainsin the healthcare sector.

CLUSTER 2: IMPLEMENTATION OF BCT IN HSC

In this cluster, twenty-three studies add to the literatureregarding the present scenario of research and adoption of BCT in HSCs. Few articles discuss healthcare challenges and the blockchain features that help resolve them. Limited studies present healthcare stakeholders' views about blockchain and their problems in this sector. Some articles propose current areas of focus of researchers and managers and the emerging areas which canbe worked upon in this area. Blockchain limitations, type ofconsensus algorithm, blockchain mainly used, and benefits of this technology in the HSCs are also debated. The research state of blockchain applications in healthcareis presented by Holbl et al. [62]. Blockchain is still in its infancy and has just lately made its way into the medical field. In this topic, most of the research has been done on data exchange, access control, and electronic health records [61].The following topics can be researched in the future: medicalbilling, supply chain management, audit trail management, and medicine counterfeit prevention. Different blockchain types may have their applicability

for different biomedical applications, but the authors suggest consortium blockchain as the most practical solution as it provides both efficiency andimmutability at a low cost [63].

Vazirani et al. [121] study the feasibility of blockchain forhealthcare record management through a systematic literature review. Most studies discuss potential benefits and drawbacks without any evaluation of their usefulness. Only a few practical implementations are performed. Appropriate standards and suitable guidelines can improve interoperability without compromising the privacy and security of patients. Hussien et al. [64] present blockchain use in healthcare considering the stakeholders' views and issues they face. Different stakeholders like healthcare providers, patients, insurance payers, research organizations, and pharmaceuticalsupply chain entities face various issues of EMR installation,fragmented patient records, need for patient control medical records, fake bills, drug counterfeiting, etc. Blockchain-based systems face challenges after their adoption in healthcare, including scalability, 51% attack, environmental sustainability, confidentiality, anonymity, and data privacy issues. According to Hylock et al. [65], blockchain applications are largely used in medicine. Blockchain technology is mainly investigated for availability, integrity, security, decentralization, and authentication. Blockchain platforms like Gem Health Network, OmniPHR, MedRec, MeDshare, and others facilitate patient-controlled healthcare data exchange.

Petticrew and Roberts [66] discuss smart contracts' security, applications, and performance aspects for blockchainapplications. Resource sharing,record management, and access control are the areas wheresmart contracts contribute significantly to healthcare, IoT, and the supply chain. Ramzan et al. [67] analyze the blockchain consideration for healthcare information systems. Blockchain benefitshealthcare systems by providing better sharing of medical information and its security, improving audit access, managing pharmaceutical supply chains, and storing both on-chain and off-chain data. Researchers focus on fraud detection, improvement of EMR systems, privacy, and security considerations, and blockchain's integration with other technologieslike IoT when considering blockchain for healthcare systems. Thome et al. [68] survey strategies based on blockchain for healthcare. Blockchain in healthcare is a recent concept, and its applications started gaining popularity in 2016. Early applications of this technology included sharing medicalrecords, managing the supply chain for medications, and remote patient monitoring [69]. Proof-of-Work and PBFT are the most popular consensus protocols for blockchain-supported healthcare applications because they are easy to implement on Hyperledger and Ethereum.

Blockchain use inhealthcare is getting attention and investigation, but most ofthe published work in this area is conceptual in nature and includes framework proposals and experimental prototypes.Further investigations into the technology's actual application in real-world settings are required. Blockchain addressesconcerns with trust, security, and privacy while maintaining storage costs and necessary performance [70]. The system helps collect data from multiple providers, secures provider-patient contact, and enhances public health management. Dhingra [71] studied the role of BCT implementation in healthcare industries, challenges toface, and opportunities created. Blockchain's transparency, immutability, decentralization, and suitability help reduce operational costs, improve data integrity, access control andhelp in interoperability and provenance of medical items. Baker et al. [72] analyze the applicability of blockchain solutions for Industry 4.0 applications. Systems presently using blockchain

applications in healthcare include MedRec, MedShare, EHR, etc. Logistics comprise RFID systems,food traceability systems, and performance systems in the supply chain. The authors discuss open healthcare issues like patient data management, main patient indices, clinical trials, data provenance and integrity, data enrichment, and drug traceability and suggest using blockchain and industry applications to solve them [73]. Supply chain issues like counterfeiting, authenticity, provenance tracking, and inefficiency deserve attention, and blockchain significantly impacts theseproblems.

Difrancesco et al. [74] assess and prioritize the implementation of healthcare 4.0 in hospitals with the help of quality function deployment. Digital integration within healthcare establishments is limited to specific sectors, departments, or processes. The common problems in both studies are lackof supply chain education, association and incorporation, mismatch between demand and supply, and improper data investigation to support decisions. The study highlights that current research focuses on using blockchain to create safe EHRs and protect patient privacy [75]. The integration of blockchain with other developing technologies has not been extensively studied. Mulligan et al [76] describe various applications of blockchain in the field of health care; the key components of blockchain are EHRs, access permission and exchange. However, the study re-emphasizes the fact that areas such as prescription drug management are still barely researched and developed, pointing to a gap in the development of these applications [77].

CLUSTER 3: APPLICATIONS OF BCT IN HEALTHCARE

Many authors have examined the various applications of BCT in the healthcare sector. Electronic medical records, the medication and blood supply chains, vaccine-based applications, specialty applicationslike telemedicine and oncology, and other applications like Covid and carbon trading are all covered by these applications.

i) Healthcare data and electronic medical record based blockchain applications:

Clauson et al. [78] introduce a blockchain-based notarization service that helps in the certification of the medical databases search and the outcome of the search by employing smart contracts. This architecture ensures data authenticity and database transaction cannot be reverse, the implemented versioning of data. They guarantee that no other person or applications can modify the data as it confirms the query as well as the retrieved data [79]. Ismail et al. [80] propose a lightweight blockchain structure to enhance the storing of healthcare data. Compared to the Bitcoin network, this architecture affords a higher transaction per second rate by reducing cinder and compute overheads. It also addresses scalability and energy issues that are associated with block chain systems like Bitcoin. Jamil et al. [81] describe a hypothetical healthcare blockchain system aimed at improving effectiveness of medical therapies. It is helpful for physicians to recommend appropriate medication according to the history of the patient. It preserves, retrieves and archives medical records and delivers them to other hospitals during patient referral eliminating the need to ferry paperwork.

Janssen et al. [82] discussed sometime on access control of Electronic Health Records using blockchain and smart contracts. They also explain how smart contracts help enforcing specific access control policies where the network is permission less and provide examples in MedRec and BHEEM. However, the problems of attribute revocation and scalability and latency and

outsourced data privacy in the use of BCT for Cloud chain, and similar cloud-integrated systems remain challenges when considering EHR access control. Kalla et al., [83] suggest a knowledge-driven blockchain for the operationalization of the HLDS in the context of IoT, wearables, sensors and health care gadgets. The method proposed in this work ensures proper and safe storage of records in side chains with preserving patients' logs and records' confidentiality and ensuring their immutability. Khatoon [84] introduce a blockchain-based system to share Electronic Medical Records (EMR) among institutions. Their design ensures countersignature; diff. Message integrity; recipience against replay attacks; forward and backward secrecy; and user anonymity. This technique reduces the time and costs associated with repeated testing and minimizes unnecessary consumption of medical resources [85].

ii) Blood, vaccine, and drug supply chain based blockchain applications:

Kleinaki et al. [86] designed a cold blood chain system based on BCT. The proposed design ensures visibility throughout the cold chain and avoids blood supply delays by reducing emergency blood transfer time. This, benefit hospitals away from blood banks. A blockchain based drug supply chain integrity framework for a new hospital [87]. The model was built using Hyperledger Fabric that ensures the safety of the administration of the drug supply chain. Tests show that the system increases echo throughput, reduces echo latency, and optimizes spatial resource utilization, which resolves medicine supply chain problems. A blockchain based method is used to counter the effect of counterfeit drug sales [88]. It guarantees that cure prescriptions are verified and prohibits industrial rights and tax fraudulent practices Masyhalum System The system is tied with medical software that will be integrated with to our banking software that manages money inward through levies, taxes, and sales for verification purposes to avoid ghost spirits. The technology provides verification that medications have been verified and helps improve the credibility of the supply chain [89]. Kshetri et al [90] reduced the underutilization and overproduction of COVID-19 vaccine waste through a blockchain based solution. This smart contract-based system ensures traceability, security, transparency and trust, and was validated against existing solutions. Using smart contracts and the trustful blockchain in a blockchain based vaccination monitoring system, Kuo et al. [91] have addressed vaccine supply chain problems. The method reduces vaccine traceability and fraud and increases vaccine accountability and transparency. Lao et al. [92] create and demonstrate the efficacy of an Ethereum blockchain network to be used in the health sector of a drug supply chain asset tracking. The concept works with smart contracts and an off-chain storage solution for the purpose of correct drug movement recording. These test findings demonstrate reliability in the use of the technology in smart contracts, energy efficiency in the technology, and economic viability for the use in drug safety.

Blockchain applications for specific areas of healthcare:

Li et al. [93] share blockchain applications fordata sharing in oncology. The technology helps in better data sharing and helps in optimizing pharmaceutical supply chains in oncology with the help of its features like traceability, transparency, and immutability. There is a lack of implementation of real-world models in oncology due to less interoperability, existing regulations, and the sensitive natureof healthcare data. Blockchain can help overcome the centralized nature of telehealth services and can bring improvement in telehealth and telemedicine by offering transparent, secure, reliable, and decentralized remote healthcare

services [94]. Liu et al. [95] discuss the applications and future trends of blockchain based waste management systems. The authors discuss how blockchain can help improve identification and tracking of waste generated in hospital environments.

CLUSTER 4: APPLICATIONS OF BCT IN SCM FOR ADOPTION, SUSTAINABILITY PRACTICES IN HEALTHCARE PRACTICES

The studies in this cluster offer perceptive viewpoints on supply chain management applications of BCT as it stands today. Most of the studies that are being given go over the adoption scenario that exists today and the variables that affect supply chains' implementation of new technologies. Some articles discuss the supply chain issues and blockchain's involvement in improving supply chain resilience, quality management, security, and privacy. There is a dearth of research on how the technology's adoption affects supply chains' sustainability and how it might be used for vaccination oversight and blood cold chain management. A comparison table of the studies in cluster 1 has been shown in table A3 of annexure.

i) BCT's potential, adoption status and its integration with supply chains:

Liu et al. [96] investigate the present status of BCT across various sectors through a systematic literature review. The authors cover healthcare, supply chain, business, data management, privacy, IoT, etc. They suggest its high ability to alter the supply chain by bringing accountability, transparency, and flexibility to the networks. Proper choice of blockchain type and the associated processes are essential for the critical needs of different industries. As the technology's maturity rises, it is expected to penetrate deeper into other industries. Mandal et al. [97] throw light on the research status of BCT in logistics and supply chain management using bibliometric analysis. In combination with BCT, IoT fixes the infrastructural gap in data quality. Blockchain's decentralized consensus among the supply chain entities and automatizing the processes using intelligent contracts solve the traceability gap of supply chains. Marbouh et al. [98] observe many sectors like manufacturing, aviation, technology, finance, healthcare, etc., and present status and various insights about blockchain's implementation. Blockchain disrupts supply chains through proper data management, transparency, responsiveness, and operational efficiency improvement. Re-engineering of supply chains, supply chain resilience, sustainability adoption, and business process management are the booming areas of research interest.

Marques et al. [99] study blockchain and supply chain integration and shed light on its applications. The integration is nascent and can bring disruptive improvements in supply chains. It will change business-to-business relationships as well as customer-to-business and customer-to-customer relationships. Industries like transportation, power, and healthcare utilize this integration and set a standard for other industries to adopt. McGhin et al. [100] analyze the application of blockchain on supply chain and logistics and transportation industries using systematic literature review. Their review classifies pertinent material into four principal themes: the extended conceptualization of global trade by exploring the relationships between the facets of, trade, trust, technology, and transparency, using co-citation analysis. This study highlights the need to apply BCT for practical uses that solves supply chain issues. This integration requires the application of appropriate tools and technology such as the IoT for Improved supply chain transparency. Increased supply chain visibility increases

reliability and sustainability to support better and more dependable logistic operations.

Ali et al. [7] study BCT's influenceon various sectors through a systematic literature review. The impact is analyzed concerning three dimensions: benefits such as economic, strategic, organizational, technological, etc., challenges like environmental, adoption, operational, technological, etc., and functionalities corresponding to data ownership, protection of data, transaction processing, etc. Chang and Chen [22] address the revolutionary potential of BCT in supply chain industry, and elucidate its benefits and risks. How BCT transforms supply chain operations enabling automation, augmentation of performance and governance throughout processes is what they explore. Blockchain for supply networks is contingent on granting transparency, traceability, the maximization of stakeholder engagement and a digitalization and connection of supply chains. This research recommends, for future study, many focuses on these domains, especially at the integration techniques, extensive technology distribution, and evaluating of societal implications of effective blockchain use in SCMS. Min et al. [101] investigates the viewpoints of global professionals with respect to the use of the BCT in supply chain management. The main advantages, according to their findings, lie in efficiency and transparency when blockchain is utilised in supply networks. Yet they also identify a host of significant hurdles to adoption, such as lack of data and its authenticity. It is anticipated that block chain will become a fundamental component of supply chain management by 2035, but for this potential to be fully realized, barriers need to be successfully confronted to influence and inform industry leaders' decision making.

ii) Analysis of factors for adoption of BCT in supply chains:

Moosavi et al. [103] consider factors of supply chain management BCT adoption. They argue that their study shows that organizations' predisposition towards new technologies and their preparedness to integrate technology, and member trust all positively affect their intention to adopt blockchain. This paper presents a framework to understand institutional implications of blockchain and its potential impact on the design of intra and inter organizational integrations, for effectively implementing BCT, given the anticipated cooperative approach to realize benefits of blockchain across the supply chain. Interpretive Structural Modelling (ISM) is used by Müßigmann et al. [104] to examine supply chain management blockchain implementation problems. Specifically, the research found that openness, governance, immutability are major impediments to adopting the BCT. This research dissects these concerns and provides management with a means to strategies and execute plans to overcome challenges, resulting in seamless integration of BCT into supply chains. This approach allows organisations to methodically contend with the difficulty and opposition such a transition will produce using blockchain enabled processes [105].

Nguyen et al. [106] discuss the emerging dynamics of blockchain adoption in supply chain management in emerging economies with a special case study of Brazil. They also empirically analyze that social influence, trust, facilitating environments and effort expectancy are important factors in facilitating the adoption of blockchain. Importantly, performance expectancy, the most cited factor for technology adoption, does not significantly contribute to the decision to adopt blockchain in these contexts. This suggests that others elements (social and operational) may be more central to the adoption process in the emerging markets [107]. Biswas et al. [16] construct a framework for barrier analysis of BCT adoption in industry and

servicesectors using the DEMATEL technique. The most persuasive obstacles are those related to market-based risks andscalability, whereas the most influential factors affecting the technology's effective adoption are bad economic practicesand excessive sustainability costs.

Ozturk and Basi [107] identify barriers to BCT implementation in supply chains. The barriers are classified into organizational, financial, technological, and social factors. Blockchain supply chain integration is faster for less complicated supply chains, thus harder for sectors like logistics and healthcare as they form a complex network ofinformation flow, product flow, and finance. The stakeholdersneed to be persuaded of the technology's benefits in eliminating resistance. Choi et al. [24] analyze issues contributing to organization's resistance to blockchain adoption in supply chains. The obstacles are divided into three categories: organizational, environmental, and technology. Regulation constraints, technological maturity, implementation costs, compatibility, scalability, and complexity are the most essential factors [108].

Paliwal et al. [109] investigate blockchain adoption determinants in supply chains concerning organizations' using AHP. Environment-related determinants are found to be more crucial than the organization or technology-related determinants. The most influential determinants include financial resources, top management support, and IT resources, impacting organizations' adoption decisions. Blockchain's integration with Customer Relationship Management or Enterprise Resource Planning deserves future attention to improve organization's efficiency. Alazab et al. [6] examine factors impacting blockchain acceptance through empirical analysis. The authors examine methods to better understand supply chain blockchain adoption behaviour and offer suggestions for improvement. Blockchain adoption is found to be positively influencedby interorganizational trust and trust in technology, whereasadoption behaviour is not affected by social influence.

iii) Blockchain's relevance for sustainable SCM:

Patil et al. [110] concise previous studies on the industry 4.0 applications used for sustainable supply chains. The review of blockchain's capability of sustainability improvement is classified into four categories: tokenization and innovative mechanisms design for promoting greenbehavior, decreasing cost and increasing system efficiency, sustainability monitoring of supply chains, and visibility improvement across the product's lifecycle. The choice of technology and optimized business strategies help achieve sustainable development goals. Patil et al. [110] present an extensive analysis of the potential usage of BCT in supply chains of sustainable supply chains, yet suggest caution on the favourable expectations. However, they promote a balanced view on blockchain enabled sustainable activities recognizing that which is achievable expectation (hope) and beyond expectations promise (hype). The authors emphasize the need for theoretical analysis and empirical studies for a complete consideration of how BCT affects sustainable supply chains. Their question is whether blockchain is really a social innovation tool or whether its utility might be constrained in sustainable contexts, calling for careful study to judge its efficacy and suitableness. Paliwal et al. [109] address the role of BCT to better sustainable supply chain management. Illuminating a few of the factious benefits of blockchain, their findings highlight its advantages of improved data management, access, decentralization, and immutability. As a result, blockchain can become a compelling solution for businesses focused on deploying technologies to advance sustainability. Additionally, the capability of blockchain to revolutionize supply chain stocks may

significantly leverage its impact on sustainability practices, which are becoming generally perceived as the essential means for a company to survive for a long time. The results of this study show that blockchain can increase operational efficiency alongside broader environmental and social governance targets.

Patrício and Ferreira [111] present a systematic literature review on blockchain's use for sustainable development. Scholarly emphasis focused on three research themes: ''business practice and economic sustainability,'' ''agriculture and food security,'' and ''business practice and environmental sustainability.'' Research gaps are categorized into four areas based on the synthesis and assessment of essential studies: theoretical underpinning, methodological limitations, research themes, and obstacles associated with implementing technology. Pournader et al. [112] assess stakeholder perspective for blockchain adoption in sustainable supply chains. The authors found 27 challenges for blockchain adoption through literature search and stakeholder perspectives. The results show that the five main barriers are unclear public data management regulations and disclosure practices, high integration costs, a lack of functional appeal, storage constraints, and a lack of financial incentives. Queiroz et al. [113] provide insights to policymakers regarding blockchain's use for sustainable development through systematic literature review. The SLR demonstrates how blockchain has primarily impacted three aspects of sustainability: supply chains, energy systems, and enabling Internet of Things solutions like smart cities, which allow for the creation of peer-to-peer energy trading networks.

iv) BCT's impact and applications in supply chains:

Min [83] examines the application of BCT to bolster the robustness of supply systems. The discourse emphasises that supply chain risks stem from multiple sources, including technological, geographic, legal, financial, and social aspects. Efficient management of these risks necessitates swift mitigation and reduction of related expenses. BCT is regarded as a crucial instrument for tackling these difficulties, particularly during periods of risk and uncertainty. The emphasis is placed on its ability to mitigate supply chain interruptions, avert dangers, enhance operational flexibility, and improve stakeholder communication. Organisations can utilise blockchain to establish more resilient and transparent supply networks that can endure and swiftly adjust to unforeseen interruptions or environmental changes. This adaptability aids in mitigating immediate risks and enhances the long-term sustainability and effectiveness of supply chain operations. Kshetri [70] evaluate blockchain's significance in providing security and privacy aspects to organisations. Blockchain's decentralized architecture provides solutions to IoT security problems that rely on centralized systems and track causes of insecurity in IoT-driven supply chains. Firms need blockchain implementation to strengthen IoT security in supply chains, which will be mandatory in such cases.

Helo and Hao [49] review studies on BCT in operations and supply chains and present the architecture of logistics monitoring systems based on blockchain. The reference architecture is tested in Ethereum and can be implemented in supply chains using the software. The blockchain architecture's automation, transparency, and trust in supply chains solve issues like managing multiple entities in the network, the need for a shared database, and transparent transactions. Attaran and Gunasekaran [11] discuss the blockchain's impact on industrial

performance. To increase productivity and cut costs, The writers emphasize the advantages of BCT., including decentralization, process integrity, value redundancy, shared control, and data security.The legislative framework, a lack of knowledge and confidence in technology, teamwork, sluggish bitcoin processing,and energy footprint are the barriers to the technology's broad use and removing them can help blockchain produce more. Queiroz et al. [114] explore BCT's impact on information sharing in supply chains. Blockchain's decentralized architecture provides excellent transparency and traceability, thus promoting better information sharing. Blockchain empowered information-sharing benefits all supply chain members and increases collaboration among supply chains such as healthcare, manufacturing, etc [115].

Rana et al. [116] study BCT applicationsfor optimizing supply chain quality management. Reliability of the data records decreased quality control cost, product traceability, and efficiency optimization benefit the framework. Challenges of blockchain framework for optimizing supply chain quality management include suppliers' information confidentiality, high initial investments, interoperability, scalability, incidental cost, and universality of the framework. Patricio and Ferriera [111] research blockchain security using bibliographic coupling analysis. There is a need to provide the right balance between public access and privacythrough blockchain and data protection from unknown elements. Treiblmaier et al. [117] stress the need for cross disciplinary studies on BCT. Generally, studies on the blockchain are conducted in a technical or managerial manner, and other social, legal, and philosophicalperspectives are not given much weight. Better technology exploration can bring more insights to discover the technology's true potential [118].

5. DISCUSSION

As the prior conducted research falls into four clusters, a cluster wise discussion of the topics argued in the papers respective to these clusters has been presented Cluster 1 sheds light on healthcare supply chain issues that need to be sorted out. There are visibility issues that hamper proper tracking of medicines. Employee training andhuman resource practices deserve more attention [119]. Cold chain shipping, medicine counterfeiting, and supply chain visibility are additional challenges faced by pharmaceutical supply chains. The areas that require further research are waste management, risk management, and cold chain management. The cluster proposes that digitalizing healthcare supply chains and adopting proper technology can bring noteworthy improvements in the healthcare sector. It helps reduce paperwork, improve performance, improve diagnosticresults, and enhance sustainability. Initial investments can be high, but they can prove beneficial in long-term investment.This group of studies also talks about the digital technologies' potential to fight against COVID -19 and the challenges it imposes. Problems such as fake information flow, funding distribution, and donation tracking, hampered food distribution and education, and uninterrupted supply of medicines and medical equipment, which are common in the COVID scenario, can be well tackled and managed with the help of technologies like blockchain [57].

Cluster 2 confirms a continuously rising trend in thepublications on BCT in recent years. The areas covered in the papers mainly include computer science,electronics, telecommunications, industrial engineering, and business fields. IEEE Access is the most productive journal and

has the maximum number of publications. India has the most significant number of publications in its name, followed by the USA, England, and China. This group of studies also talks about integrating BCT with IoT, artificial intelligence, machine learning, a cloud of things, etc. Blockchain features include decentralization, security, and trust, and its integration with the technologies mentioned above can help overcome the challenges faced by the technology like scalability and interoperability and improve the flexibility and performance of blockchain-based systems [58], [71], [79].

Cluster 3 shares that blockchain is evolving and has just entered the healthcare sector. Most of the proposals have been conceptual with significantly fewer practical implementations. Clinical trials, patient data management, medication traceability, data provenance and integrity, and main patient indices are among the healthcare-related concerns. The cluster discusses the barriers to technology adoption in the healthcare sector, including data accessibility, blockchain size issues, skill problems, scalability, interoperability, lack of experts, and infrastructural challenges. Post-implementation challenges include sustainability, security, confidentiality, 51% attack, and privacy issues [27]. Effective tackling of these challenges can boost the technology's widespread adoption. Different healthcare applications may require different blockchain types. This group suggests consortium blockchain as the best type for healthcare purposes as many studies support it. Both private and consortium are suitable with proper regulations and guidelines to improve interoperability without compromising security and privacy. OmniPHR, Gem Health Network, MedRec, MeDshare, etc., are blockchain solutions that help in patient-controlled data sharing. There is always a trade-off between blockchain usage's performance and cost. In blockchain-supported healthcare, Proof-of-Work and Practical Byzantine Fault Tolerance (PBFT) are the main consensus mechanisms. The two blockchain platforms most employed in the medical field are Ethereum and Hyperledger. The cluster also talks about the stakeholders' views about BCT's adoption in healthcare. The stakeholders are still hesitant for hosting the technology. Physicians reluctantly clinch the technology, and healthcare service providers often trust healthcare data exchange as the current regulations don't support the same in an anonymized form. The adoption of blockchain necessitates work force training, human resource development, infrastructure and adaptation to a present circle or style of functioning. There issues of an imprecise framework and legal accountability over security, privacy and medical blunders has led to uncertainties on use of the technology by the stakeholders [24].

Most of the published studies mainly concentrated on healthcare data management and medical records management. Many proposals have been given, like lightweight architectures, innovative contract based systems, and health log data management systems to manage sensitive healthcare data. These applications help maintain patient-controlled, decentralized healthcare records that other users can access on the patient's agreement. Other proposals consider a blood cold chain management system to avoid delays in real-time access of blood to hospitals, vaccine supervision systems, and drug supply chain management systems for tracking drugs and reducing drug counterfeiting. The area-specific applications include sharing healthcare data in oncology and tele healthcare, and telemedicine. Other various technology applications in healthcare include COVID-based applications and uses in carbon trading.

The possibility of supply chain disruption due to BCT is covered in Cluster 4. Supply networks are just now starting to apply BCT. According to the studies in this cluster, supply chain problems including origin, authenticity, counterfeiting, tracking, and inefficiencies can be

resolved by BCT.Systematic data management, decentralization, immutability, traceability, and transparency offered by the technologyhelp reduce costs and achieve other supply chain objectives like speed, sustainability, trustworthiness, flexibility, andrisk management. The authors justify that using blockchain means incorporating more automation, involving fewer people, reducing interactions, and less paperwork to help achieve the objectives [16]. Transparency, traceability, automation,and trust are the major advantages of the technology. It helps improve customer-related and business-related relationships. The supply chain's stakeholders will feel more confident when technology is used since it can provide improved information sharing and supply chain quality control. It assistsin keeping supply and demand from being out of balance. Blockchain contributes significantly to supply chain resilience and risk management, as well as enhancing supply chain privacy and security. Supply networks can become more sustainable with the help of technology. Poor economicbehavior and high sustainability costs act as barriers to sustainable development. The studies argue that the technology's coordination with modified business strategies helps attain sustainable development goals [71], [13].

This cluster also expresses that many organizations are still in doubt regarding the technology's adoption due to high implementation costs, scalability, interoperability, and lack of trust in technology. Other possible reasons include security, privacy, energy footprints, compatibility, and network complexity that deserve workable solutions. IT resources, financial backing, and government and top managementsupport are needed to achieve this. Proper governance and standard regulations are desirable to make the blockchain systems interoperable. High investments are necessary to hire blockchain developers, and proper training needs to be imparted to the working staff regarding the technology's use. The studies stress a need to change business strategies to impact the technology after adoption better. The authors propose that blockchain is not the solution for every problem in supply chains and should be implemented only after analyzing its benefits and drawbacks [26].

6. IMPLICATIONS, LIMITATIONS AND FUTURERESEARCH DIRECTIONS

This work offers relevant evidence to researchers, practitioners, policymakers, and managers regarding blockchain's use in the healthcare system. Theoretical contribution, managerial consequences, limitations, and future research objectives are explored in the sections that follow as:

A. THEORETICAL CONTRIBUTION

This review paper takes significant theoretical steps towards blockchain research, specifically in the healthcare context. This study aims to synthesize up to date research on BCT in healthcare by presenting perspectives of leading researchers driving the development, use and how BCT is to be conceptualized and understood. The paper augments the existing body of related knowledge by incorporating recent, insightful studies on blockchain in healthcare use. A structured literature overview is elaborated, as the contributions of various researchers are systematically analyzed via formation of clusters. It reviews published works but, at the same time, positions itself as a basis for future research directions grouped by clusters. The overall dynamics and trends in Indian healthcare supply chains are provided in this report.

For assessing blockchain research in healthcare supply chains, we propose a novel approach to assess four clusters of papers following the SWOT analysis, in which strengths and weaknesses of the first two clusters and opportunities and threats for the last two clusters are discussed. Yet 62 years after the introduction of trichloroethylene as an anesthetic, this review extends the literature well beyond a mere review of chemical structure, based on historical and contemporary research and contains several potential areas for future inquiry. Despite voluminous review of the literature in this area, there is a strong requirement for empirical and mathematical research to verify and extend results to different contexts.

The paper further looks at the current transition to blockchain enabled healthcare systems, also indicated the paucity of works that have documented the extent to which healthcare organizations have realized significant financial benefit from this technology. Part of the reason lies in the absence of detailed reporting which adds to the lack of empirical data, and as such, accounts of BCT's effects are predominantly anecdotal. This suggests more research in this area to find real world practicability and true value in using blockchain in healthcare. The findings and framework developed in this study will serve as priceless tools for academic or research organizations seeking to implement BCT in healthcare in practice. This report suggests many study directions that may spur effective investigations on the pros and cons of blockchain integration in Indian healthcare. As mentioned, additional practical investigations can overcome theoretical constraints and improve blockchain technology adoption in healthcare.

B. MANAGERIAL IMPLICATIONS

The results of the study discussed in this paper provides essential insights into the Indian healthcare sector managers, especially in the supply chain, for the importance of digitization efforts to turn to BCT. Healthcare supply chain managers fill a key, but often overlooked role. Consequently, the senior management must recognize their role, make the right investments that can spur innovation and operational efficiency.

In corroboration with the study done, it presents a novel viewpoint of the supply chain managers' duties by referring to other studies that present how BCT can be incorporated within the Indian healthcare system effectively. BCT presents a raft of benefits to healthcare including transparency, traceability, immutability, and a decentralized framework for delivering consensus driven processes. This is important to improve the supply chain management in the healthcare industry. In the supply chain, blockchains will make it easier to manage accountability, monitor pharmaceutical and medical devices, and prevent fraud. The entire healthcare ecosystem could benefit by a more secure, efficient and reliable healthcare delivery system. Hospital administrators interested in innovative technology that could improve operations and supply chain management will find this paper to be important. Both preserving its privacy and its security, this can be used to safeguard sensitive patient data and important supply chain information with distributed technology. Real time visibility of the technology helps managers to decrease reported medicine and medical device stockouts and increase inventory levels.

The technology can offer a shared and trusted platform to thedifferent healthcare stakeholders like manufacturers, distributors, pharmaceuticals, regulators, healthcare providers etc. for better coordination and communication among them. To prevent any resistance to adoption, managers

must make sure that stakeholders are informed about the technology and how it is used. Managers can ensure safe and high-quality patient care by tracking and verifying medications and medicaldevices with BCT. Managers need to utilize blockchain functions compatible with other technologiesfor better outcomes. When managers integrate BCT with big data analytics or artificial intelligence to optimize the healthcare supply chain, they can make betterdata-driven decisions.

Governmental organizations and policymakers can build legal frameworks, laws, and standardized protocolsfor interoperable healthcare blockchain networks accepted globally. It is recommended that small businesses obtainBT services from reliable companies, and that strict regulations be implemented by the government to prevent securitybreaches. Practitioners can use the literature provided in thismanuscript to better understand the use of blockchain and make improved decisions for managing Indian healthcare supply chains. This work can help managers better analyze BCT and improve their decision-making regarding its adoption in healthcare organizations. Manychallenges come in the way of blockchain adoption like privacy, security, cost, government policies, regulations etc. It requires exploring the challenges to blockchain's adoption in the Indian healthcare sector by research scholars. Following this, managers can make a roadmap first and suggest strategies for tackling these adoption-related challenges and take advantage of the technology. There is a need for healthcare organizations to adopt suitable business policies before implementing the technology to get desired benefits. Additionally, the blockchain platform can link consumers who are open to having their health data used in studies ina health data marketplace with research organizations. The BCT would allow researchers to connect with patients across the world. This will raise the possible sample size for study and raise the accuracy of the findings.

Early healthcare blockchain installations, we learned early, that adoption would be defined only when the connection point between the HCP, patients, and the pharmaceutical business is redefined. Before rethinking healthcare with BCT, legal, regulatory, and blockchain challenges have to be overcome. Though BCT in healthcare is new, there are so many interesting applications. While the technology hasn't been fully adopted by healthcare, usage will continue to grow in the next years. There aren't many studies on the topic, thus further research with real-world applications will be helpful in the future. The need to promote blockchainadoption is becoming more pressing among academics for additional theoretical research as well as in the business sector for practical implementations, given its potential for efficiency and dependability. Healthcare supply chains mustbe dedicated to having the same goals and principles and must be in alignment with this shared innovation because they are interdependent webs of diverse stakeholders' interests and behaviors.

C. STUDY LIMITATIONS

This review was limited to journal articles indexed in Scopus, ScienceDirect, Webof Science, IEEE Explore, EBSCO, Taylor and Francis and Springer. The search information was restricted to keyword use and other articles were not considered. In addition, articles with blockchain's use in healthcare supply chains were mostly preferred. The primary constraint of this study isthat its findings were pertaining to the phrase ''blockchain in healthcare,'' rather than technologies associated with the healthcare sector. Only English language papers were considered for this study; therefore, cross-cultural differences were not accounted. This

study is a conceptual work with no statistical significance. The research structure is conceptual; to provide a more thorough analysis, subsequent studies should test the stated premises empirically. The systematic reviews lack statistical significance and exhibit some limitations, which are crucial for any quantitative research.

7. CONCLUSION

This paper analyses the present level of blockchain research in medicine and delineating the problems that face the Indian healthcare and supply chain sector, such as medicine counterfeiting, disjointed patient records, and fear of medical data privacy and security, insurance fraud, this text explores how blockchain technologies can tackle these challenges. While it is still in its nascent stage in the healthcare sector of BCT, it has been accompanied by a steady burst of associated publications. India leads in publishing output in the most prolific journal (IEEE Access) followed by it being recognized as the most prolific journal. For the most part, the bulk of research in this field is conceptual, theoretical, and consist of literature reviews, with few empirical analyses and practical applications. They mostly focus on medical data management, medical data sharing and control, and in particular the technology's potential to improve medication supply chains, biomedical research, remote patient monitoring, medical insurance, and education.In health care system, the development of the nation's economy is deeply affected. Currently healthcare is under pressure to address the demand for new solutions that can help to enhance patient outcomes. As for the patient-centered model that will establish a possibility of gaining a quick access to the healthcare services and products, the inventions that advance the health care organization are required. The BCT on the other hand is a feasible solution and which offers better services and adequate care. It is impossible to have anything like that. Nevertheless, even if the number of articles is growing exponentially, it remains unknown which blockchain applications in healthcare have been investigated most thoroughly, and which deserve further investigation. This research study critically discusses and synthesizes the published literature on blockchain uses in Indian healthcare and reveals oversight knowledge areas and research.

Healthcare Blockchain applications include the management of electronic health records (EHRs), overseeing the medicine supply chain, implementing a telehealth solution, monitoring the vaccine, managing the blood cold chain and COVID related projects. These blockchain applications are addressable to the Indian healthcare sectoral with specific demands. Healthcare supply chains can be digitized, and technologies utilised such as blockchain can generate significant progress in tackling counterfeiting, ensuring provenance, tracking, and verifying authenticity. Blockchain can supplement the faith and confidence of healthcare supply network stakeholders. Such research adds to the current information base of policymakers and practitioners. This proposed framework outlines the status quo of this domain with respect to research. However, applying BCT (BT) to the Indian healthcare industry is often hindered by security and privacy concerns, elevated implementation costs, scalability constraints, interoperability issues, complexity, and a pervasive absence of trust. By recognizing such obstacles and designing proper solutions for the same, blockchain implementation in Indian healthcare institutions gets itself persuaded amongst stakeholders.

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