Revolutionizing Healthcare Organizations with Operational Excellence and Healthcare 4.0: A Systematic Review of the State-of-the-Art Literature

Abstract

Purpose- This study examines current research on the relationship between Operational Excellence and Healthcare 4.0 for healthcare organizations.

Design/Methodology/Approach- We have performed a systematic literature review of 102 documents published between 2011 to 2022 from the Scopus database to identify the research trends on Operational Excellence and Healthcare 4.0. Through a descriptive bibliometric analysis, we have highlighted the year-wise trend in publication, top authors, prominent sources of publications, the country-wise spread of research activities, and subject area analysis. Further, through content analysis, we have identified four clusters and proposed directions for future research of each identified cluster.

Findings- Results reflect overall growth in this area, with a few parts of the world being underrepresented in research related to Operational Excellence and Healthcare 4.0. The content analysis focused on describing challenges pertaining to healthcare industries and the role of Operational Excellence tools and Healthcare 4.0 technologies in dealing with various healthcare delivery aspects. We concluded our analysis by proposing a theoretical framework and providing theoretical and managerial implications of the study.

Originality- The article is one of the first to analyze the existing literature on the healthcare sector at the interface of Operational Excellence and Healthcare 4.0 technologies. The conceptual framework and cluster-wise future research prepositions are some of the unique offerings of the study.

Keywords- Healthcare, Operational Excellence, Industry 4.0, Systematic Review

1. Introduction

Supply chain management is a crucial aspect of any business. The ability to successfully manage the movement of goods and services from suppliers to clients is essential for companies to remain competitive and profitable. Operational Excellence is crucial in supply chain operations, ensuring that goods and services are sent to customers at the right time, quantity, and price. Achieving Operational Excellence requires businesses to optimize their processes continually, reduce costs, and improve efficiency (Malhotra *et al.*, 2022). The benefits of Operational Excellence include improved customer service, reduced costs, increased efficiency, and enhanced flexibility (Tlapa, Tortorella, *et al.*, 2022). As such, businesses that achieve Operational Excellence are better

positioned to remain competitive and profitable. The healthcare industry is one of the most critical sectors in any country, and its success is measured by the quality of care offered to patients. Operational Excellence is a crucial component that healthcare organizations can leverage to improve their performance (Tlapa, Franco-Alucano, *et al.*, 2022).

One of the critical benefits of Operational Excellence in healthcare organizations is the improvement of patient outcomes. When healthcare organizations focus on Operational Excellence, they streamline their processes and reduce the likelihood of medical errors. According to a National Academy of Medicine study, medical mistakes cause an estimated 250,000 deaths yearly in the United States alone (Steuerle and Jackson, 2016). Operational Excellence helps to reduce the incidence of medical errors and improves patient safety, ultimately leading to better health outcomes.

Another benefit of Operational Excellence in healthcare establishments is the reduction of costs (Stock and McDermott, 2011). Healthcare organizations are under pressure to provide quality care while minimizing costs. Operational Excellence provides a framework for achieving these objectives. By continuously improving processes and systems, healthcare organizations can reduce waste, eliminate inefficiencies, and optimize the use of resources. A study by the International Journal of Health Planning and Management found that implementing Operational Excellence principles in a hospital setting resulted in a 25% reduction in costs (Chen and Lin, 2018). Operational Excellence also plays a critical role in improving employee engagement and job satisfaction. Healthcare organizations prioritizing Operational Excellence create an ethos of continuous improvement where workforces are empowered to detect and solve problems. This approach increases job satisfaction and engagement among healthcare professionals, resulting in better patient outcomes.

To achieve Operational Excellence, healthcare organizations must adopt a systematic approach to continuous improvement. One such approach is the Lean methodology, widely used in healthcare organizations. Lean principles emphasize the identification and elimination of waste, the optimization of resources, and the reduction of variability (Fortineau *et al.*, 2016; Soriano-Meier *et al.*, 2011). Another approach is Six Sigma, which focuses on reducing defects and improving quality using data-driven methodologies (Kelly, 2016).

The world of healthcare is changing a lot because of new technology and the growing need for better care. Healthcare 4.0 technologies, such as big data analytics and Artificial Intelligence (AI), can help healthcare organizations to identify patterns and trends in patient data, which can aid in improving diagnosis, treatment, and outcomes (Tortorella *et al.*, 2022).

Healthcare 4.0 technologies can help organizations optimize processes, reduce costs, and improve efficiency. For example, Internet of Things (IoT) devices can help to track and manage inventory levels, reducing waste and improving supply chain management (Latif *et al.*, 2022). Healthcare 4.0 innovations have the potential to augment the patient journey by enabling customized care, diminishing waiting periods, and enhancing the exchange of information between patients and healthcare practitioners (Kumari *et al.*, 2018a).

The preceding discourse highlights the burgeoning enthusiasm and acknowledgement of the necessity to combine Operational Excellence methodologies and Industry 4.0 in healthcare to attain enduring enhancements and deliver high-quality healthcare services to patients while ensuring sustainability. This study attempts to study the effect of Operational Excellence coupled with Healthcare 4.0 technologies on the performance of healthcare organizations. We aim to address the succeeding research questions (RQs) through this study-

RQ1. What is the existing state of research in the area?

RQ2. Which authors have made a significant impact by studying the connection between Operational Excellence and Healthcare 4.0?

RQ4. What is the geographic distribution of research and collaboration involving Operational Excellence and Healthcare 4.0?

RQ3. How has the introduction of Operational Excellence and Healthcare 4.0 technologies impacted healthcare businesses?

RQ5. What major research issues need future investigation in the field?

The rest of the article is laid out into specific sections. Section 2 analyzes the existing literature review in the field. The following section discusses the data collection and methodology adopted for the study. Section 4 highlights the key results derived from the descriptive bibliometric analysis. Section 5 covers the findings and discussion of cluster analysis. Section 6 contains a theoretical framework and the study's managerial and theoretical implications. At last, the conclusion is presented in section 7.

2. Literature Review

In recent times, numerous scholars have undertaken the task of examining scholarly articles pertaining to the healthcare sector, with a specific focus on enhancing the operational performance of healthcare enterprises (Awad et al., 2021; D'Andreamatteo et al., 2015). But few researchers have considered reviewing literature exploring the interface between Operational Excellence and Healthcare 4.0 technologies. In Table 1, we have compared some of the past literature review studies concerning the healthcare sector and our study. The comparison reaffirms the need for a more comprehensive and detailed analysis that explores the literature on integrating Operational Excellence and Healthcare 4.0 technologies and acts as a reference for future research undertakings.

Table 1 Comparison of past literature review studies and our study

Criteria	(Aceto *et al.*, 2020)	(Jayaraman *et al.*, 2020)	(Ramori *et al.*, 2021)	**Our Study**
Timeframe	Not specified	Not specified	Not specified	2011 to 2022
Keywords	Industry 4.0 and Healthcare	Artificial Intelligence, Digital Health, and Healthcare 4.0	Lean Six Sigma, lean thinking, and healthcare performance improvement	Healthcare, Operational Excellence, and Industry 4.0

The focus of the study	Analyzes industry 4.0 technologies applied to the health domain. Provides technologies and their applications	Review of current digital frontiers in Healthcare 4.0	A systematic review focusing on lean business models utilized in the healthcare sector	A systematic review focusing on analyzing trends, developing a framework, and suggesting future directions
Methodology	Content Analysis	Wisdom Pyramid	Content Analysis	Descriptive bibliometric analysis and content analysis
Framework Proposed (Yes/No)	No	No	No	Yes

3. Methodology

The methodology employed for this study is shown in Figure 1. Our compilation of articles was derived from an extensive search of the Scopus database utilizing the keywords Operational Excellence, Industry 4.0, and Healthcare. The initial query yielded a total of 621 documents.
Subsequently, we conducted an initial screening to exclude conference papers, book chapters, and review papers from our literature collection. Considering the emergence of Operational Excellence in healthcare primarily after the early 2000s, we limited our review timeframe to the period between 2011 and 2022. Only a scanty fifteen articles were published prior to this timeframe, and hence we have excluded them from our review. This led to the exclusion of 394 articles based on document type and timeframe criteria. Additionally, we scrutinized the abstracts of the remaining papers to identify the target literature for our review, resulting in the removal of 125 articles.
Finally, we arrived at a refined set of 102 documents for the systematic literature review analysis. Our analysis encompassed two key components: a descriptive bibliometric analysis of the articles and a cluster-based content analysis. We also provided future research directions to consolidate our findings from the content analysis. Subsequently, we delved into a discussion where we introduced a theoretical framework based on our descriptive and content analysis outcomes. We highlighted the study's implications from theoretical and managerial standpoints within our discussion. Lastly, we concluded our review by summarizing the study's key points while acknowledging the limitations of our research.

4. Descriptive and bibliometric analysis results

The categorization of the selected articles is structured around six distinct criteria, namely: Year-wise publication distribution, Country-wise publication distribution, Prominent sources of publication, Leading authors in terms of contributions, Major affiliations of authors (institute/organization), and Classification based on subject areas. The bibliometric analysis was

conducted utilizing the statistical package R-Studio, which provided the necessary data and insights for this analysis.

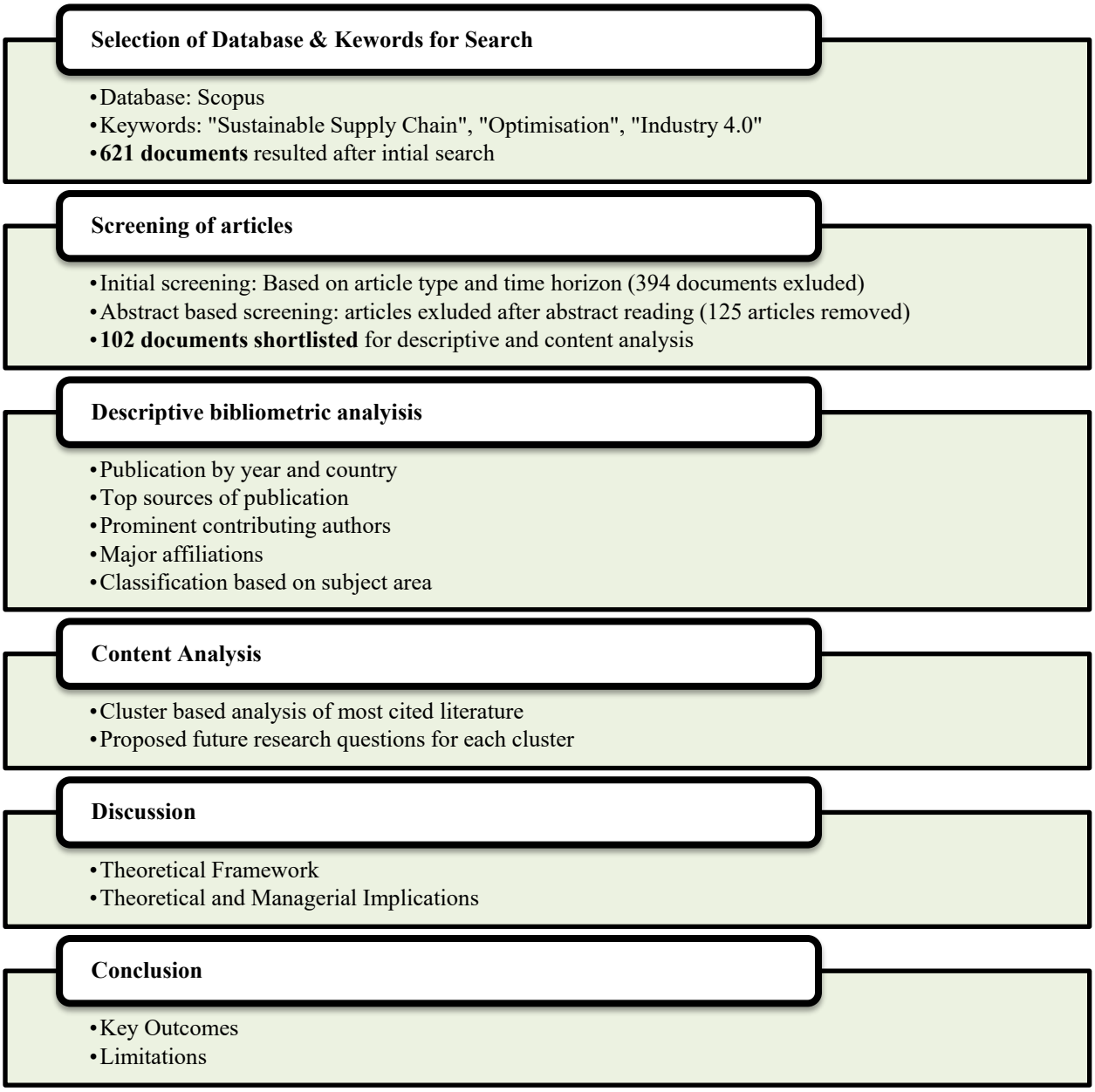

Figure 1 Methodology adopted for systematic literature review

4.1 Publication by year

This examination showcased the chronological distribution of publications focusing on Operational Excellence and Healthcare 4.0. Figure 2 illustrates the progression of publications in this field from 2011 to 2022. Notably, there is a significant surge in the graph starting from 2020,

which can be attributed to the heightened demand for enhancing performance in the healthcare sector following the repercussions of the COVID-19 pandemic. In 2022, the highest number of publications emphasized the importance of integrating Operational excellence with Healthcare 4.0 technologies.

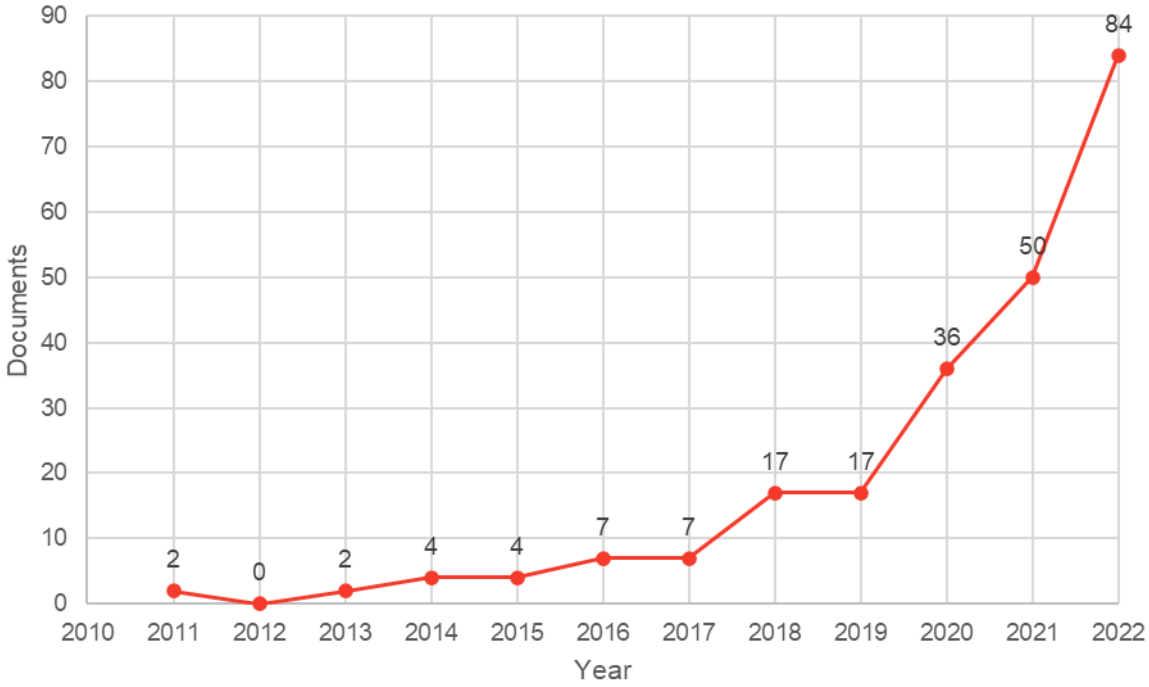

Figure 2 Year-wise publication trend

4.2 Publication by country

Researchers worldwide have shown interest in Operational Excellence in the healthcare sector, considering Industry 4.0 applications. Table 2 illustrates the top ten countries that contributed the most in the area and the number of documents. With 57 papers, India leads the list, followed by the United States, United Kingdom, China, and Italy.

Table 2 Country-wise frequency of articles

Country/Territory	Documents
India	57
United States	32
United Kingdom	31
China	25
Italy	18
Australia	15
Brazil	15

Saudi Arabia	12
Malaysia	9
Poland	7
South Africa	7
Russia	7
Spain	7
Ireland	6
Pakistan	6

To enhance this comprehensive analysis, we visually depicted the global distribution of research in the field, as illustrated in Figure 2. The frequency of articles has been color-coded to provide a clear representation. The white region signifies areas with low research activity, whereas the light red region indicates low frequency. The yellow-coloured region represents a medium frequency of research, and the dark green region represents a high frequency. From the geographical dispersion displayed, it becomes apparent that the research on Operational Excellence combined with Industry 4.0 in healthcare organizations is primarily concentrated in Europe, with significant gaps in representation from various African countries.

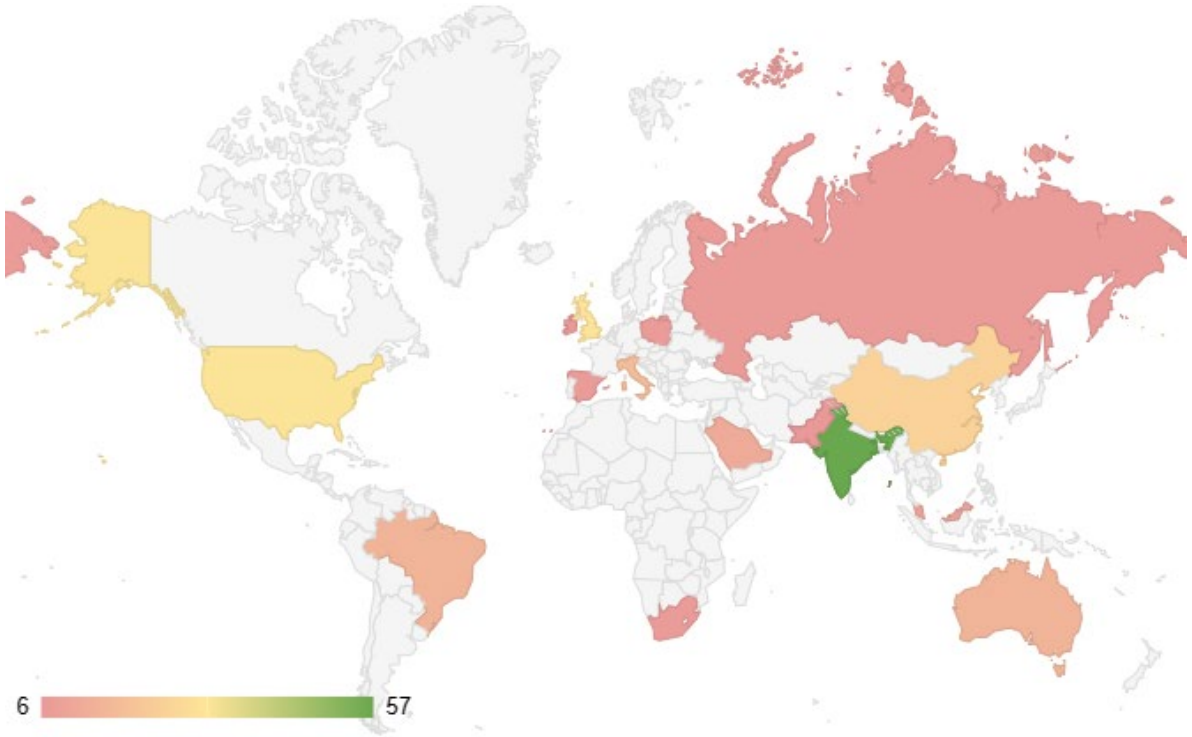

Figure 3 Geographic dispersion of research

4.3 Prominent sources of publication

A total of 621 articles were published across 159 diverse journals. Table 3 showcases the influential journals that have played a significant role in disseminating literature about the employment of Industry 4.0 and Operational Excellence in healthcare organizations. Notable publications such as IEEE Access, Sustainability, Materials Today Proceedings, Wireless Communications, Mobile Computing, "International Journal of Environmental Research and Public Health", Sensors, and "Technological Forecasting and Social Change" have actively embraced research in this domain. The involvement of esteemed publishing houses in these journals underscores the attention this research area has garnered from influential stakeholders.

Table 3 Top sources of publications

Source/Journal Name	Publisher	Documents per year
IEEE Access	Institute of Electrical and Electronics Engineers Inc.	15
IEEE Transactions On Industrial Informatics	IEEE Computer Society	10
Sustainability	M.D.P.I.	6
Materials Today Proceedings	Elsevier Ltd	5
Wireless Communications And Mobile Computing	Hindawi Limited	5
International Journal of Environmental Research And Public Health	M.D.P.I.	4
Technological Forecasting And Social Change	Elsevier Ltd	4
Sensors	M.D.P.I.	4
Electronics	M.D.P.I.	3
IEEE Journal of Biomedical And Health Informatics	Institute of Electrical and Electronics Engineers Inc.	3
International Journal Of Production Research	Taylor and Francis Ltd.	3
TQM Journal	Emerald Group	3
Applied Intelligence	Springer	2
Computers And Electrical Engineering	Elsevier Ltd	2
Healthcare	Elsevier Ltd	2

4.4 Top contributing authors

In this field, a collective effort from 829 authors representing 580 organizations has contributed to the advancement of knowledge through their research publications. Figure 4 illustrates the notable

contributions of individual authors, with Kumar N. S leading the field with five published articles, closely followed by Tortorella G.L with four articles in this domain. The list of distinguished authors also features esteemed names such as Fogliatto F.S., Tanwar S., Haleem A., Javaid M., Suman R., Pieroni A, Rodriguies J.J.P.C, Singh R.P., and Tyagi S, among others.

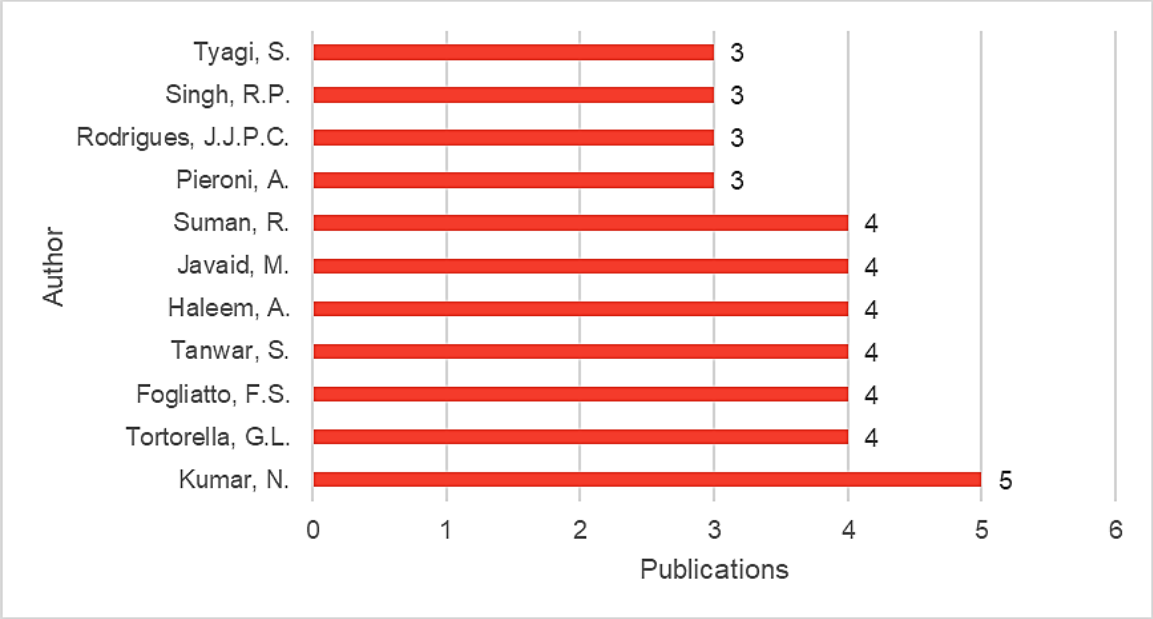

Figure 4 Prominent Authors

4.5 Major affiliations

Numerous organizations from various backgrounds have actively contributed to the research on integrating Industry 4.0 and Operational Excellence in healthcare. Table 4 highlights the leading institutions involved in this endeavour. Rio Grande do Sul, a Brazilian public federal research university with seven published documents, is at the forefront of the list. The University of Melbourne in Australia has contributed with six articles, followed closely behind by, Thapar Institute of Engineering & Technology in India, with five articles. Other notable institutions include Universidade Federal de Santa Catarina in Brazil and Vellore Institute of Technology in India, both with five articles, and Universidad Austral in Argentina and the National University of Singapore, each with four articles, among others.

Table 4 Notable affiliations

Affiliation	Documents
Universidade Federal do Rio Grande do Sul	7
University of Melbourne	6
Thapar Institute of Engineering & Technology	5
Universidade Federal de Santa Catarina	5

Vellore Institute of Technology	4
Universidad Austral	4
National University of Singapore	4
Jamia Millia Islamia	4
University of Petroleum and Energy Studies	4
Nirma University, Institute of Technology	4

4.6 Classification based on the subject area

In this analysis, we have attempted to identify the area-wise distribution of literature on Operational Excellence coupled with Healthcare 4.0 technologies. Engineering, Computer Science, and Business management account for approximately half of the articles published in the area. We have also found evidence of operational excellence and industry 4.0 technologies in subject areas such as medicine (8%), material sciences (5%), decision sciences (5%), social science (4%), mathematics (3%), environmental science (3%), physics, and astronomy (2%) among others.

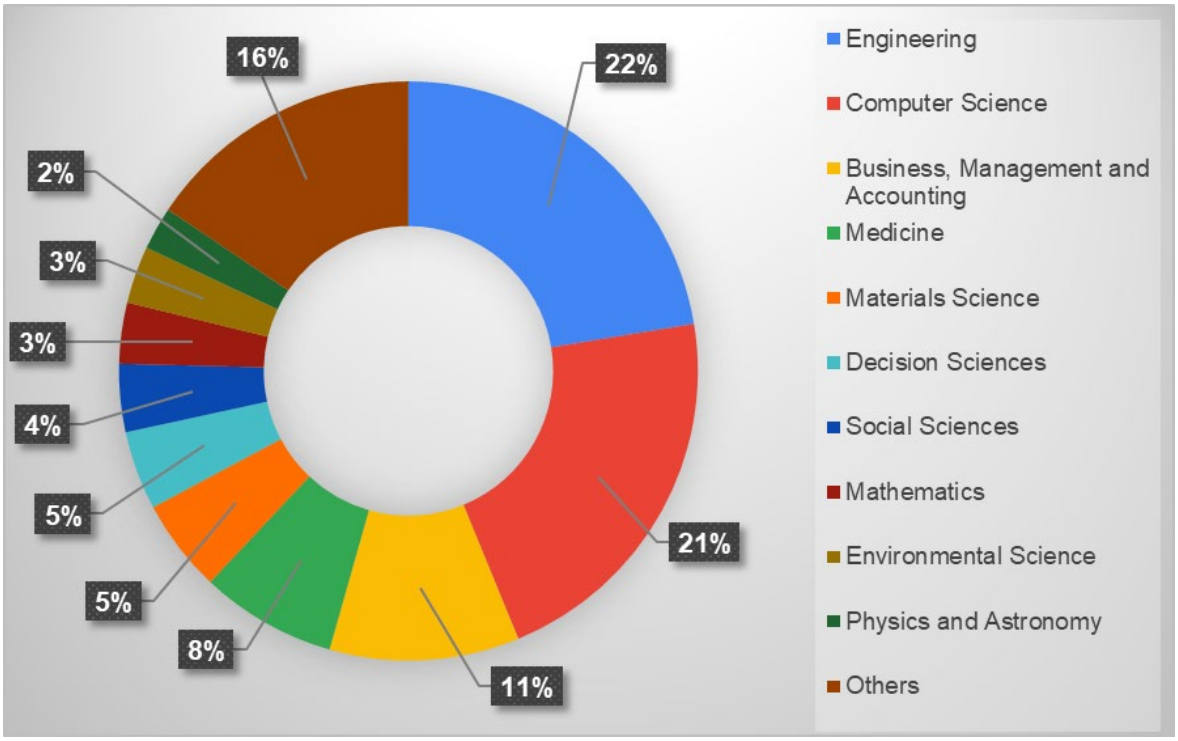

Figure 5 Subject area-wise distribution of articles

High contributions from engineering and business can be attributed to Operational Excellence tools such as Six Sigma and lean manufacturing, which have been inalienable parts of Industrial Engineering. Further, these tools have been successfully implemented in healthcare organizations. Similarly, a high contribution from the computer science area emphasizes the importance of

industry 4.0 technologies such as big data, artificial intelligence, digitalization, and automation in the healthcare sector.

5. Content Analysis

Content analysis is a structured research approach utilized to analyze and comprehend the information communicated through diverse mediums such as written texts, audio recordings, visuals, and videos (TATE *et al.*, 2010). This method involves identifying and categorizing repetitive patterns, themes, and underlying meanings found within the collected data. By employing a well-established methodology, researchers can gain valuable perspectives into phenomena' occurrence, features, and contextual intricacies, thereby enabling the extraction of profound insights and conclusions from the reviewed literature (Kazemi *et al.*, 2019).

So far, we have understood the distinguished themes and underlying trends in the literature concerning Operational Excellence and Industry 4.0 technology in healthcare businesses. In this section, we present the content analysis of our literature review. We have identified four major clusters during the investigation- Challenges in the healthcare sector, Operational Excellence tools, Healthcare 4.0 technologies, and Healthcare delivery. For this analysis, we focused on articles within each cluster that have garnered at least thirty citations. This selection allowed us to delve deeper into the most influential literature within each cluster and identify significant research gaps. By thoroughly examining the literature, we formulated future research propositions to fortify our findings. Within each cluster, we first extensively analyzed the highly regarded literature and subsequently delineated the research gaps we identified. These research gaps guided us in formulating pertinent research questions, aligning with our interpretation of the literature within each cluster.

Cluster 1: Challenges in Healthcare Sector

Cluster 1 has a total of 21 documents. This cluster revolves around the challenges in the healthcare sector and how organizations have devised different strategies to tackle those challenges. Data security and privacy (Larrucea *et al.*, 2020), patient safety (Iyengar *et al.*, 2022), resistance to change, ethical concerns (Dobrzański *et al.*, 2021), regulatory compliances, and technical complexity are inherent challenges in most healthcare supply chains (Jose *et al.*, 2022).

Upadhyay et al. (2021), with 144 citations, critically reviews blockchain technology's present and probable contributions to the circular economy from the perspective of sustainability and social responsibility. The study identifies, collates, and organizes different research on blockchain, focusing on its favorable impact and potential challenges for the ethics objective. The results indicate that the utilization of blockchain technology has the potential to make valuable contributions to the circular economy. It can play a role in minimizing transaction expenses, improving supply chain operations and communication, safeguarding human rights, preserving the confidentiality and well-being of healthcare patients, as well as diminishing the overall carbon footprint. Gupta et al. (2019), which has 90 citations and attempts to provide a comprehensive

examination of advanced applications for mitigating delay using 5G network technology and tactile internet for highly reliable and low-latency use cases such as Industry 4.0, Healthcare 4.0, smart education, augmented reality, and virtual reality. This paper emphasizes the significant distinctions between the Internet of Things (IoT) and the tactile internet within the framework of the 5G revolution. It also analyzes challenges for smart applications and the tactile internet's active issues.

Zolotová et al. (2020), with 76 citations described operators' evolving role in the Industry 4.0 concept. It also introduces the concept of "Human Cyber-Physical Production Systems". The authors introduce various categories of Operator 4.0 and explore methods to amplify their physical, cognitive, and sensory capacities. Additionally, they showcase real-life examples of intelligent and cognitive solutions designed for Operator 4.0. The work presented by Pang et al. (2018), which has 66 citations, examines the progress made in the convergence of biomedical engineering, automation technology, and health informatics. It also identifies the gap between state-of-the-art research and industrial demands. Sarfraz et al. (2021), with 31 citations, discuss the impact of Society 5.0 and Industry 4.0 technologies, such as Big Data (BD) and Artificial Intelligence (AI), on healthcare amenities during the COVID-19 pandemic. The study reviews various technologies being used to control the transmission of COVID-19 and demonstrates how advanced information technologies can be applied to healthcare. The article further explores the transformation of Industry 4.0 into Society 5.0, highlighting the influence of the COVID-19 pandemic in expediting this evolutionary process. Overall, the article highlights the potential for personalized healthcare systems and the role of technology in achieving this goal. Table 5 highlights identified gaps and corresponding future research questions (FRQs) under this cluster.

Table 5 Future research questions derived from Cluster 1

S. No.	Gaps identified in Cluster 1	Future Research Questions
1.	A very high initial cost is involved in implementing blockchain technology, which limits its adoption in some contexts.	• What are the challenges of blockchain implementation concerning legislation and policy development in the healthcare sector?
2.	The concept of the tactile internet is still in its nascent stages, and there are numerous open issues and research hurdles that require attention to unlock its complete capabilities.	• How can the tactile internet be used for smart applications in services, and healthcare? • What are the security and privacy concerns associated with tactile internet?
3.	Future studies should emphasize on investigating the impact of productivity and job satisfaction.	• How does "Operator 4.0" affect the productivity, safety, and job satisfaction? • What are the ethical and social implications of Operator 4.0 in the workplace?
4.	There is a need to study the role of automation and robotics in the healthcare industry.	• How can an automated medical production system be developed to elevate the efficiency and quality of healthcare services? • How can healthcare robotics and human-robot symbiosis help enhance the safety and effectiveness of healthcare delivery?

5.	There is a scope for applying Society 5.0 and Industry 4.0 technologies in healthcare.	• How can a comprehensive data management system be developed to collect, store, and analyze healthcare data for research and policy-making purposes?

Cluster 2: Operational Excellence tools

Operational Excellence tools have helped healthcare organizations establish smart factories, reduce waste, and improve efficiency. This cluster describes how tools such as lean six Sigma (Sordan *et al.*, 2022), root cause analysis, smart manufacturing processes, and automation have assisted healthcare businesses. We have identified 16 articles under this cluster.

Wan et al. (2019), with 78 citations, introduced a data-centric and adaptable production model for the pharmaceutical manufacturing domain within the Smart Factory framework. This innovative approach aims to address the growing need for enhanced flexibility, agility, and cost-effectiveness in the healthcare industry. The authors presented a "Manufacturing Semantics Ontology-driven knowledge repository" within the perception layer, which plays a crucial role in the strategic scheduling of pharmaceutical manufacturing operations. Further, they tested the proposed solution by experimenting with demand-based drug packing production. Chauhan et al. (2021), which received 74 citations, identified a comprehensive set of seven factors for the development of intelligent waste management systems in the healthcare sector, with a particular focus on circular economy principles to extract value from disposable materials. The authors employed the "decision-making trial and evaluation laboratory (DEMATEL)" technique to evaluate and prioritize these parameters based on their significance and the underlying cause-and-effect relationships, which were graphically represented through a causal diagram. This research article emphasized the significance of digitally interconnected waste management companies, healthcare facilities, and environmental regulatory bodies in the context of waste disposal. Furthermore, it elucidated the valuable role played by pollution control boards in delivering feedback to individuals and other relevant stakeholders, thereby underscoring the compelling rationale for the implementation of intelligent healthcare waste disposal systems. With 69 citations, Daú et al. (2019) introduced a novel conceptual framework that combines the principles of circular economy transition and corporate social responsibility mirror to enhance the sustainability of healthcare supply chain 4.0. The authors devised an innovative observation protocol to gather real-world data from a private healthcare facility situated in Rio de Janeiro, renowned for its commitment to embracing cutting-edge technologies in its operations. This enlightening article establishes a compelling connection between the societal responsibilities of healthcare institutions and their pursuit of sustainable practices, while also highlighting the positive impact of corporate social responsibility on the advancement of smart technologies in the healthcare sector.

Furterer (2018), which received 42 citations, provides a case study-based demonstration of Lean Six Sigma DMAIC methodology implementation to improve throughput and patient flow in an emergency department. It highlights the importance of Operational Excellence in healthcare and

how it can be achieved through process improvement methodologies. The article also identifies the key factors that affect patient flow and throughput in an emergency department and provides recommendations for addressing these factors. Habidin et al. (2014) with 30 citations, delve into the implementation of lean healthcare methodologies within the healthcare sector of Malaysia. The study investigates the correlation between adoption of lean healthcare practices and the supply chain innovation performance. Through their analysis, the authors pinpoint four key dimensions of lean healthcare practice, namely effective leadership, employee engagement, customer-centric approach, and organizational culture, which exhibit a significant and direct influence on the success of supply chain innovation endeavors. To further enhance their findings, the study presents a comprehensive structural relationship model utilizing advanced statistical technique known as structural equation modeling (SEM). Table 6 shows this cluster's identified research gaps and corresponding future research questions (FRQs).

Table 6 Future research questions derived from cluster 2

S. No.	Gaps identified in Cluster 2	Future research questions
1.	There is a need to develop a comprehensive semantics ontology-based knowledgebase to improve the scheduling of pharmaceutical production.	• How to develop a more comprehensive and accurate semantic ontology-based knowledgebase to improve the planned scheduling of pharmaceutical manufacturing? • What is the impact of integrating advanced technologies such as big data analytics and artificial intelligence on the performance of the Smart Factory?
2.	There needs to be a more detailed discussion on the technical aspects of implementing an intelligent healthcare waste disposal system.	• What can be a potential case study to validate a intelligent healthcare waste disposal system? • How to develop a prototype of this proposed system and test it in a real-life setting?
3.	There is inadequate empirical evidence on the applicability of a circular economy transition conceptual framework for improving sustainable Healthcare 4.0.	• How to empirically test and validate the circular economy transition conceptual framework for healthcare institutions in different countries to improve sustainability with supply chains?
4.	There exists a disparity between the latest advancements in research and the requirements of the industry, hindering the progress in developing innovative technologies with wider applicability in medical treatments.	• What strategies can be employed to create an autonomous medical manufacturing system that enhances the efficiency and quality of healthcare services? • What methodologies can be employed to evaluate the reception and implementation of robotics in healthcare settings?
5.	Researchers should explore the lean and six sigma principles to improve the operational efficiency of emergency departments.	• What is the impact of root cause analysis and bottlenecks in patient flow? • How to implement a real-time patient tracking system to monitor patient flow? • What is a standardized patient triage and prioritization process to ensure patients are seen promptly and appropriately?

		• How can a continuous improvement program be implemented to sustain the gains achieved through the process improvement initiative? • How to conduct a cost-benefit analysis to evaluate the financial impact of a process improvement initiative?
6.	The influence of lean healthcare strategies needs to be examined within the framework of supply chain innovation effectiveness.	• How do lean healthcare practices impact patient outcomes and customer satisfaction? • What is the role of technology in supporting lean healthcare practices? • How do lean healthcare approaches impact the financial outcomes of healthcare institutions?? • How to conduct a longitudinal study to assess the sustainability of lean healthcare practices over time?

Cluster 3: Healthcare 4.0 technologies

Cluster 3 contains critical findings obtained through the analysis of 37 documents. In this cluster, we have identified cutting-edge technologies that promise to change how healthcare businesses operate. Blockchain, IoT devices, Care 4.0, Artificial Intelligence, and Operator 4.0 are some of the technologies discussed in the literature at great length (Tortorella *et al.*, 2020). Introducing these technologies in healthcare businesses is meant to enhance these entities' performance and operational capabilities.

With a maximum of 253 citations, Bodkhe et al. (2020) conducted a comprehensive examination of different blockchain-driven solutions and their suitability in a wide range of applications within the Industry 4.0 paradigm. It also illustrated the base architecture for blockchain applicability in various Industry 4.0 use cases. The authors have also discussed the merits and demerits of conventional security solutions compared to their countermeasures. Abdel-Basset et al. (2021), which has accumulated 121 citations, presented an innovative framework that leverages disruptive technologies for the investigation of COVID-19. The research also proposes a viable solution to address the critical scarcity of personal protective equipment (PPE) for healthcare workers, alleviate the overwhelming burden on hospitals, and monitor the recovery progress of patients to facilitate plasma treatment for individuals affected by COVID-19. Furthermore, the study offers valuable guidance to governments on embracing technological advancements to mitigate the repercussions of unprecedented COVID-19 outbreaks. Kumar et al. (2018), with 86 citations, examined the attributes of challenges existing at the intersection of Information Systems and Operations Management. The research critically assessed prior studies that have played a crucial role in establishing the framework and trajectory of research in this converging domain.

The study by Kumar et al., (2020), which acquired 85 citations, designed a smart healthcare system by integrating blockchain technology and healthcare industry 4.0 processes. The authors verified the effectiveness of healthcare industry 4.0 strategies employed for data availability using statistical simulation-optimization techniques and algorithms. The research also conducted an

extensive and comparative examination of cutting-edge blockchain-powered intelligent healthcare systems, encompassing their methodologies, applications, prerequisites, achievements, and prospective advancements. With 42 citations Zahedi et al. (2021), devised two novel approaches to create a relief supply chain network utilizing Internet of Things (IoT) technology, aimed at addressing numerous potential cases during a pandemic, such as the recent SARS-COV-2 outbreak. The initial method focuses on minimizing the maximum response time of ambulances, while the second approach aims to minimize the overall critical response time, ensuring efficient and timely assistance. They investigated and validated the proposed approaches by means of a real-life case in Iran and several test problems. Following the deployment of this innovative Internet of Things (IoT)-enabled method over a span of three consecutive weeks, a notable reduction of 35.54% in confirmed cases was observed.

Al-Jaroodi et al. (2020), which attracted 32 citations, provided an improved understanding of Health 4.0 and its purposes. The research explored pioneering potential applications of Health 4.0, examining their diverse functionalities, and classifying them into distinct beneficiary groups. Additionally, the authors introduced a service-oriented middleware framework that offers fundamental services to application developers, facilitating seamless integration of various services for the development of innovative applications within the Health 4.0 paradigm. With 31 citations, Tortorella et al. (2021) delved into the influence of ten digital innovations within the Healthcare 4.0 (H4.0) paradigm on the resilient functioning of hospital-based healthcare systems. Through the study, four specific digital technologies were identified as having a profound impact on resilience: digital non-invasive care, real-time remote consultations and care planning, collaborative platforms for patient data and information sharing, and interconnected medical emergency support. As per the authors' findings, these technological advancements have the potential to greatly enhance the resilience of healthcare systems, minimizing the need for excessive reliance on human adaptability skills while promoting robust performance. Table 7 shows this cluster's recognized research gaps and corresponding future research questions (FRQs).

Table 7 Future research questions derived from cluster 3

S. No.	Gaps identified in Cluster 3	Future research questions
1.	The need to develop more user-friendly interfaces for blockchain-based solutions in the healthcare sector is suggested.	• How can blockchain-based solutions empirically validate the performance and effectiveness in real-world scenarios?
2.	It is required to conduct more empirical studies exploring the use of other disruptive technologies, such as virtual reality and autonomous robots, to enhance the capabilities of healthcare businesses.	• What is the role of disruptive technologies such as virtual reality and metaverse in enhancing the capabilities of hospitals/clinics?
3.	A multidisciplinary approach that combines management and information system insights can be helpful in the healthcare sector.	• How does a multidisciplinary approach combining operations management and information systems affect adopting IoT and blockchain technologies in healthcare?

4.	The blockchain-based network system is not implemented in a real-world scenario, and simulation results may not reflect the system's actual performance.	• How can the blockchain-based network system be implemented over different tools and techniques? • How to assess the effectiveness of blockchain-based network systems and enhance their suitability for implementation in the healthcare sector?
5.	Optimization models that minimize total critical response time need to consider different parameters related to patient care.	• What is the impact of different parameters on the optimization models (that minimize the total critical time), such as the number of ambulances, hospitals, and patients? • How to develop a decision support system that integrates existing optimization models with real-time data from IoT devices to provide timely and accurate decision-making information?
6.	There is a need to investigate the potential of Health 4.0 in different healthcare domains.	• How to extend the applications of Health 4.0 for domains such as telemedicine, remote patient monitoring, and personalized medicine?
7.	Further investigation is needed to evaluate the influence of Healthcare 4.0 technologies on the effectiveness of robust healthcare systems within hospital settings.	• What is the potential trade-off between using Healthcare 4.0 technologies and developing human adaptive skills in healthcare professionals? • What is the role of leadership and organizational culture in promoting the adoption of Healthcare 4.0 in healthcare?

Cluster 4: Healthcare delivery

This cluster focuses on healthcare delivery aspects such as patient care, employee engagement, service quality, and patient satisfaction. A total of 28 documents have been analyzed under this cluster. Kumari et al. (2018b) which received a whopping 291 citations, conducted an examination of the significance of cloud computing, fog computing, and the Internet of Things in the healthcare sector. The study introduces a patient-centric healthcare framework consisting of three layers, aimed at enabling the seamless acquisition, analysis, and dissemination of real-time healthcare data. This paper offers valuable contributions by shedding light on the utilization of technology to provide uninterrupted context-aware services to end users. Additionally, it addresses the challenges faced by individuals with chronic illnesses who often have to make frequent visits to hospitals for routine checkups. The study by Wu et al. (2013), cited 45 times, identifies hotel design elements that can be applied in healthcare settings to enhance the physical environment and foster healing. In addition, the authors have provided instances of current healthcare facilities that have integrated hospitality features, including rooms and decorations reminiscent of hotels, high-quality dining options akin to those found in hotels, and inviting reception areas and common spaces. The research also presents recommendations for incorporating future hospitality elements into

healthcare environments, such as executive lounges, centralized patient controls, and adaptable furnishings.

Chute and French (2019) which has 45 citations, presents an innovative model known as "Care 4.0," which centers around reliable and interconnected networks of institutions, individuals, and technologies, fostering tailored services that are highly attuned to the demands and desires for care. The document explores the potential transformative impact of this methodology on the advancement of digital healthcare and caregiving services, delivering proactive strategies that culminate in a dynamic and enduring collection of comprehensive healthcare and social welfare provisions, bolstering purposeful involvement and exchanges. Table 8 represents this cluster's acknowledged research gaps and corresponding future research questions (FRQs).

Table 8 Future research questions derived from Cluster 4

S. No.	Gaps identified in Cluster 4	Future research questions
1.	There exists a need to delve into the realms of artificial intelligence and machine learning, harnessing their potential to enhance the precision of data examination and prognostication pertaining to patient results.	• How can a data-driven machine learning model be developed to predict patient outcomes accurately?
2.	The paper advocates for the application and impact of hospitality design elements in healthcare settings.	• How to assess the impact of hospitality design elements, such as the incorporation of executive lounges, implementation of centralized control, flexible furniture, etc., on patient experience and comfort in hospitals? • What is the impact of hospitality design elements on patient outcomes and satisfaction?
3.	Future work should focus on developing Care 4.0 paradigm to enable personalized healthcare services.	• What strategies can be employed to cultivate and actualize the Care 4.0 model, which entails the establishment of reliable interconnected networks of institutions, individuals, and technologies, fostering personalized and highly adaptable healthcare services? • How to facilitate co-design and person-centered approach in developing digital health care services?
4.	There is a scope of implementing Society 5.0 and Industry 4.0 technologies in healthcare.	• How to develop personalized healthcare systems using AI and Big Data to cut down healthcare costs and improve patient outcomes?

6. Discussion

6.1 Conceptual Framework

This section offers a conceptual framework developed using content analysis themes. Figure 6 shows our conceptual framework, built around four pillars- Challenges in the healthcare industry, Operational Excellence tools, Healthcare 4.0 technologies, and implementation outcomes. As discussed in the content analysis, the healthcare sector has faced numerous challenges over the last few years, such as resistance to change, data privacy and security (Humayun *et al.*, 2020), regulatory compliance, cost and resource constraints (Oughton *et al.*, 2019), technical complexity, and ethical constraints.

Operational Excellence tools and Healthcare 4.0 technology have profoundly addressed challenges and incorporated healthcare delivery aspects. Operational Excellence tools such as Lean Six Sigma (Edelman et al., 2017) and Value Stream Mapping have helped healthcare organizations in patient logistics planning and reduction in patient waiting time (Al Owad *et al.*, 2022). Lean Six Sigma practice has also enabled healthcare businesses to waste management. Root cause analysis, a prominent lean manufacturing tool, has been used to improve clinical quality.

Further application of industry 4.0 technologies has dramatically impacted the performance and efficiency of healthcare organizations (Sony *et al.*, 2022). Industry 4.0 powered biomechanics technique has been instrumental in smart ergonomics and occupational healthcare. Business model innovation in healthcare is also being supported through Industry 4.0 techniques. Cloud computing dramatically improves medical image processing efficiency (Pace *et al.*, 2019; Roy *et al.*, 2019). Digitalization has helped in our fight against virus and pandemic threats (Javaid *et al.*, 2020). Artificial Intelligence and Blockchain technologies (Chen *et al.*, 2022; Qahtan *et al.*, 2022; Verma *et al.*, 2022) have played important roles in healthcare organizations' applications, such as security, data privacy, and server management (Arachchige *et al.*, 2020; Sittón-Candanedo *et al.*, 2019). The application of Healthcare 4.0 supports complex medical procedures, such as convolutional neural network-based unobtrusive monitoring and beg sensor network-assisted smart implants (Vujica Herzog *et al.*, 2018).

So it's evident from the discussion so far that integrating Operational Excellence tools and industry 4.0 techniques has given a much-needed impetus to the healthcare industry. Figure 6 illustrates the merging of Operational Excellence and Healthcare 4.0, represented by two converging arrows. This integration can potentially revolutionize multiple facets of healthcare, as depicted by the central crown-shaped circle. Major outcomes include improved clinical care quality (Swarnakar *et al.*, 2021), improved patient safety (McDermott *et al.*, 2021) and privacy, enhanced patient satisfaction (Gizaw *et al.*, 2021), a culture of continuous improvement (Persis *et al.*, 2022), reduction and better management of healthcare waste, higher employee engagement and job satisfaction among healthcare workers (Bondurant and Armstrong, 2016) and innovative business models with the improved financial performance of businesses (Al-Marsy *et al.*, 2021).

6.2 Theoretical and Managerial implications of the results

The intended investigation introduces a methodical examination of the existing body of literature concerning Operational Excellence and the advancements in Healthcare 4.0 technologies. The year-wise publication trend reflects the growing research interest of researchers in the area (Research Question 1). Further analysis of prominent sources, most impactful authors (Research Question 2), and area-wise analysis can help understand the scope and reach of the current research work. The geographical and countrywide analysis depicts the countries leading in the research in this area and provides insight into which countries are still underrepresented (Research Question 3).

Subsequently, based on our findings from the cluster analysis, we have provided a conceptual framework. The framework talks about challenges in the healthcare industry and how these challenges have been addressed using Operational Excellence tools and Industry 4.0 technologies in healthcare organizations (Research Question 4). The framework will help policymakers, industry experts, and researchers in decision-making. The proposed framework will also help stakeholders from diverse domains to redirect their resources for future undertakings in the area.

Through content analysis, we have also proposed future research questions based on research gaps identified during the literature review analysis. The research questions delineated within each cluster will serve as a launching pad for exploring future research opportunities (Research Question 5). This analysis will also allow the researchers to pick out the unnoticed and relevant problems in the healthcare sector. Overall, this systematic review is essential for managers since it objectively analysis the literature, underlying trends, prominent themes, and directions for future research.

7. Conclusions

The study attempts to present a comprehensive literature review that integrates Operational Excellence tools and industry 4.0 technologies for healthcare businesses. For this purpose, we have picked a literature collection from the Scopus database published from 2011 to 2022. We divided our analysis into two stages after shortlisting the final articles for our review. The first stage was to conduct descriptive bibliometric research, which classifies the literature into year-wise publications, prominent publication sources, top authors, the geographical dispersion of articles, and subject area-wise classification of articles.

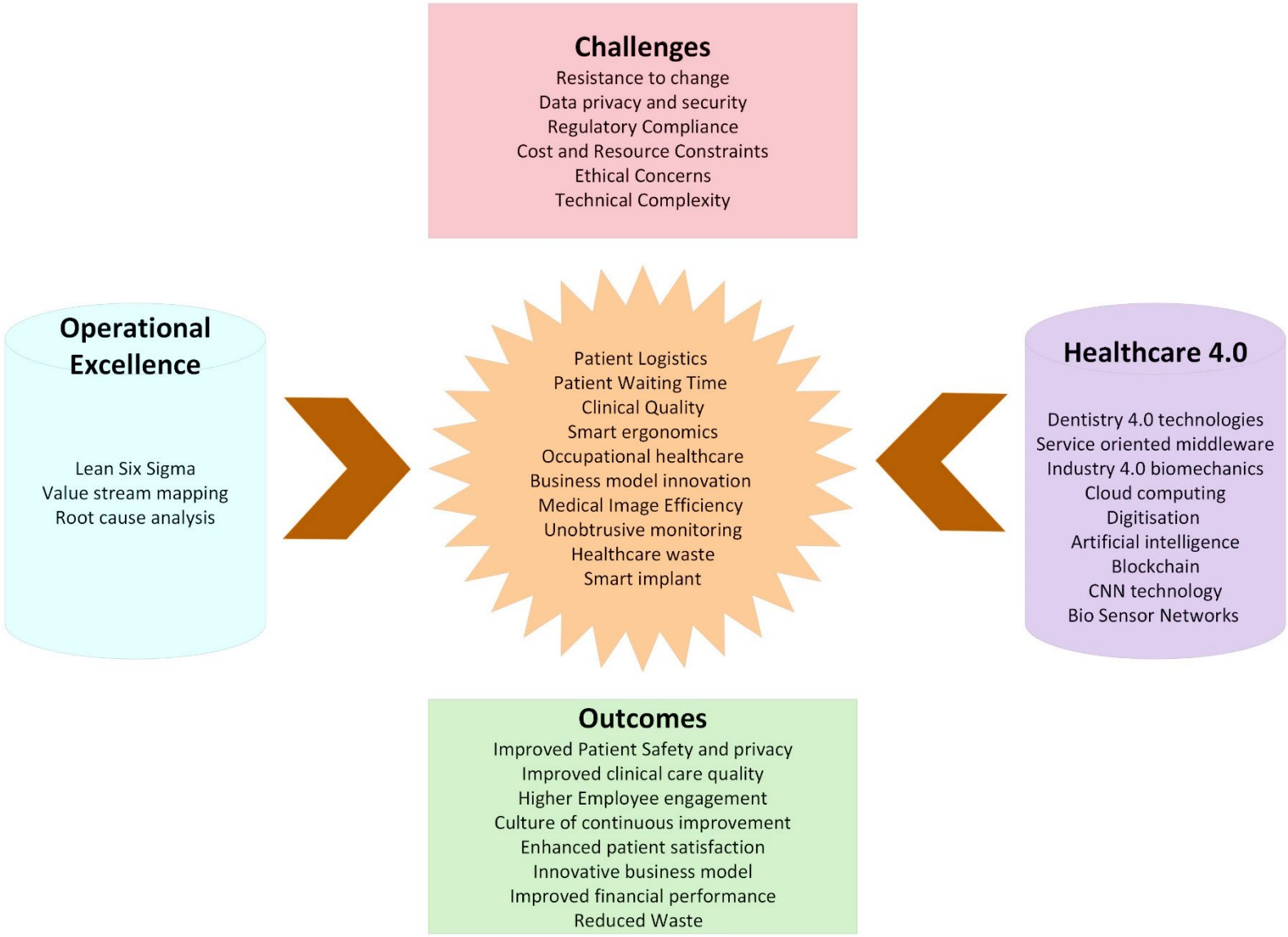

Figure 6 Theoretical framework on operational excellence and healthcare 4.0

We then conducted a content analysis of the shortlisted articles. Four clusters have been identified, and based on the critical analysis of the articles, we have proposed directions for future research in the form of future research questions (FRQs) for each cluster. Further, we developed a conceptual framework highlighting the challenges, tools related to Operations Excellence, and Healthcare 4.0 technologies and outcomes witnessed in the healthcare industry. We concluded the discussion section with an elaboration on the theoretical and managerial implications of the study. Though we have reviewed the literature with the utmost discretion, the study has limitations, like any other work. We have obtained the data exclusively from the Scopus database, which leaves the possibility of skipping some of the relevant articles not present in the database. There are some bibliometric classifications, such as citation analysis which we have not performed. The future research opportunities identified in the cluster-based content analysis are derived from the summarized articles within each cluster. It is important to note that some of the research gaps presented in this study may have been addressed by researchers in work conducted after the timeframe mentioned in this article. Therefore, readers are advised to exercise discretion when interpreting these future research questions. We highly encourage prospective researchers to delve into the amalgamation of Industry 4.0 and Operational Excellence within the healthcare sector and draw comparisons with analogous instances in diverse industries. This comparative analysis can provide valuable insights and further contribute to understanding these concepts in different contexts. The presented theoretical framework has been developed based on understanding and interpreting the literature. The validity and applicability of the proposed framework can be tested in future research.

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