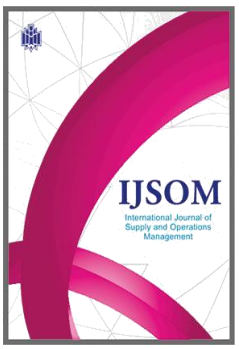
International Journal of Supply and Operations Management

IJSOM

2025, Volume 12, Issue 3, pp. 396-430
ISSN-Print: 2383-1359
ISSN-Online: 2383-2525
www.ijsom.com



Preliminary Framework for Lean Supply Chain Integration Assessment Index in the Healthcare Sector

Marwan Ail Mauloud Hfeda [a*], Azanizawati Ma'aram [a], Muhd Ikmal Isyraf Mohd Maulana [a] and Ahmad Naufal Adnan [a]

[a] *Faculty of Mechanical Engineering, Universiti Teknologi Malaysia, Bahru, Johor, Malaysia*

Abstract

Healthcare providers face the formidable challenge of providing high-quality treatment without passing the costs on to their patients. Rising hospital inventory costs in recent years have highlighted the critical importance of developing a more efficient healthcare supply chain management (SCM) system. Despite the importance and the potential of lean supply chain applications in the healthcare sector, extensive development is necessary for the successful adaptation of lean integration across the supply chain network. There have been very few comprehensive frameworks of all the critical success factors (CSF) that enable lean-supply chain integration (LSCI) for healthcare. Only a few studies provided an index for lean-related activities in the healthcare context. The objective of this paper is to propose a obtain the critical success factors in lean-supply chain integration for healthcare and develop an LSCI assessment index to measure. The paper used a systematic literature review of recent studies on critical success factors of lean supply chain in healthcare. The results of the review enabled the development of the proposed LSCI assessment index based on the identified CSF of supply chain and lean implementation in the healthcare context. The index is divided into categorical factors related to organization, supply, patients, technology, and lean implementation. The expert validation process involved feedback from 20 academics and experts with expertise in Lean Supply Chain Management and healthcare operations, ensuring the questionnaire's comprehensiveness and relevance. The pilot reliability study with experts assessed the questionnaire's reliability using Cronbach's Alpha, demonstrating acceptable consistency for the research variables.

Keywords: Critical Success Factors; Lean Supply Chain; Integration; Healthcare; Assessment; Index.

1. Introduction

Healthcare providers face the formidable challenge of providing high-quality treatment without passing the costs on to their patients (Khorasani et al., 2020). Rising hospital inventory costs in recent years have highlighted the critical importance of developing a more efficient healthcare supply chain management (SCM) system (Khorasani et al., 2020). Recent research has shown that healthcare organisations may benefit from SCM by removing non-value-added elements from their system (Khorasani et al., 2020). A 2023 survey indicating >75% of leaders expect ongoing disruptions (labour, raw materials, transportation and logistics) as indicated in Figure 1.

*Corresponding author email address: mauloud@graduate.utm.my
DOI: 10.22034/ijsom.2025.110756.3365

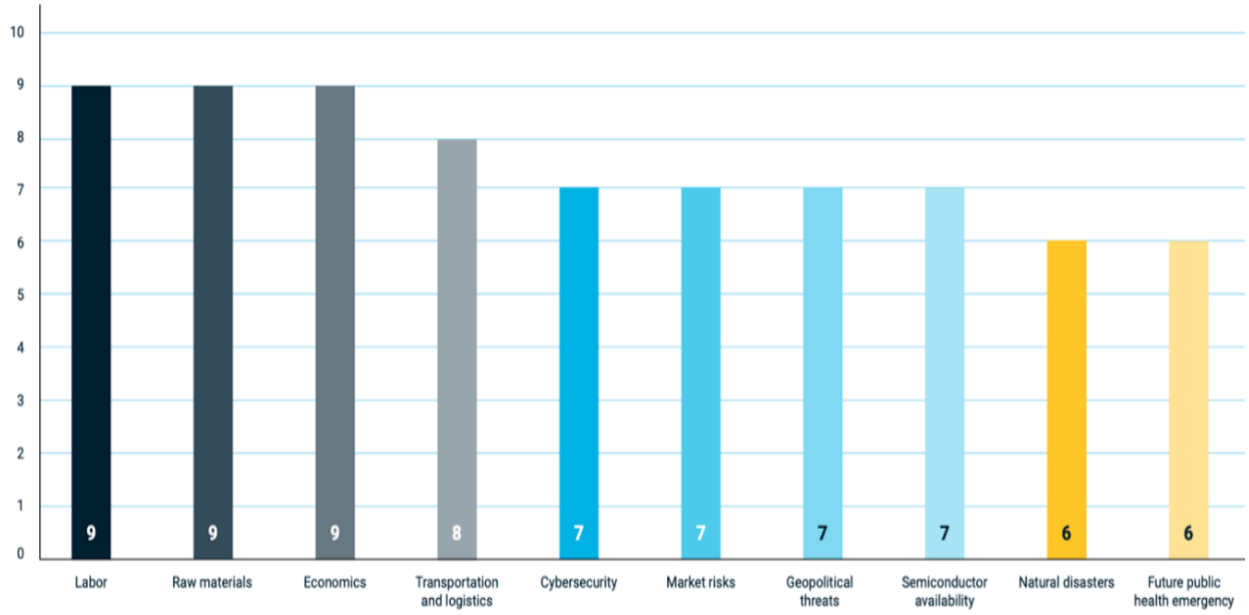


Figure 1. Major risks to healthcare supply chains: labour, inflation, and shortages impacting SCM resilience, source (premierinc.com, 2023).

The healthcare sector faces the critical challenge of delivering high-quality treatment while effectively managing costs. In this context, Lean Supply Chain Management (LSCM) plays a pivotal role in enhancing operational efficiency, reducing waste, and improving the overall quality of care. Efficient LSCM not only streamlines processes but also ensures the timely delivery of healthcare services and products to patients (Baliga et al., 2020).

Integrating lean principles into healthcare supply chains is essential for optimizing resource utilization, minimizing errors, and enhancing patient outcomes. By eliminating non-value-added activities and focusing on continuous improvement, lean integration in healthcare can lead to significant cost savings and improved service quality. The existing HSC has a fundamental flaw due to a lack of integration between the various stages of the supply chain, which prevents the chain from functioning as a unified whole (Govindan et al., 2020). Abbasi et al. (2023) have proposed a comprehensive location-allocation-routing model for home healthcare supply chains during the COVID-19 pandemic. The model is demonstrating how integrated approaches can enhance operational efficiency and service quality in healthcare logistics. A multi-objective model incorporating economic, environmental, and social sustainability aspects has been successfully applied in pharmaceutical supply chains to guide strategic distribution decisions, demonstrating the importance of integrated approaches in supply chain management by Janatyan et al., (2018). Moradi & Jolai (2018) have introduced a novel approach combining fuzzy graph theory with multi-objective linear programming to prioritize and select sustainable pharmaceutical suppliers, particularly for critical medications like clotting agents used by haemophilia patients. By incorporating economic, environmental, social, and health-related criteria, the model aims to minimize total procurement, ordering, and holding costs while maximizing supplier reliability and purchase value. The approach utilizes the GT-MP-DM method for supplier ranking and solves the bi-objective optimization problem via fuzzy MAX-MIN and GAMS software, validated through sensitivity analysis to enhance supply chain sustainability and efficiency in healthcare settings (Moradi & Jolai, 2018)

The application of lean principles in the healthcare supply chain, known as Lean-Supply Chain Integration (LSCI), aims for continuous quality improvement by addressing the root causes of issues and enhancing quality. Factors enabling successful LSCI include leadership, commitment, engagement, teamwork, communication, culture, and training. Healthcare teams should learn from past failures to ensure patient safety and utilize electronic clinical information systems for better patient preparation (Baah & Jin, 2019). This study by Abbasi et al. (2025) highlights the integration of advanced technologies like IoT in logistics networks to enhance responsiveness and sustainability, which complements lean principles by improving operational efficiency during complex disruptions such as epidemics. Efficient healthcare supply chain management, supported by integration and technologies such as RFID,

is essential for minimizing waste, enhancing coordination, and improving patient care outcomes in resource-constrained settings (Arora & Gigras, 2018).

Hospitals must strive to treat patients correctly on the first attempt and enhance care quality by staying updated with medical technology and facilities (Yu et al., 2021). Collaboration among employees, sharing best practices, and waste management principles are crucial for quality and productivity improvement (Musamba et al., 2025). Implementing lean waste management strategies can enhance patient care by simplifying processes and maintaining a clean and organized physical environment. Efficient housekeeping staff can streamline hospital admission and discharge processes, contributing to overall healthcare facility effectiveness.

Supply chain management (SCM) encompasses the planning and management of activities related to sourcing, procurement, conversion, and logistics (Farooque et al., 2019). A hospital's supply chain comprises internal (managed by the hospital's administration) and external (managed by third parties) components (Ivanov, 2022). Healthcare supply chain activities involve physical products, information, and monetary flows that require efficient management (Antony, Sunder, et al., 2019). Product utilization varies across hospitals and specialities. Hospitals electronically transmit medication stock information to suppliers for automatic restocking. The healthcare team, consisting of various medical professionals, collaborates to treat patients, emphasizing the importance of communication and up-to-date medical information. Financial flows, such as expenditures and receipts, are essential components of healthcare supply chain management (Antony, Sunder, et al., 2019). The global healthcare supply chain management (SCM) market was valued at approximately USD 1.28 billion in 2024 and is projected to reach USD 2.98 billion by 2031, reflecting a robust compound annual growth rate (CAGR) of 12.29 % over the forecast period. This significant growth underscores the increasing demand for efficient and integrated supply chain solutions in the healthcare sector as shown in Figure 2.

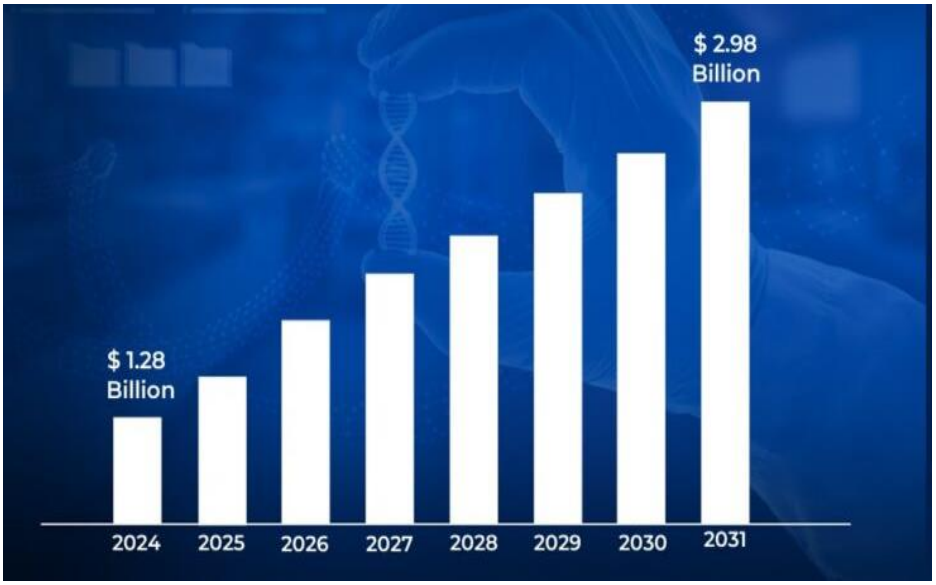


Figure 2. Projected growth of global healthcare SCM systems (2024-2031), highlighting expanding investment, source (verifiedmarketresearch.com)

The supply chain in healthcare is also divided into external and internal supply chains. The internal healthcare supply chain includes the healthcare team, patient rooms, emergency and urgency rooms, intensive care units, hospital administration including general management and billing, in-house pharmacy, and ancillary services like diagnostic testing laboratory, medical counselling, blood and organ banks, and transportation services (e.g., ambulances) are depicted as the core layer of a hospital's internal supply chain (Moons et al., 2019).

The external healthcare supply chain may not come into direct contact with patients, but they all have a role in the delivery of care via the hospital (Chakraborty & Gonzalez, 2018). External healthcare supply chains include healthcare-related businesses, such as health insurers, therapists, and specialists. Businesses that offer intermediate services, such as IT support, medical record transcription, equipment, pharmaceutical companies and other supplier

services, cleaning, and security, may be considered to be outsourced to a third party. Patients are also part of the external supply chain, although patients won't have any direct dealings with all the entities (Chakraborty & Gonzalez, 2018). Many of the entities portrayed here may not be encountered by the majority of out-patients due to the relatively minor nature of their illnesses (Benzidia et al., 2021).

Successful supply chain management in the context of healthcare requires the facility to take into account patient and material flow management (Chakraborty & Gonzalez, 2018b). The availability of major hospital facilities like intensive care units and minor equipment like drip stands is essential to ensuring that procedures are not delayed (Ferreira et al., 2020). Scheduling applications that take into account patients' medical conditions and demands, as well as the hospital's room and equipment availability, might be used to execute material flow management in hospitals (Chakraborty & Gonzalez, 2018).

Despite the recognized importance of lean integration in healthcare supply chains, there remains a gap in comprehensive frameworks that address all critical success factors (CSF) necessary for successful Lean Supply Chain Integration (LSCI). The current research aims to bridge this gap by developing a novel Lean Integration Assessment Index tailored specifically for the healthcare sector. Despite the importance and potential of lean supply chain applications in the healthcare sector, extensive development is necessary for the successful adaptation of lean integration across the supply chain network (Tortorella et al., 2018). Many healthcare facilities have failed to implement lean supply chains because they lacked the necessary expertise and instead focused narrowly on a single step of the supply chain (Argiyantari et al., 2020a; Baliga et al., 2020).

2. LITERATURE REVIEW

Most empirical research has concentrated on the personal dimension, Ahmed & Huma (2021) claimed that there had been little effort to combine upstream and downstream activity. Tortorella *et al.* (2018) emphasised the significance of researching the use of integrated lean practices in the supply chain to gain a competitive edge. Several studies that survey the literature on supply chain or general lean tool adoption in healthcare have appeared in recent years (Almutairi *et al.*, 2019; Chakraborty & Gonzalez, 2018; Khorasani *et al.*, 2020; Primadasa & Alfarisi, 2018; Tortorella *et al.*, 2018), but there have been very few comprehensive frameworks of all the CSF that enable lean-supply chain integration (LSCI) for healthcare. Only a few studies provided an index for lean-related activities in the healthcare context. Awang *et al.* (2022) developed a lean readiness index for Malaysian hospitals. The Lean Readiness Index (LRI) is formulated as an LRI ruler. The index has "measurement items for hospital behaviour including leadership (4), commitment (4), engagement (4), teamwork (4), communication (4), and measurement items for lean readiness including customer alignment (4), enterprise alignment (4), process alignment (4), culture enablers (4) training and Education (4). Another study by (Narayanamurthy et al., 2018) developed a HCF Lean Readiness Index and an assessment methodology to quantify the readiness of HCFs for implementing lean the proposed HCF Lean Readiness Index by (Narayanamurthy et al., 2018) include leadership and executive team (7 items), frontline management team (7 items), lean sensei and team (5 items), patients and other customer groups (3 items), supplier groups (3 items), HCF attributes (4 items). The previous index was only linked to the lean readiness of the organization without regard to the supply chain integration with the lean concept. Additionally, the previous studies did not take into account factors essential for lean implementation including but not limited to technology related factors, a comprehensive supply related factors or comprehensive organization related factors. Hence, the objective of this paper is to propose a comprehensive framework for the CSF in lean-supply chain integration for healthcare and develop a LSCI assessment index to measure.

Additionally, recent studies have highlighted the importance of developing validated lean culture measurement tools to assess organizational readiness. Osman et al.(2025) is presenting a rigorously validated self-administered questionnaire that captures key dimensions such as teamwork, communication, problem-solving, and innovation for sustaining lean transformation in manufacturing settings. Rosa et al. (2024) further contributed by validating a scale measuring Lean Six Sigma and quality performance readiness in Italian public healthcare organizations, highlighting continuous quality improvement, teamwork, and patient safety as essential dimensions for successful implementation. Costa et al. (2024) proposed a novel readiness level assessment model specifically for Lean Six Sigma implementation in healthcare, integrating critical readiness factors and their interrelations to better guide improvement priorities. Alotaibi (2025) developed a comprehensive Remanufacturing Readiness Index for MSMEs using graph theory to quantitatively assess organizational readiness based on critical attributes such as resource availability, design

considerations, and collaboration, demonstrating the value of structured readiness indices for supporting sustainable manufacturing transitions. Dewi et al. (2024) applied a fuzzy logic-based assessment to develop a Lean Six Sigma readiness index in the manufacturing sector, highlighting organizational culture, leadership commitment, and waste elimination as key factors influencing sustainability outcomes. Similarly, Anzum & Kibria (2024) developed a fuzzy logic-based lean readiness assessment model tailored for Bangladeshi healthcare institutions, emphasizing leadership commitment, workforce capabilities, operational processes, technological infrastructure, and organizational culture as pivotal factors in evaluating readiness for lean implementation. Sulistyoa et al. (2024) extended this approach by developing an integrated Lean 4.0 readiness assessment tool specifically for the chemical industry, combining lean principles with Industry 4.0 technologies across five core dimensions to provide a comprehensive evaluation framework.

Despite the growing interest in lean readiness and quality improvement in healthcare, most existing studies have focused on either organizational culture or internal operational dimensions, often neglecting the integration of upstream and downstream supply chain activities. Furthermore, previous indices have been sector-specific, limited to lean readiness alone, and have not addressed essential dimensions such as technological infrastructure, supplier collaboration, or patient-related factors in a unified framework. To date, no comprehensive assessment index exists that holistically integrates critical success factors (CSFs) from both lean implementation and supply chain perspectives specifically within the healthcare sector. This research addresses this critical gap by proposing a Lean-Supply Chain Integration (LSCI) Assessment Index that combines organization, technology, supply, patient, and lean-related factors into a validated and scalable tool for healthcare organizations. A summary of the reviewed previous lean readiness and assessment models is demonstrated in Table 1.

Table 1. Comparative Overview of Previous Lean Readiness and Assessment Models Highlighting Gaps in Healthcare Supply Chain Integration

Author(s)	Sector / Setting	Tool / Index Type	Dimensions / Factors Covered	Limitations / Gap
Alotaibi (2025)	MSMEs	Remanufacturing Readiness Index	Resource availability, design, collaboration	Not related to Lean or healthcare
Osman et al. (2025)	Manufacturing	Lean Culture Questionnaire	Communication, problem-solving, teamwork, innovation	Not specific to healthcare or SCM; cultural readiness only
Costa et al. (2024)	Healthcare	LSS Readiness Model	Critical readiness factors with interrelations	No supply chain scope; model-based not operationalized as an index
Rosa et al. (2024)	Italian public hospitals	LSS Readiness Scale	Quality, teamwork, continuous improvement	No SCM integration; lacks technology & external supplier links
Sulistyoa et al. (2024)	Chemical industry	Lean 4.0 Readiness Index	Lean + Industry 4.0 dimensions	Sector-specific (chemical); not applicable to healthcare
Dewi et al. (2024)	Manufacturing	LSS Fuzzy Logic Readiness Index	Org. culture, leadership, waste elimination	Manufacturing only; lacks SCM and healthcare focus
Anzum & Kibria (2024)	Bangladeshi healthcare	Fuzzy Lean Readiness Model	Leadership, workforce, operations, tech, culture	Does not integrate SCM or validate through wide expert input
Awang et al. (2022)	Malaysian hospitals	Lean Readiness Index (LRI)	Leadership, commitment, teamwork, communication, process alignment	Focused on readiness only; did not cover SCM or tech-related factors
Narayanamurthy et al. (2018)	Healthcare institutions	HCF Lean Readiness Index	Leadership, frontline mgmt., patients, suppliers, org. attributes	Readiness-focused; excluded supply chain integration

Through a systematic literature review, this study seeks to identify and categorize key CSF for LSCI in healthcare settings. By answering research questions such as the effectiveness of lean tools and techniques in healthcare supply chains and the impact of organizational readiness on lean deployment, this research aims to provide valuable insights for healthcare organizations striving to enhance their supply chain management practices.

The proposed Lean Integration Assessment Index is poised to make a significant contribution to the field by offering a comprehensive tool for evaluating the level of lean integration within healthcare supply chains. This index will enable stakeholders and decision-makers to assess the readiness, application, and effectiveness of lean principles in supply chain management, ultimately leading to improved efficiency, cost savings, and quality of care in healthcare settings.

3. Methodology

The study employed a systematic literature review methodology following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The process involved the following steps:

1. Determination of Research Problem and Objectives: The study began by defining the research problem and objectives related to critical success factors for lean/supply chain integration in healthcare.
2. Database Search: A comprehensive search was conducted across multiple databases, including Google Scholar, Scopus, IEEE Xplore, and Web of Science. The search utilized specific keywords such as "critical", "success", "factors", "lean supply chain", and "healthcare" to identify relevant literature.
3. Initial Search Results: The initial database search yielded a total of 893 articles related to the research topic.
4. Time Interval Selection: To focus on recent studies, the time frame between 2018 and 2025 was selected for the review.
5. Refinement of Search Results: After applying the time filters, the number of articles was reduced to 465. Further refinement was carried out by reviewing the titles of the articles to include healthcare-related terms like "hospital, medical, pharmaceuticals, healthcare".
6. Inclusion and Exclusion Criteria:
Inclusion Criteria:

- Studies focusing on factors for lean/supply chain integration.
- Articles containing keywords related to the research topic "critical", "success", "factors", "lean supply chain", and "healthcare"
- Articles related to healthcare terms.
- Research and review articles written in English.

Exclusion Criteria:

- Exclusion of book chapters, mini-reviews, practice guidelines, and short communications.
- Exclusion of articles not in English.
- Removal of repeated articles.

7. Final Selection Process: Following the application of inclusion and exclusion criteria, 252 articles were further scrutinized. Duplicates, studies lacking factors related to lean/supply chain implementation, and non-healthcare-related articles were removed. This process led to the identification of 150 articles, which were then reviewed based on their abstracts. Subsequently, 48 articles that did not meet the criteria were excluded, resulting in a final selection of 102 articles for the review.
The detailed process is visually represented in Figure 3, illustrating the PRISMA flowchart and demonstrating the systematic approach followed in the literature review.

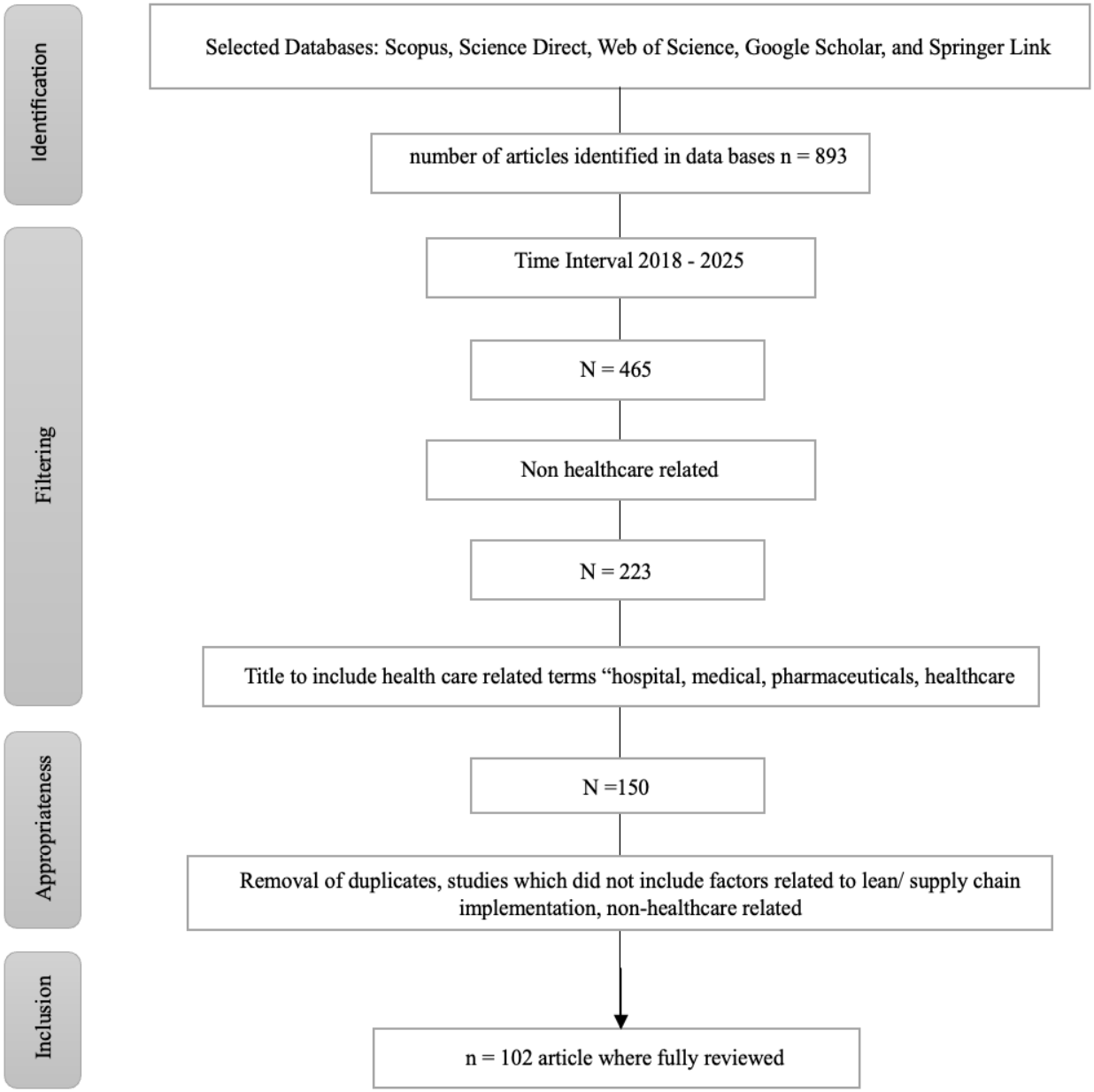


Figure 3. Systematic review PRISMA flow chart

4. Results

The surveyed literature was used to identify the CSF that needs to be applied to LSCI in healthcare settings. Various factors were identified and categorized into organization-related factors, supply-related factors, lean-related factors and technological-related factors. The results are provided in Table 2.

Table 2. Summary of the Reviewed studies

Author, Year	Country	Type of lean	Field / Industry	Factors
(Waqas et al., 2023)	Pakistan	The application of the ISM-MICMAC approach	Healthcare	Process efficiency, waste reduction, continuous improvement, quality management, and supply chain optimization
(Sony et al., 2023)	Multiple countries	Healthcare 4.0	Healthcare	Healthcare 4.0 operates within a digitally connected and integrated ecosystem, linking platforms used by diverse stakeholders including government bodies, private hospitals, health agencies, insurance companies, and pharmacies. The effectiveness of healthcare 4.0 largely hinges on its capacity to enhance patient experience and emphasize patient-centred care. Further research is encouraged to investigate the ways in which Healthcare 4.0 technologies influence various aspects of the patient experience.
(Sohal et al., 2022)	NA	Healthcare operations.	Six Sigma projects	Leadership, organizational culture, effective communication, comprehensive training, performance measurement and incentive systems, decentralized management approach, and a holistic perspective on processes from start to finish.
(McDermott et al., 2022)	Global study	Lean Six Sigma	Healthcare	Strong management dedication, leadership focused on driving change, employee engagement, training programs, collaborative teamwork, organizational focus on delivering patient value, a culture that encourages ongoing improvement, motivated employees with adaptable skills, expertise in knowledge and project management, sufficient financial support, accessible data, decentralized decision-making processes, effective time management, and efficient work coordination.
(Alanazi, 2022)	Saudi Arabia	Implementing effective Supply Chain Management Practices	Healthcare	Support from top management, transparent information exchange, training and education related to supply chain management activities, effective communication, a supportive organizational culture, established recruitment criteria for supply chain management personnel, implementation of appropriate IT tools, and a well-functioning logistics information system.
(Nasrabadi & Mohammadipour, 2022)	Iran	Health tourism supply chain	Health tourism supply chain	Management of environmental factors, adaptability within the supply chain, effective supplier oversight, collaboration and coordination throughout the supply chain, and control of inventory
(Rojas et al., 2022)	Chile	Hybrid robust compromise multi-criteria approach	Inventory management and supply chain optimization	Procurement entities, cost advantages from scale, coordinated supply processes, key elements for successful supply chain management, and bias due to endogenous relationships in the proposed models.
(Alemsan et al., 2022)	NA	Lean practices in the healthcare supply chain	Healthcare	Operational effectiveness, transparency, cooperative efforts, removal of inefficiencies, workforce productivity, risk mitigation, and fulfilling growing demand while maintaining superior service quality.
(Ageiz et al., 2022)	Egypt	Lean management practice	Healthcare	Management dedication and backing, development of organizational culture and capabilities, active participation and cooperation with partners, provision of resources and training assistance, clear strategic direction and objective formulation, incorporation of lean

				principles, methodologies, and practices, uniformity in operational procedures, organizational mindset and preparedness, collaboration among versatile and cross-functional teams, and staff empowerment with engagement of frontline personnel.
(Barclay et al., 2022)	International	Lean implementation	Different industries	Leadership, finance, skills and expertise, organizational culture, stage of lean implementation, and national culture
(L. Naidoo, 2021)	South Africa	Lean principles	Healthcare	Leadership and managerial guidance, organizational backing, strong commitment from senior management, organizational culture, effective communication, training and development of skills, financial resources, performance measurement systems, leadership and management capabilities, expertise, employee empowerment, transparency of information, early achievements in performance, long-lasting sustainability, dedication to continuous enhancement, emphasis on practical problem-solving, proactive leadership, results-driven service delivery, comprehensive and cross-functional thinking, creation of performance monitoring frameworks, and successful adoption of best human resource practices.
(Santos, 2020)	Brazil	Lean Healthcare Implementation	Healthcare	Organizational environment, dedication from leadership, active employee participation, training and development programs, distribution of resources, effective communication, ongoing enhancement processes, evaluation of performance, incorporation of technology, and a focus on patient-centred care.
(McDermott et al., 2022)	NA	Lean supply chain management	Lean supply chain management	Financial resources, patient participation, limited time for Lean adoption, leadership in Lean practices, professional organizational environment, clear and specific goals, well-defined organizational vision, skills and expertise, Lean education, and workforce involvement.
(Awang M et al., 2020)	Malaysia	Lean Healthcare	Hospital Management	Readiness, Critical Success Factors, Lessons learned from initial pilot projects
(Kelendar et al., 2020)	Kuwait	Lean Thinking	Healthcare	Insufficiently robust methods in applying Lean, missing control groups in research designs, limited genuine patient engagement in Lean efforts, Lean initiatives focusing mainly on efficiency rather than the patient viewpoint, the necessity of fostering a culture of ongoing improvement to achieve lasting outcomes, the demand for comprehensive Lean implementation to realize its full benefits, and the need for a nationwide framework to support Lean adoption system-wide.
(Tidwell, 2020)	United States	Lean principles and quality management in the healthcare supply chain industry	Healthcare	Constant technology evolution, Lack of product standards, Inadequate business education, Hesitation by executives, Opposition to change by physicians, Perception of supply chain technology being too expensive
(Naidoo, 2019)	South Africa	Lean principles in the healthcare industry	Healthcare/public hospitals	Leadership Commitment, Employee Autonomy, Information Transparency, Performance Improvements, Training and Skill Development, Data Accuracy, Team Collaboration, Employee Empowerment, Supportive Environment, Continuous Improvement
(Logandran Naidoo & Fields, 2019)	South Africa	Lean thinking	Healthcare sector	Difficulties in executing policies that impact healthcare, characteristics of organizational structures and culture within the public healthcare system, preparedness for change coupled with performing situational assessments, the expertise and experience held by senior healthcare

				managers, dedication and participation from management, autonomy and decision-making power granted to employees, openness and clarity regarding Lean objectives, early gains in performance alongside efforts for enduring sustainability, active involvement and dedication of leadership, and opportunities for cultural transformation as well as education and training.
(Jain & Ajmera, 2019)	India	lean principles	healthcare industry.	Organizational factors, Management commitment, Communication, Human resource factors
(Antony, Sunder, et al., 2019)	NA	Lean assessment, evaluation, measurement, and quantification	Healthcare sector	Driving factors include enhancing patient care, increasing operational efficiency, improving service quality, transforming organizational culture, standardizing processes, eliminating waste, and gaining a competitive edge. Obstacles and constraints arise from the absence of a systematic evaluation of Lean practices at both organizational and hospital levels, highlighting the necessity for a thorough assessment framework. The advantages of applying Lean principles encompass higher customer satisfaction, lowered costs, and better overall financial performance.
(Ajmera & Jain, 2020)	India	Lean principle	Healthcare	Lean leadership, Clarity of goals, Proper lean training, Supportive organizational culture, Focus on quality, Involvement of top management, Cross-functional teams, Leadership, Organizational culture, Communication of goals, Proper training
(Sohal et al., 2021)	Oman	Lean readiness factors for healthcare	Healthcare sector	Leadership support for lean, identifying lean with the strategic agenda, understanding values and customer groups, Undertaking an end-to-end process view, Personnel training and involvement, Measurement and reward systems, Matching demand and capacity levels
(Kaupa & Naude, 2020)	Malawi	Supply chain management of essential medicine	Public health-care system	Top management commitment, Service quality/customer focus, Cost minimisation, Processes
(Mathur et al., 2018)	India	Lean principles in the healthcare supply chain management	Healthcare	Supply chain integration, Information systems, Performance measurement, Organizational effectiveness, Barriers in healthcare supply chain, Impact of lean practices on performance measures
(Argiyantari et al., 2020a)	NA	Lean principles in the pharmaceutical industry Field	Pharmaceutical supply chain	Emphasis is placed primarily on manufacturing, overlooking upstream suppliers, downstream operations, and the comprehensive supply chain process. There is insufficient attention to managing information technology, supplier relationships, customer interactions, and logistics. Practitioner engagement is underdeveloped, and there is a clear need to integrate quality compliance with digital innovation, especially pertaining to Pharma 4.0.
(Khorasani et al., 2020)	Multiple countries	Lean supply chain management applications	Healthcare	Supply chain features include its complexity, the need for collaboration across different sectors, and the costs associated with holding inventory. Leadership qualities involve the active participation of healthcare managers and strong commitment from top management. Organizational traits encompass resistance to change, the existing organizational framework, and the effectiveness of communication channels.
(Borges et al., 2019)	Brazil	Lean healthcare management	Healthcare	There is a lack of extensive academic studies addressing the obstacles to effective lean implementation. The healthcare sector experiences a slow uptake of lean methodologies, facing difficulties in transferring

				manufacturing supply chain practices to healthcare settings. Healthcare organizations rarely achieve improvements across the entire system. Implementation-related challenges impede the positive impact on performance. Additionally, there is insufficient attention given to lean practices and associated barriers during their implementation in healthcare supply chains, as well as a limited comprehension of the factors that hinder lean adoption in this context.
(Almutairi et al., 2019)	Saudi Arabia.	Lean principles and tools in a healthcare setting	Healthcare	Enablers and factors are categorized based on the European Foundation for Quality Management (EFQM) framework. Elements connected to healthcare policy and strategy are identified under the leadership category. There is a correlation between obtaining accreditation from quality institutions and the extent of lean implementation in healthcare organizations. The findings have been validated in other developing countries to confirm that the developed model is effective and consistent across various contexts.
(Gupta, 2018)	United States	Quality Management System	Healthcare	Adherence to the regulatory requirements set by the FDA, implementation of a Quality Management System (QMS), and compliance with Good Manufacturing Practices (GMP) are essential. Key processes include design transfer, supplier qualification, ensuring service quality and traceability, defining the project scope, developing sourcing strategies, and establishing target costing. Early involvement of suppliers (ESI), validation of manufacturing processes, forming effective contracts with suppliers and distributors, and collaborating with major industry players help to minimize supply risks and attract investment.
(Zepeda-Lugo et al., 2018)	USA, Finland, and Colombia	healthcare, hospitals, emergency departments, surgery departments, and radiology.	Lean thinking, Lean Six Sigma methodology, Lean Healthcare methodology, and Lean Manufacturing techniques	Diverse healthcare teams composed of multiple disciplines, ongoing education and training for healthcare personnel, and strong commitment from healthcare staff are critical. Emphasizing culture change, effective leadership, active involvement of healthcare management, clear communication within healthcare teams, support from external consultants, utilization of clinical pathways, and empowerment of healthcare staff all contribute to improved healthcare delivery.
(Gholizadeh et al., 2018)	Iran	Lean management in hospitals	Public hospitals	The human factor, Technology factor, Management factor, Process factor, Relational factor
(Pereira & Tortorella, 2018)	Brazil	Lean Manufacturing	Small manufacturing companies	Company size, Availability of resources, Structuring and process standardization, Hierarchical levels, Proximity between top management and operations, Support for improvement projects
(Willis, 2019)	United States	Lean management principles	Healthcare	Leadership support, Organizational culture and environment where Lean interventions are implemented., Support and buy-in from leadership at all levels of the organization., The vision of the organization includes continuous improvement., Learning from past experiences and incorporating lessons into future initiatives., Involvement of internal consultants with expertise in Lean, especially those with clinical backgrounds., Building capacity within organizations through training programs for staff to lead Lean projects., Focus on

				developing an organizational culture that supports long-term continuous improvement., Commitment and participation of healthcare staff in the improvement process., Support from all managers at all levels in the organization.
(Anuar et al., 2018)	Malaysia	Lean healthcare practices	Private hospitals	Operational aspects, Sociotechnical aspects, Operational Performance, Sustainability
(Rojalin Patri & Suresh, 2018)	India.	Lean healthcare	Healthcare industry	Lean Leadership, Goal specificity, Lean training, Professional culture, Notion of the inappropriateness of lean systems in healthcare, Notion of lean implementation as cost-cutting and layoffs, Frontline workforce engagement, Interdepartmental cooperation, Healthcare organizational resistance, Time commitment for Lean implementation
(Régis et al., 2019)	Brazil	Lean healthcare	Hospital operations	Incentives and driving forces, scheduling and time management, structure and organization, collaboration and team effort, ongoing consistency, resources and instruments, challenges and obstacles, and essential elements are all important aspects.
(García-Villarreal et al., 2019)	Germany	Supply Chain Management	Medical Technology sector	Demand and supply alignment, new product design and development, standards and regulatory adherence
(Das et al., 2018)	India	Total Quality Management practices	Healthcare	Leadership commitment, financial resource management, Team management, Organizational culture, Treatment practices, Training and human resource development, Infrastructure and facility management, social image and reputation
(Prasad et al., 2018)	India	Sustainable supply chain management	Steel sector	Internal organizational elements, sustainable supply chain practices, sustainability outcome indicators, external influences, workforce education and readiness, sustainable purchasing programs
(Bentahar, 2018)	France	Purchasing group projects in healthcare facilities	Healthcare	Project manager skills, Purchaser training, managing resistance to change, Fair distribution of savings, Performance measures, Communication and cooperation within the purchasing group, Management commitment
(Almutairi et al., 2020)	Saudi Arabia	Lean Six Sigma	Healthcare	Hospitals face limitations in resources and financial backing. There is a challenge in managing expenses while enhancing healthcare services. It is essential to lower costs and elevate care quality without compromising patient safety. Through interviews with seasoned healthcare professionals in Saudi Arabia, various facilitators and obstacles were identified. Recognizing the correct lean enablers, key success factors, and essential characteristics is crucial for effective implementation. Lean champions, along with Lean Six Sigma black belts and master black belts, play a pivotal role in leading lean efforts. Ensuring that every component of the assessment model translates into practical, real-world application is of great importance.
(Chakraborty & Gonzalez, 2018)	United States	Lean supply chain framework	Healthcare	Hospitals have resources accessible within both their internal and external supply chains. Effective utilization of these resources is key to delivering patient care. This involves optimizing the movement of physical goods, information, and financial transactions. Additionally, fostering cooperative relationships with external supply chain partners is essential for efficient operations.

4.1 Organization related factors

The organization-related factors, which are considered the first lean enabler in LSCI, are interconnected. There are several ways in which this facilitator might be enhanced. Organizational readiness for successful lean deployment is determined by the following leadership characteristics, as outlined by (Alnajem et al., 2019; Antony, Laux, et al., 2019; Raju & Antony, 2019): the ability to communicate the organization's goals and vision; the willingness to delegate authority within the organisation; the ability to inspire employees to work together to achieve the organization's mission; the ability to convey optimism about the future; the encouragement of teamwork; the promotion of innovation and the search for better ways of doing things; and the emphasis on individual responsibility.

Lean leadership, professional organisational culture, objective specificity, clarity of the organization's vision, competence and knowledge, Lean training, and employee engagement are all aspects that depend on one another to achieve success (McDermott et al., 2022). Case studies consistently demonstrate the interconnectedness between company culture and the human resources management approach (Vaishnavi & Suresh, 2020). Evaluation of management's skill with time and resource management, as well as employees' familiarity with relevant tools and paradigms, is crucial (Maphumulo & Bhengu, 2019). Readiness characteristics related to the external environment include customer focus, an approach centred on suppliers and partners, and the efficient application of technology (De Lima et al., 2018).

Leadership engagement, aligning LSCI with strategy, assigning resources, and keeping employees motivated and trained are essentials for a successful LSCI (Bhat et al., 2020). Furthermore, healthcare has its own set of problems that may make LSCI more difficult than in other sectors. The following section briefly describes the various factors related to organization LSCI as identified in the reviewed literature.

4.1.1 Readiness

Readiness variables include whatever a company does or has in place that aids in transformation by removing obstacles to enacting continuous improvement paradigms (Al-Balushi et al., 2014; Alnajem et al., 2019; Garza-Reyes et al., 2018; Marolla et al., 2022; Miake-Lye et al., 2020; L. Naidoo, 2021; Narayanamurthy et al., 2018; R. Patri et al., 2021; Sharma et al., 2018; Vaishnavi et al., 2019; Vaishnavi & Suresh, 2020). Analysis of the literature reveals that management engagement, effective change-oriented leadership, employee engagement, training, teamwork, an emphasis on the patient value within the organisation, and a culture that promotes continuous change are the most frequently discussed readiness factors (Régis et al., 2019).

4.1.2 Leadership

Leadership is one of the most discussed factors in Literature related to successful LSCI (Antony et al., 2019; Gilson et al., 2018; Govender et al., 2018; Ingelsson et al., 2020; Patri et al., 2021; Toledo et al., 2018; Vito, 2019). Patri et al. (2021) argued that leaders in the healthcare industry might best prepare their organisations for the transition by demonstrating excitement, respect, and a high value for service. Top-level management must demonstrate CSFs, including leadership, engagement, and support; follow-up; alignment with the organization's vision and goal; culture; success celebration; benchmarking and best practice sharing; and empowerment (Yadav et al., 2021)

4.1.3 Strategy

An organisational strategy has a major influence on employee actions, and research shows that when an organization's strategy is focused on continuous development, employees are more open to new experiences and opportunities (Hallam & Contreras, 2018). Strategic alignment is seen as the single most important aspect in determining the success or failure of a LSCI (Al-Balushi et al., 2014). The process through which a company's mission, policies that are congruent with existing resources, and all of the business plans that are developed from the strategic agenda are disseminated to the appropriate parties (Vaishnavi & Suresh, 2020). Employees' efforts during and after LSCI are better understood, justified, and supported according to the strategic agenda (Narayanamurthy & Gurumurthy, 2018).

4.1.4 Organization culture

The culture of an organisation is crucial to the success of any lean endeavour (Almutairi et al., 2020). Organisational culture is often a critical subject in the workplace (Vaishnavi & Suresh, 2020). OC means "need and belief about

ongoing improvement" (Iswanto, 2019). The senior management should take the lead in enhancing OC (Kuiper et al., 2022). Organizational culture is an essential factor for a successful LSCI process it is important to have a high communication level within the employees of the organization (Horwitz et al., 2019). A high-performing and supportive organizational culture beings a proactive improvement (Govindan et al., 2020).

4.1.5 Human resources and skills,

Human Resources in Healthcare is an important LSCI enabler. When implementing new policies and procedures, medical supply chain personnel should be taken into consideration (Dombrowski et al., 2019). The LSCI strategy cannot be implemented without training the HSC staff. Training hospital supply chain staff is one way to enhance human resources, and adopting job-rotating systems that encourage workers to take on many roles might help mitigate quality problems (Ghobakhloo & Fathi, 2019). Amaro et al. (2021) found that when HSCs are given more control, they are more motivated and productive. Executive management choices are important to the success of lean SCM, but the execution technique and the participation of hospital staff in the implementation process are equally crucial (Jasti & Kodali, 2019).

4.1.6 Financial resources

Despite its importance, financial resources are the least discussed factor for LSCI. Hospitals can invest resources like specialised teams, information technology systems, and consistent communication to systematically streamline physical product, information, and financial flows among the various units in their internal supply chain and to optimise these same flows with the two entities of the inner layer of their external supply chain (Chakraborty & Gonzalez, 2018)

4.1.7 Top management support and commitment

Numerous academics agreed that management commitment is crucial in the process of LSCI (Yadav *et al.*, 2021). Top management commitment can be demonstrated in developing a strategic plan for an LSCI, Staff LSCI Education and Training, the interdependencies within and across departments, mutual respect and trust between business parties, participation of suppliers in process and product planning, allocation of resources, organisational policy deployment that takes into account the whole system, empowerment of workers and formation of leaders (Argiyantari et al., 2020b). Top-level management commitment, strong leadership, and clear communication are all dependable aspects of the LSCI enablers. Employee enthusiasm and confidence in the methods also increase when upper management is on board (Niñerola *et al.*, 2020).

4.1.8 Employee involvement.

Having skilled workers reduces the amount of time and energy needed to train, involve, and overcome the distrust of staff and management (Bhat *et al.*, 2023), making organisational maturity in managing process improvement activities an enabling element. Multidisciplinary teams are necessary for improvement projects based on the Lean, Six Sigma, or LSS improvement paradigms. Skills in managing teams effectively are a major enabler (Ajmera & Jain, 2020). Additionally, at the functional level, project management, interdisciplinary teams, strong and reliable data, sustainment strategies, cross-functional teams, measurable targets, individual team member deliverables, and a plan for continuous improvement (Leite *et al.*, 2020).

4.1.9 Training

Empirical studies have generally concluded that training is essential as workers are actively engaged in quality management and improvement initiatives inside their organisations (Ingelsson *et al.*, 2020). It's crucial to focus on CSFs like teamwork, training and development, training manuals, project selection and prioritisation, metrics of measurement, deployment strategies, team formation, cross-functional collaboration, the use of tools and techniques, the involvement of process stakeholders, knowledge management, the voice of the internal and external customer, IT support, and effective communication (McDermott *et al.*, 2022).

4.2 Supply related factors

Another category of CSF related to LSCI in healthcare is supply-related factors, including supplier relations, supply chain strategy adopted by the healthcare facility (HCF), and logistic integration which are discussed in the next sections. Despite the importance of supplier relations and supply-related factors, it has been neglected as a critical factor in assessing the preparedness and readiness of the healthcare organization for LSCI.

4.2.1 Supplier relations

Suppliers' relations important enablers for successful LSCI. Integrating hospitals and their suppliers is key to raising LSCI standards. Collaborative efforts between hospitals and their suppliers can improve LSCI outcomes (Moons *et al.*, 2019). Most hospitals spend more than 40 per cent of their budget on medical supplies, making it one of their most important expenditures (Almutairi *et al.*, 2020). LSCI methods have been shown to reduce this expenditure (Quan *et al.*, 2020).

Decreasing the number of suppliers can help healthcare organizations achieve a more efficient and cost-effective SCM. According to (Argiyantari et al., 2020b), effective LSC can be achieved by single, dependable sources or a small number of suppliers, relying on a small number of reputable, single-source vendors. This can help the healthcare organization bargain with vendors based on costs and have supplier negotiations focused on costs. Another way is done through group purchasing organisation (GPO), which is an organisation that aids healthcare providers, including hospitals, nursing homes, and home health agencies, in realising savings and efficiencies by pooling their purchasing volume and using that leverage to bargain for lower prices from producers, distributors, and other vendors (Almutairi *et al.*, 2020). By making use of economies of scale and purchasing from chosen suppliers/vendors for a large number of hospitals at once, GPOs have created a major cost-saving potential for healthcare providers (Moons *et al.*, 2019). According to Almutairi *et al.* (2020), using a GPO can save money on supply chain charges by up to 15%, which contributes to supply chain efficiency. According to Moons *et al.* (2019), GPOs oversee about 70% of healthcare spending. Supplier relations management is of strategic importance to successful LSCI; according to (Argiyantari et al., 2020b), it can involve enhancing Strategic Procurement, evaluation and accreditation of vendors, protracted cooperation with reliable vendors, commitment to a stable network of suppliers, suppliers' input into the design process, proximity to suppliers.

4.2.2 Logistics integration

Another important element in LSCI that is not emphasized by many studies assessing lean and supply chain implementation is logistics integration. Logistics integration refers to the systematic process by which an organisation incorporates logistics as a comprehensive system, enabling the company to enhance the delivery of value to its customers with increased efficiency (Tortorella *et al.*, 2018). Logistics integration refers to the efficient coordination of material flow from suppliers, enabling companies to ensure a seamless production process (Alshahrani *et al.*, 2018). This coordination facilitates a seamless integration between companies and suppliers, resulting in a convergence of activities that obscures the delineation between the two entities (Alshahrani *et al.*, 2018). Research has demonstrated that logistic functions are of paramount importance in effectively managing an organization's performance and optimising its resource utilisation (Castro *et al.*, 2020; Fathollahi-Fard *et al.*, 2022; Tortorella *et al.*, 2018). The integration of logistics can enhance the efficiency of managing processes by promoting enhanced connectivity and coordination among logistics stakeholders (Alshahrani *et al.*, 2018).

Logistics integration in the healthcare sector encompasses various aspects, including the arrangement of the distribution network, implementation of distribution strategies, management of inventory control, the establishment of supply contracts, integration of the supply chain, strategic partnering, outsourcing, procurement strategies, utilisation of information technology, implementation of decision support systems, and enhancement of customer value (Alshahrani *et al.*, 2018). The configuration of the distribution network encompasses several key components, including the determination of warehouse locations and their corresponding capacities, the production levels of products, and the transportation flows that facilitate the movement of product units from production facilities to designated warehouses. The issues of network flows and capacity utilisation hold significant importance in this context. The efficiency with which suppliers organise matters has an impact on hospitals (Castro *et al.*, 2020). Logistic integration components include the ability to meet tight deadlines or windows for delivery, designing a reliable

logistics network, structure for advanced planning and scheduling of material needs, transportation and logistics outsourcing, and accurately predicting future demand requirements (Fathollahi-Fard *et al.*, 2022).

4.3 Patient-related factors

Patients are part of the external supply chain, although they may not have to have direct contact with all parts of the supply chain. Various factors have been identified as CSF for LSCI, namely, patients' relations, patients' safety and the quality of care provided. Patient safety has a close association with other organizational factors of LSCI, such as transformative leadership, which in turn fosters the growth of a safety culture, the implementation of patient safety programmes, and the improvement of patient safety results. The culture of patient safety benefits from this. There is no denying Organization Culture's importance in the LSCI process (Almutairi *et al.*, 2020).

4.3.1 Patients' relations

Patients' relations are important CSF of LSCI. Patients are the ultimate users, but doctors are the "surrogate consumers" they rely on for guidance; therefore, both are consumers in the end. Forty per cent of a hospital's medical supply budget goes towards products chosen by physicians (Duque-Uribe *et al.*, 2019); therefore, getting their input is crucial. According to Argiyantari *et al.* (2020), patient relations can be highlighted through value definition from the patient's perspective, taking into account patients' input during the process, continuous review of patients' comments, adding value for the client and analysis of causes and effects of failure.

4.3.2 Quality of care

Despite its importance, the Quality of care provided by the patients has not been focused on as an important outcome of LSCI. One of the primary issues currently facing the healthcare industry is the escalating cost of healthcare services, coupled with the imperative to enhance the quality of care provided to patients to achieve improved positive outcomes (McBride & Tietze, 2021).

The implementation of lean management principles in an academic operating room resulted in favourable outcomes, as demonstrated by the quantifiable financial gains observed (McBride & Tietze, 2021). Healthcare managers express apprehension regarding the escalating costs and aim to implement management strategies to mitigate expenses. Conversely, clinicians prioritise the reduction of medical errors and the enhancement of care quality without considering the potential financial implications. Hence, a discernible divergence of interests arises between hospital administrators and healthcare practitioners. Clinicians typically assume the role of primary decision-makers with respect to the procurement of supplies in the majority of hospital settings (Alshahrani *et al.*, 2018).

4.4 Technology related factors

4.4.1 Information and technology in healthcare

Information Technology (IT) enables the effective management of data and information, thereby facilitating smooth operational activities characterised by increased productivity and resource efficiency (Alshahrani *et al.*, 2018). The primary function of this pillar is to integrate information technology (IT) systems between hospitals and their suppliers has both direct and indirect effects on healthcare service integration (HSI) and the overall performance of the supply chain (Alshahrani *et al.*, 2018).

According to (Argiyantari et al., 2020b), lean supply chain in healthcare context is characterised by the implementation of Electronic Data Interchange (EDI) for company-wide messaging, a consolidated repository for the relevant paperwork, the use of enterprise resource planning (ERP) in business management software, the technology used by the clientele base in the form of information systems, supply chain-wide information sharing that is both efficient and open, logistics that include bar codes and scanners, Internet-based business and software for modelling, analysis, decision support systems and simulation.

4.4.2 Information Sharing

The exchange of information between hospitals and their suppliers is a crucial factor in achieving competitive advantage and serves as a significant strategic resource for SCM (McBride & Tietze, 2021).

Inter-organisational information sharing between hospitals and their key suppliers is defined in research as the degree to which hospitals share information pertaining to business transactions to generate specialised knowledge (Sundram et al., 2018). The implementation of seamless information sharing within a HCF has been found to enhance its responsiveness and effectiveness in enhancing performance concerning service quality (Alshahrani et al., 2018).

4.4.3 Technological infrastructure

Information technology (IT) is commonly employed to improve the performance of specific functions, as well as to facilitate collaboration across different functions and boundaries. Good technological infrastructure in the HCF is essential for achieving success in LSCI (Sundram et al., 2018). The implementation of the Integrated Supply Infrastructure (ISI), is a novel framework that encompasses both software and hardware elements utilised to manage and eliminate "embedded waste" within a supply chain (Sundram et al., 2018). The supply chain information systems (SCIS) facilitates the execution and control of various processes, communication channels, and interfaces within a network of supply chain partners (Sundram et al., 2018). Consequently, this integration enhances the ability to effectively manage and streamline logistics operations, ultimately resulting in a reduction in lead time. This is achieved through the firm's implementation of strategies to reduce delays, such as the elimination of bottlenecks and the reduction of slack time (Sundram et al., 2018). These strategies are facilitated by the adoption of technologies such as automatic data capture, automated material handling, and electronic data exchange. (Sundram et al., 2018)

As such, the ISI greatly influences the performance of the supply chain by providing the information supply chain with the required functional support (McBride & Tietze, 2021). The SCIS expands the range and efficiency of the supply chain network for the business by presenting an infrastructure which expedites the efficient interchange of data across assorted value chain components (Sundram et al., 2018). The intrinsic characteristics of the IS help leading manufacturers anticipate the demands of customers in addition to meeting their current needs. The SCIS infrastructure intends to utilize the efficiency of the information flow mechanism in order to coordinate and monitor operations in the supply chain. In additional, literature on SCM, agility, lean manufacturing and business process reengineering highlights the importance of SCIS in influencing timing performance within a SC (Alshahrani et al., 2018; McBride & Tietze, 2021; Sundram et al., 2018).

4.5 Lean related factors

4.5.1 Continuous improvement

Continuous improvement and the alignment of operational goals with strategic objectives are only possible with effective horizontal and vertical communication (Ahmed et al., 2018). Previously the application of lean SCM was only to improve the quality, safety and efficiency of healthcare delivery in certain areas in order to drive a continuous improvement in service delivery through the implementation of IT solutions and appropriate strategic implementation. De Lima et al. (2018) emphasised the same limitation as there is a lack of research in continuous improvement approaches compared to production organization methods, visual management, and diagnosing and problem-solving tools. Argiyantari et al. (2020) indicated that applying lean principles (LPs) to the pharmaceutical supply chain could become a significant competitive differentiator while not requiring major capital investments. Redesigning the operation is required to ensure regulatory compliance while simultaneously supporting continuous improvement (Argiyantari et al., 2020b). A successful continuous cycle of improvement that may act as a dynamic capability can be achieved by establishing a framework in which personnel at all levels are taught and empowered in the continuous improvement process (Fainshmidt et al., 2019).

4.5.2 Assessment and control

This factor is associated with the concept of ongoing enhancement. Evaluating and managing modifications and accomplishments can serve as a catalyst for maintaining a vibrant, lean culture within the organisation. According to Gohr et al. (2019), when information is made visible and transparent to all individuals, it tends to enhance their motivation to enhance various processes. Swarnakar et al. (2022) assert that the lean approach emphasizes metrics, data analysis, and goal setting. Establishing a performance measurement system is of utmost importance in ensuring the success of lean initiatives, as it enables the evaluation of the program's effectiveness (Gohr et al., 2019).

4.5.3 Waste elimination

Hospitals are among the biggest waste generators, with 24-hour operations to cater to patient care and a huge amount of water and energy used to operate the hospital operation (Zhu et al., 2018). In addition, medical waste disposal needs to undergo special disposal processing to prevent environmental and human hazardous issues (Ajmera & Jain, 2020; Vaishnavi & Suresh, 2020). Controlling waste generation and reducing it is necessary because, as an industry related to society, hospitals are under pressure to comply with green needs for environmental sustainability (Zhu et al., 2018). Decreasing the cost of inventory, increasing the value in the SCM, increasing SC relationships and eliminating waste are considered to be quite complex for reducing the cost of the healthcare industry in general. The overall goal of implementing integrated LSCM in the healthcare industry is to eliminate waste arising from non-value-added activities, including waiting, overproduction, motion, transportation, excessive processing, inventory, and underutilization of staff members, all of which are costly and inconvenient for health care in healthcare (Khorasani et al., 2020). LSCM concept's main purpose is reducing the cost of inventory and optimizing waste management (Khorasani et al., 2020). Despite being one of the essential goals of lean implementation in healthcare, waste elimination as part of CSF of LSCI is not widely acknowledged in the literature. However, in the context of this study, waste management is added as a factor in the LSCI assessment model. Table 3 summarise the categories and factors affecting LSCI.

Table 3. Summary of categories and factors affecting LSCI

Category	Factors	References
Organization related factors	Readiness	(Al-Balushi et al., 2014; Alnajem et al., 2019; Garza-Reyes et al., 2018; Marolla et al., 2022; Miake-Lye et al., 2020; L. Naidoo, 2021; Narayanamurthy et al., 2018; R. Patri et al., 2021; Régis et al., 2019; Sharma et al., 2018; Vaishnavi et al., 2019; Vaishnavi & Suresh, 2020)
	Leadership	(Aij & Teunissen, 2017; A. Almutairi et al., 2020; A. M. Almutairi et al., 2019; Antony, Laux, et al., 2019; Bijl et al., 2019; Eamranond et al., 2020; Fournier & Jobin, 2018; Gilson I.A., 2018; Govender et al., 2018; Ingelsson et al., 2020; R. Patri et al., 2021; Podsakoff & Podsakoff, 2019; Shung-King L. and Mbachu, C. and Molyneux, S. and Muraya, K.W. and Uguru, N. and Govender, V., 2018; Toledo et al., 2018; Uhl-Bien & Arena, 2018; Vito, 2019)
	Organisational strategy	(Al-Balushi et al., 2014; Hallam & Contreras, 2018; Honda et al., 2018; Kuiper et al., 2022; Narayanamurthy et al., 2018; Narayanamurthy & Gurumurthy, 2018; Vaishnavi & Suresh, 2020)
	Organization culture	(A. Almutairi et al., 2020; A. M. Almutairi et al., 2019; Horwitz et al., 2019; Iswanto, 2019; Kuiper et al., 2022; Vaishnavi & Suresh, 2020)
	Human resources and skills	(Amaro et al., 2021; Chakraborty & Gonzalez, 2018; Dombrowski et al., 2019; Ghobakhloo & Fathi, 2019; Jasti & Kodali, 2019)
	Top management support and commitment	(Argiyantari et al., 2020a; Harris et al., 2014; Niñerola et al., 2020; Woodnutt, 2018; R. Yadav et al., 2021; V. Yadav et al., 2018)
	Employee involvement.	(Ajmera & Jain, 2020; Bhat et al., 2023; Honda et al., 2018; Leite et al., 2020; Swarnakar et al., 2021).
	Training	(Damián Sanz et al., 2019; Ingelsson et al., 2020; McDermott et al., 2022)
Supply related factors	Supplier relations	(A. Almutairi et al., 2020; A. M. Almutairi et al., 2019; Argiyantari et al., 2020a; Duque-Uribe et al., 2019; Moons et al., 2019; Quan et al., 2020)
	Logistics integration	(Alshahrani et al., 2018; Argiyantari et al., 2020a; Castro et al., 2020; Fathollahi-Fard et al., 2022; Tortorella et al., 2018)

Patient-related factors	Patients' relations	(Argiyantari et al., 2020a; Duque-Uribe et al., 2019)
	Quality of care	(Alshahrani et al., 2018; McBride & Tietze, 2021)
Technology related factors	Information and technology in healthcare	(A. Almutairi et al., 2020; Alshahrani et al., 2018)
	Information Sharing	(Alshahrani et al., 2018; McBride & Tietze, 2021; Sundram et al., 2018)
	Technological infrastructure	(Alshahrani et al., 2018; McBride & Tietze, 2021; Sundram et al., 2018)
Lean related factors	Continuous improvement	(S. Ahmed et al., 2018; Argiyantari et al., 2020a; Fainshmidt et al., 2019; Linderman et al., 2010)
	Assessment and control	(Gohr et al., 2019; Swarnakar et al., 2022)
	Waste elimination	(Ajmera & Jain, 2020; Khorasani et al., 2020; Vaishnavi & Suresh, 2020; Zhu et al., 2018)

4.6 LSCI assessment index

The previous research results were used to identify the CSF for LSCI in the healthcare sector. Since mere identification of the CSF does not actively help the healthcare organization in the application or integration between lean principles and supply chain management. Additionally, the lack of literature on a comprehensive model or index assessing the organization's preparedness, readiness, or level of application of lean principles in supply chain management, the need for an easily applicable LSCI assessment index that enables stakeholders and decision-makers in healthcare organizations to assess the level of LSCI. The proposed LSCI assessment index is designed to be comprehensive as it covers most of the CSF in LSCI identified in the literature. The proposed index is categorised into factors including Organization related factors (strategy (7 items), culture (4 items), readiness (5 items), human resources (4 items), financial resources (5 items), Management commitment and support (3 items), Leadership and Management styles (6 items), training (4), Employee involvement and recognition (4 items). Patient-related factors: Patients' relations (7), Quality of care (5), Supply related factors: logistic integration (4 items), suppliers' relations (7 items), supply chain integration (11 items). Technology-related factors: Information Technology in healthcare (9 items), information sharing (5 items), technology infrastructure (4 items), lean related factors (6 items). The proposed LSCI assessment index has 100 statements that cover the LSCI. The index is answered using a 5-point scale between 1, "not at all applied," 2, "not applied", 3 applied, 4 strongly applied and 5 ", continuously applied". The proposed LSCI assessment index is demonstrated in Table 4; the proposed scale is demonstrated in Table 5.

Table 4. The proposed "LSCI assessment index"

Category	No.	Strategy:	Source
Organization related factors	1.	LSCI is used to gain a sustainable competitive advantage	(De Beer, 2015)
	2.	LSCI is the route chosen by the organization for future growth	
	3.	LSCI is the organization's strategy for dealing with competitive pressure	
	4.	LSCI is the healthcare facility strategy for achieving patient satisfaction	
	5.	The organization uses external experts/consultants on a regular basis to evaluate the overall performance and LSCI.	(Al-Najem et al., 2012)
	6.	LSCI's vision is shared across the organization	
	7.	LSCI strategy is used to integrate supply and demand management across the organization	(De Beer, 2015)
	Organization Culture:		
	1.	Integration across different parts of the Organization is actively encouraged.	(Al-Najem et al., 2012)
	2.	Different parts of the organization often integrate to create change.	
	3.	Teams are our primary building blocks.	
	4.	Employees from different parts of the organization share a common perspective regarding LSCI.	
	Organization Readiness		
	1.	The Organization embrace the various attitudinal aspects of LSCI	

2.	LSCI is reflected in the organization's strategy	(Helten & Lindemann, 2012)
3.	LSCI is driven as a high-priority strategic business initiative.	
4.	The mindset, attitude, and behaviour of the medical and non-medical staff are fundamental to LSCI's success.	
5.	There is a clear link between the organization's goals, key objectives, and LSCI activities.	
Human Resources		
1.	Both medical and non-medical staff have the required skills for LSCI	(Das et al., 2018; Gholizadeh et al., 2018; Jain & Ajmera, 2019)
2.	Both medical and non-medical staff receive the right training to enhance their skills for successful LSCI.	
3.	The healthcare facility has the required resources for LSCI.	
4.	The healthcare facility cares about providing the required resources for LSCI.	
Financial resources:		
1.	The healthcare facility provides the necessary budget for LSCI.	(A. Almutairi et al., 2020; Das et al., 2018; McDermott et al., 2022)
2.	The healthcare facility has the required budget to hire experts for LSCI.	
3.	The healthcare facility has the required financial budget for technical utilities.	
4.	The healthcare facility has the required financial budget for employee training.	
5.	The healthcare facility is willing to pay the required financial resources for consultation regarding LSCI.	
Management commitment and support:		
1.	Top management encourages and coaches' staff by visiting the workplace on a regular basis.	(L. Naidoo & Fields, 2019)
2.	Top management supports LSCI.	(Lee & Joo, 2020)
3.	Top management is committed to LSCI.	
Leadership and Management Styles:		
1.	The healthcare facility management and leaders continuously track the progress against the stated goals	(Al-Najem et al., 2012)
2.	Leaning is an important objective in our day-to-day work.	
3.	The healthcare facility leaders have a long-term viewpoint.	
4.	The healthcare facility leader sets goals that are ambitious but realistic.	
5.	Work is organized so that each person can see the relationship between his or her job and the goals of the organization.	
6.	The leaders and managers practice what they preach.	
Training:		
1.	The healthcare facility invests in training programmes and encourages cross-job training.	(Al-Najem et al., 2012)
2.	Each of the medical and non-medical staff receives training related to LSCI.	
3.	The capability of the medical and non-medical staff is constantly improving.	
4.	The medical and non-medical staff capabilities are viewed as an important source of competitive advantages.	
Employee involvement and recognition:		
1.	Most medical and non-medical staff are highly involved in their work	(Al-Najem et al., 2012)
2.	Both medical and non-medical staff believe that they can have a positive impact.	
3.	Supply chain integration is ongoing and involves both medical and non-medical staff in the process.	
4.	The healthcare facility has an employee suggestions system.	
Patients' relations		

Organization related factors	1.	Patients' comments and recommendations often lead to changes	(MIT, 2001)
	2.	Patients' input directly influences our decisions.	
	3.	All members have a deep understanding of patients' wants and needs.	
	4.	We encourage direct contact with patients by our staff.	
	5.	New and improved ways to do work are continually adapted to meet patients' demands.	
	6.	Patients help the healthcare facility by providing information about their future demands.	
	7	There is a system in place for collecting patients' complaints so that problems can be avoided in the future.	
	Quality of care		
	1	A physician did not have the product needed during a procedure	(Cardinal Health Hospital, 2018)
	2	The patient experienced an adverse event because the facility did not have the right supplies.	
	3	Supplies had to be borrowed from another hospital.	
	4	We had to delay a case due to a lack of supplies.	
Supply related factors	**Logistics integration**		
	1.	The healthcare facility recognizes the importance of logistics integration with the suppliers.	(Alshahrani et al., 2018)
	2.	The healthcare facility's logistics activities are well integrated with the suppliers' logistics activities.	
	3.	The healthcare facility has a seamless integration of logistics activities with our suppliers.	
	4.	Our inbound and outbound distribution of hospital supplies with our vendors/suppliers is well integrated.	
	Supplier relations		
	1.	A clear strategy is in place by which to evaluate supplier performance in terms of quality, delivery and prices.	(Al-Najem et al., 2012)
	2.	Local suppliers are used to avoid shipment delays.	
	3.	Active steps are taken to reduce the number of suppliers in each category.	
	4.	Suppliers are cooperative and committed to maintaining a long-term relationship.	
	5.	Suppliers are provided with feedback regarding quality and delivery performance.	
	6.	The healthcare facility has long-term strategic alliances with suppliers.	
	7.	The healthcare facility has consistent relationships with group purchasing organizations (GPOs) and other partners.	
	Supply chain integration		
	1.	The use of the computer system for recording and managing the flow of material circulating inside the healthcare facility	(Sundram et al., 2018)
	2.	The level of using enterprise application integration among internal functions.	
	3.	The degree of exploitation of enterprise resource planning by staff in storage, processing, broadcasting and access to information.	
	4.	The utilization of periodic interdepartmental meetings among internal functions.	
	5.	The degree of collaboration between departments in establishing supply plans and production schedules	
	6.	The degree of commitment and collaboration between departments to resolve problems related to order fulfilment	
	7.	The healthcare facility uses Electronic Data Interchange in order.	

	8.	The healthcare facility uses conference calls and video conferences with major suppliers.	
	9.	The healthcare facility uses information systems linked with its major suppliers.	
	10.	The healthcare facility shares of supply forecast and inventory level	
	11.	The degree of collaboration with suppliers in product development and process improvement.	
	Information and technology in healthcare		
Technology related factors	1.	In the healthcare facility, information sharing is used effectively in upstream and downstream operations that occur in the LSCI.	(Alshahrani et al., 2018)
	2.	Information and technology increase productivity and improve patient safety and satisfaction.	
	3.	The healthcare facility has information systems that work seamlessly across key suppliers/ vendors.	
	4.	Most of the invoices, purchase orders, funds, and other transactional processes with suppliers are done electronically.	
	5.	The healthcare facility has advanced information systems that enable online tracking of orders and shipments.	
	6.	The healthcare facility has electronic mailing capabilities with key suppliers.	
	7.	In the healthcare facility, information sharing helps is used effectively in upstream and downstream operations that occur in the LSCI.	
	8.	Information transfer among people involved in linked activities" in the medical supply chain is described as Accurate and timely.	
	9.	Efficient hospital LSCI is built on an information-sharing foundation.	
	Information Sharing		
	1.	Staff share sensitive information (financial, production, design, research, and/ or competition) with our key suppliers.	(Alshahrani et al., 2018)
	2.	Suppliers are provided with any information that might help them.	
	3.	We keep each other informed about events or changes that may affect the other party.	
	4.	The exchange of information takes place frequently, informally and/ or in a timely manner.	
	5.	We have frequent face-to-face planning/ communication.	
	Technological infrastructure		
	1.	Utilize automated data capture systems such as barcode and RFID tags	(Sundram et al., 2018)
	2.	Automated material handling system to perform daily operations	
	3.	Utilize electronic data interchange to perform daily operations.	
	4.	Utilize computerized production planning systems such as Material requirements planning.	
	Lean related factors		
lean related factors	1.	The LSCI process has a pilot project	(Helten & Lindemann, 2012; L. Naidoo & Fields, 2019)
	2.	The application of lean tools and techniques will ensure the success of LSCI.	
	3.	All the performance indicators plus lead time have been improving since LSCI.	(Brito et al., 2019)
	4.	The standards were revised and improved monthly.	
	5.	The application of lean principles enhanced waste elimination in the supply chain	
	6.	All workers feel responsible for continuous improvement, actively and participate frequently (more than once every six months)	

The LSCI assessment index is also proposed to be easily calculated by the organization's stakeholders and decision-makers, so the overall score of the index is proposed to be between 0 to 100 score. Using the LRI used in (Awang et

al., 2022), a score between 0 and 40 indicates that LSCI is not applied and still needs a lot of work from the organization. 41 to 60 indicates that LSCI is applied but still needs some enhancement and work; the score between 61-80 indicates that LSCI is applied with few improvements required. Scores between 81 and 100 indicate the utmost application of LSCI in the healthcare organization.

Table 5. The index score and weight

Score	**1**	**2**	**3**	**4**	**5**
Indication	**Not at all applied**	**Not applied**	**Applied**	**Strongly applied**	**Continuously applied**
Weighted score	0.2	0.4	0.6	0.8	1

5. Expert validation and pilot study results.

The optimal number of experts for content validation in lean supply chain management is recommended to be at least 6 and not exceed 10. Experts are selected based on their expertise in LSCM and healthcare operations (Polit and Beck, 2006). The process involves sending the questionnaire to 20 academics and experts, who provide feedback via email. A cover letter outlines the study's objectives, confidentiality assurances, and requests for their position, academic institute, and experience. This expert validation process aims to gather informed opinions to enhance questionnaire quality for conducting a high-quality survey. Table 6 provides an overview of the experts involved in the validation process.

Table 6. The background of experts

Experts	**Institutions/Organizations**	**Designation**	**Years of Experience**	**Expertise Area**
Expert 1	Indian Institute of Technology Delhi, India	Professor of Operations and Supply Chain Management	27	Supply chain management
Expert 2	Indiana University, USA	Professor of Operations and Supply Chain Management	15	Supply chain and operation management
Expert 3	Cairo University, Egypt	Professor of Operations and Supply Chain Management	12	Smart Warehousing and Logistics Systems
Expert 4	King Abdulaziz University, KSA	Lecturer and researcher	7	Health logistics and supply chain management
Expert 5	Ain Shams University, Egypt	Supply chain expert	17	Procurement and logistics services
Expert 6	College of International Transport & Logistics (CITL)	Professor	11	Logistics, supply chain management and international transport

The experts were asked to evaluate the questionnaire in terms of content, wording, respondent interest, sequence, continuity and flow, relevance, and length and time. The experts were also asked to evaluate and give their recommendations regarding the interview questions. The summary of comments and suggestions from the experts are presented in Table 7. All comments were taken into consideration. Feedback from the experts indicated that the questionnaire was comprehensive, clear, specific, and relevant to the study context. The experts found the questionnaire to be well-structured, with a logical sequence and smooth flow of questions. Suggestions for improvement included removing confusing or biased items and ensuring unbiased wording in the questionnaire. Overall, the experts provided positive feedback on the questionnaire's quality and suitability for assessing Lean Supply Chain Integration in healthcare settings.

Table 7. The summary of comments and suggestions from the experts on the LSCI assessment index

Experts	Parameter	Expert's comments
Expert 1	Content	comprehensive range of factors affecting the successful integration of lean supply chain management in healthcare
	Wording	Items are clear and specific.
	Respondent interest	The survey is likely to keep participants interested.
	Sequence	Logical sequence
	Continuity and flow	a smooth flow
	Relevance	Highly relevant
	Length and time	The survey is appropriately structured.
Expert 2	Content	Items number 4 and 5 of the organization readiness are confusing, it's better to be removed as mindset, attitude, and behaviour do not represent organization readiness, and item No. 5 seems suggestive and biased to words certain correlation, Items should be unbiased.
	Wording	Straightforward and professional manner
	Respondent interest	Focusing on critical issues influencing healthcare supply chain operations.
	Sequence	More coherent as a whole
	Continuity and flow	No trouble navigating the questions and providing insightful feedback
	Relevance	Precisely right, highlighting important aspects that play a role in healthcare supply chains' ability to successfully integrate lean principles.
	Length and time	A suitable length
Expert 3	Content	It is sufficient to use items to evaluate the dimension
	Wording	Clear
	Respondent interest	The sequence seems to be appropriate.
	Sequence	Excellent flow.
	Continuity and flow	Items are relevant to the study context.
	Relevance	The questionnaire is good.
	Length and time	The sequence seems to be appropriate.
Expert 4	Content	Satisfactory; however, there is an opportunity for enhancement in terms of the overall organization and layout.
	Wording	Clear and specific.
	Respondent interest	Can maintain respondent interest
	Sequence	Good sequence
	Continuity and flow	Questions have good continuity and flow.
	Relevance	The items highlight important elements that affect the effective adoption of lean principles in healthcare supply chains, making them extremely pertinent to the research topic.
	Length and time	Too lengthy.
Expert 5	Content	Thorough analysis of the variables influencing the effective adoption of lean supply chain management in the healthcare industry
	Wording	Properly worded
	Respondent interest	Ok.
	Sequence	The sequence is good.
	Continuity and flow	Very good
	Relevance	Items are relevant to the study context.
	Length and time	The questionnaire is appropriate.
Expert 6	Content	A thorough look covers a wide range of topics
	Wording	Clear and precise
	Respondent interest	Acceptable
	Sequence	Organized
	Continuity and flow	Acceptable
	Relevance	Relevant
	Length and time	Adequate

Following expert validation, a pilot study is essential in quantitative research to select data collection instruments and strategies for participant inclusion. In this study, 15 experts were chosen to enhance the questionnaire's quality before

data collection. The pilot study helps in designing the quantitative study and assessing the measurement properties and survey viability. Reliability in this research will be evaluated using Cronbach's Alpha, with values closer to 1.00 indicating high consistency. A Cronbach's Alpha of at least 0.70 is considered accurate for testing instruments. This process ensures the questionnaire's reliability and validity before conducting the main survey.

Participant demographics from the pilot survey are detailed in Table 8. Among the participants, 18 were male and 3 were female. Educational backgrounds included diploma (14.3%), graduate studies (52.4%), and postgraduate studies (33.3%). Participants represented departments such as general administration, procurement, supply chain, medical, and quality. Notably, 52.4% had 11 to 20 years of experience, and most (61.9%) worked in hospitals with 100–299 beds, while 38.1% were from hospitals with 300–499 beds.

Table 8. Frequency analysis of the pilot survey

Variable	Category	Frequency	Percentage
Gender	Male	18	14.3%
	Female	3	85.7%
Position	Manager	21	100%
Degree of education	Diploma	3	14.3%
	Graduate studies	11	52.4%
	Postgraduate studies	7	33.3%
Departments	General administration	8	38.1%
	Procurement	4	19%
	Supply chain	3	14.3%
	Medical	4	19%
	Quality	2	9.5%
Experience	Less than 10	10	47.6%
	Between 11-20	11	52.4%
Hospital size	100-299 Beds	13	61.9%
	300-499 Beds	8	38.1%

To evaluate internal consistency reliability, Cronbach's Alpha was calculated for each research variable. Cronbach's Alpha is a widely accepted statistical measure used to determine the reliability of a scale, serving as a benchmark for assessing how consistently a set of questionnaire items measures an underlying construct. Values above 0.70 are generally considered acceptable, while values above 0.80 indicate high reliability (Murphy & Davidshofer, 2005).

In this study, Cronbach's Alpha values ranged from 0.512 to 0.892 across all variables, indicating moderate to excellent internal consistency. High reliability was observed for constructs such as organizational strategy ($\alpha = 0.841$), training ($\alpha = 0.854$), quality of care ($\alpha = 0.877$), and logistics integration ($\alpha = 0.892$), supporting the soundness of the instrument. Some constructs, including financial resources ($\alpha = 0.512$) and organizational readiness ($\alpha = 0.526$), showed lower reliability scores. However, these values remain within acceptable limits for exploratory research setting. Overall, the reliability results are summarized in Table 9.

Table 9. Cronbach's Alpha Results

Variable	No. of items	Cronbach's Alpha (α)	Reliability
Organisation Strategy	7	0.841	High reliability
Organization Culture	4	0.699	Moderate reliability
Organization Readiness	3	0.526	Moderate reliability
Human Resources	5	0.606	Moderate reliability
Financial resources	5	0.512	Moderate reliability
Management commitment and support	3	0.535	Moderate reliability
Leadership and Management styles	5	0.742	High reliability
raining	3	0.854	High reliability
Employee involvement and recognition	4	0.604	Moderate reliability

Variable	No. of items	Cronbach's Alpha (α)	Reliability
Patients' relations	6	0.706	High reliability
Quality of care	5	0.877	High reliability
Logistics integration	4	0.892	Excellent reliability
Supplier relations	7	0.612	Moderate reliability
Supply chain integration	11	0.615	Moderate reliability
Information Technology	9	0.722	High reliability
Information Sharing	5	0.601	Moderate reliability
Technological infrastructure	4	0.654	Moderate reliability
Lean factors	11	0.623	Moderate reliability

In summary, it is important to note that, while Cronbach's Alpha does not directly measure validity, it contributes to construct validity by indicating whether the items within a scale are internally consistent. Therefore, the results of this pilot study provide preliminary evidence of the questionnaire's reliability and validity, supporting its use in the main phase of the study, which will focus on evaluating Lean Supply Chain Integration in healthcare settings.

6. Conclusion

This study proposed a comprehensive framework for Lean-Supply Chain Integration (LSCI) in the healthcare sector by identifying and categorizing critical success factors (CSFs) across organizational, supply-related, lean, patient, and technology dimensions. Through a systematic literature review and expert validation, the research developed a 100-item LSCI Assessment Index that enables healthcare institutions to measure their level of integration and lean maturity. The index utilizes a 5-point scale and generates a weighted score between 0 and 100, with score bands indicating the extent of LSCI application within the organization.

Experts from academia and professionals in lean and healthcare operations validated the process and confirmed the questionnaire's clarity, relevance, and comprehensiveness. Feedback emphasized the appropriateness of the structure and provided suggestions for refinement. A subsequent pilot reliability study demonstrated acceptable to high reliability across most variables, with Cronbach's Alpha values confirming internal consistency in the measurement of constructs such as leadership, logistics integration, training, and quality of care.

Overall, the LSCI Assessment Index represents a novel and practical tool for healthcare organizations to benchmark their lean implementation and supply chain integration efforts, offering actionable insights to drive continuous improvement and performance optimization.

6.1 Managerial Implications

The proposed Lean-Supply Chain Integration (LSCI) Assessment Index offers significant practical value for healthcare managers and decision-makers seeking to improve operational efficiency, cost-effectiveness, and service quality. By providing a structured and comprehensive tool composed of 100 measurable items across the organizational, technological, patient-related, supply chain, and lean implementation dimensions, the model equips managers with clear indicators to assess the current state of lean integration within their healthcare facility. For instance, hospital administrators can use the index to identify weaknesses in supplier collaboration or logistics integration and implement targeted interventions, such as digitizing inventory tracking or renegotiating supplier contracts to ensure timely delivery of critical medical supplies.

In a real-life engineering setting, such as a large urban hospital managing hundreds of supply and demand nodes daily, the index can be embedded into regular quality audits or annual strategic planning sessions. It provides actionable insights that help prioritize investments, whether in workforce training, ERP systems, or waste reduction initiatives. The model's structure allows it to be easily adapted to a facility's specific scale and resource level. For example, a

mid-sized private clinic can apply the index in phases, starting with organizational and training-related items, while a larger government hospital can adopt the full scale for holistic improvement planning.

The benefits to organizations adopting this model are multifid. It enables data-driven decision-making, fosters a culture of continuous improvement, and strengthens alignment between departments, suppliers, and end-users (patients). Ultimately, applying the LSCI index supports better resource utilization, reduced operational waste, improved patient outcomes, and a measurable return on investment. Given its design as a self-assessment tool with a 5-point scale and weighted scoring, it is also user-friendly and does not require extensive technical expertise or external consultancy for initial implementation. This ease of integration makes it a practical and scalable solution for healthcare facilities aiming to mature their lean supply chain practices and remain competitive in increasingly resource-constrained environments.

6.2 Research Limitations

This study makes a significant contribution to the field of Lean-Supply Chain Integration (LSCI) in healthcare. However, some limitations must be acknowledged. One notable limitation is the sample size and scope, as the number of experts involved in the validation and pilot testing was relatively limited. Expanding the expert panel to include a larger and more diverse group could yield broader insights and enhance the generalizability of the findings. Additionally, the study's focus on healthcare supply chains may restrict the applicability of the results to other sectors or to highly specialized healthcare environments. There is also a potential for expert bias, given that participants in the validation process were selected based on their expertise in lean and supply chain management, which may have unintentionally excluded perspectives from other critical stakeholders such as clinical staff or patient representatives. Lastly, while Cronbach's Alpha was used to assess internal consistency and demonstrated acceptable reliability for most variables, the robustness of the index could be further strengthened by incorporating additional psychometric evaluations such as construct validity testing and factor analysis.

6.3 Recommendations for Future Research

To further advance the understanding and application of Lean-Supply Chain Integration (LSCI) in healthcare, future research should focus on several key areas. First, broader empirical application and validation across diverse healthcare settings such as public versus private hospitals, and rural versus urban contexts are essential to assess the generalizability and practical utility of the proposed index. Additionally, adapting the LSCI assessment tool for use in related sectors, including pharmaceuticals, diagnostics, and elder care, would allow for meaningful cross-sector comparisons of maturity levels and integration strategies. Future studies should also incorporate advanced statistical techniques such as exploratory and confirmatory factor analysis and structural equation modelling to test construct validity and refine the grouping of factors within the index. Longitudinal research is recommended to evaluate how LSCI scores evolve within individual organizations, helping to identify which critical success factors contribute to sustained lean transformation. Lastly, developing stakeholder-specific sub-indices tailored for clinical staff, supply chain managers, or executive leaders could provide more targeted insights and practical recommendations for implementing lean principles effectively across various roles within the healthcare system.

Acknowledgement

The authors would like to acknowledge the institutional support provided by Zawia Higher Institute of Science and Technology, under the Ministry of Higher Education and Scientific Research.

References

Abbasi, S., Sıcakyüz, Ç., & Erdebilli, B. (2023). Designing the home healthcare supply chain during a health crisis. *Journal of Engineering Research (Kuwait)*, *11*(4), 447–452. https://doi.org/10.1016/j.jer.2023.100098

Ageiz, M., Elshrief, H., & Rashad, R. (2022). Success Factors Key for Lean Management Practice and Clinical Governance Climate Implementation as Perceived by Nurse Managers: A comparative Study. *Assiut Scientific Nursing Journal*, *10*(28.), 25–40. https://doi.org/10.21608/asnj.2022.118137.1309

Ahmed, S., Abd Manaf, N. H., & Islam, R. (2018). Measuring Lean Six Sigma and quality performance for healthcare organizations. *International Journal of Quality and Service Sciences*, *10*, 267–278.

Ahmed, W., & Huma, S. (2021). Impact of lean and agile strategies on supply chain risk management. *Total Quality Management & Business Excellence*, *32*(1–2), 33–56.

Aij, K. H., & Teunissen, M. (2017). Lean leadership attributes: a systematic review of the literature. *Journal of Health Organization and Management*.

Ajmera, P., & Jain, V. (2020). A fuzzy interpretive structural modeling approach for evaluating the factors affecting lean implementation in Indian healthcare industry. *International Journal of Lean Six Sigma*, *11*(2), 376–397.

Al-Balushi, S., Sohal, A. S., Singh, P. J., Al Hajri, A., Al Farsi, Y. M., & Al Abri, R. (2014). Readiness factors for lean implementation in healthcare settings–a literature review. *Journal of Health Organization and Management*.

Al-Najem, M., Dhakal, H., & Bennett, N. (2012). The role of culture and leadership in lean transformation: a review and assessment model. *International Journal of Lean Thinking*, *3*(1), 119–138.

Alanazi, M. S. (2022). Identifying Critical Success Factors for implementing Effective Supply Chain Management Practices in Prince Sultan Medical City in Riyadh. *Saudi Journal of Medical and Pharmaceutical Sciences*, *8*(11), 660–673. https://doi.org/10.36348/sjmps.2022.v08i11.005

Alemsan, N., Tortorella, G., Taboada Rodriguez, C. M., Balouei Jamkhaneh, H., & Lima, R. M. (2022). Lean and resilience in the healthcare supply chain – a scoping review. *International Journal of Lean Six Sigma*, *13*(5), 1058–1078. https://doi.org/10.1108/IJLSS-07-2021-0129

Almutairi, A. M., Salonitis, K., & Al-Ashaab, A. (2019). Assessing the leanness of a supply chain using multi-grade fuzzy logic: a health-care case study. *International Journal of Lean Six Sigma*, *10*(1), 81–105.

Almutairi, A., Salonitis, K., & Al-Ashaab, A. (2020). A framework for implementing lean principles in the supply chain management at health-care organizations: Saudi's perspective. *International Journal of Lean Six Sigma*, *11*(3), 463–492.

Alnajem, M., Garza-Reyes, J. A., & Antony, J. (2019). Lean readiness within emergency departments: a conceptual framework. *Benchmarking: An International Journal*.

Alotaibi, A. (2025). Development of Remanufacturing Readiness Index for MSMEs : A Comprehensive Framework.

Alshahrani, S., Rahman, S., & Chan, C. (2018). Hospital-supplier integration and hospital performance: evidence from Saudi Arabia. *The International Journal of Logistics Management.*

Amaro, P., Carvalho Alves, A., & Manuel Sousa, R. (2021). Lean Thinking as an Organizational Culture: A Systematic Literature Review. *Organizational Cultures: An International Journal*, *21*(2).

Antony, J., Laux, C., & Cudney, E. (2019). Leadership for Lean Six Sigma Deployment. *In The Ten Commandments of Lean Six Sigma (Pp. 45-55). Emerald Publishing Limited*.

Antony, J., Sunder, V., Sreedharan, R., Chakraborty, A., & Gunasekaran, A. (2019). A systematic review of Lean in healthcare: a global prospective. *International Journal of Quality and Reliability Management*, *36*(8), 1370–1391. https://doi.org/10.1108/IJQRM-12-2018-0346

Anuar, A., Saad, R., & Yusoff, R. Z. (2018). Sustainability through lean healthcare and operational performance in the private hospitals: A proposed framework. *International Journal of Supply Chain Management*, *7*(5), 221–227.

Anzum, K. M. T., & Kibria, M. G. (2024). A conceptual model for evaluating readiness for lean practices using a fuzzy logic approach: A case study in Bangladeshi healthcare institutes. *Heliyon*, *10*(17), e36356. https://doi.org/10.1016/j.heliyon.2024.e36356

Argiyantari, B., Simatupang, T. M., & Basri, M. H. (2020a). Pharmaceutical supply chain transformation through application of the lean principle: A literature review. *Journal of Industrial Engineering and Management*, *13*(3), 475–494. https://doi.org/10.3926/jiem.3100

Argiyantari, B., Simatupang, T. M., & Basri, M. H. (2020b). Pharmaceutical supply chain transformation through application of the Lean principle: A literature review. *Journal of Industrial Engineering and Management (JIEM)*, *13*(3), 475–494.

Arora, M., & Gigras, Y. (2018). Importance of supply chain management in healthcare of third world countries. *International Journal of Supply and Operations Management*, *5*(1), 101–106.

Awang, M., Idris, R., & Zakaria, Z. (2022). Lean Readiness Index for Malaysian Hospitals: An Exploratory Study. *Int. J. Ind. Eng. Prod. Res*, *33*, 1–11.

Awang M, Kamarruddin Z, & Zakaria Z. (2020). Framework of Lean Healthcare Implementation in Malaysian Hospitals: a Case Study on Readiness and Critical Success Factors. *Journal of Health Management*, *2*, 44.

Baah, C., & Jin, Z. (2019). Sustainable supply chain management and organizational performance: the intermediary role of competitive advantage. *J. Mgmt. & Sustainability*, *9*, 119.

Baliga, R., Raut, R., & Kamble, S. (2020). The effect of motivators, supply, and lean management on sustainable supply chain management practices and performance: Systematic literature review and modeling. *Benchmarking: An International Journal*, *27*(1), 347–381.

Barclay, R. C., Cudney, E. A., Shetty, S., & Antony, J. (2022). Determining critical success factors for lean implementation. *Total Quality Management and Business Excellence*, *33*(7–8), 818–832. https://doi.org/10.1080/14783363.2021.1894919

Bentahar, O. (2018). Key success factors for implementing purchasing groups in the healthcare sector. *Supply Chain Forum*, *19*(1), 90–100. https://doi.org/10.1080/16258312.2018.1433437

Benzidia, S., Makaoui, N., & Bentahar, O. (2021). The impact of big data analytics and artificial intelligence on green supply chain process integration and hospital environmental performance. *Technological Forecasting and Social Change*, *165*, 120557.

Bhat, S., Antony, J., Gijo, E. V., & Cudney, E. A. (2020). Lean Six Sigma for the healthcare sector: a multiple case study analysis from the Indian context. *International Journal of Quality & Reliability Management*, *37*(1), 90–111.

Bhat, S., Gijo, E. V., Antony, J., & Cross, J. (2023). Strategies for successful deployment and sustainment of Lean Six Sigma in healthcare sector in India: a multi-level perspective. *The TQM Journal*, *35*(2), 414–445.

Bijl, A., Ahaus, K., Ruël, G., Gemmel, P., & Meijboom, B. (2019). Role of lean leadership in the lean maturity—second-order problem-solving relationship: a mixed methods study. *BMJ Open*, *9*(6), e026737.

Borges, G. A., Tortorella, G., Rossini, M., & Portioli-Staudacher, A. (2019). Lean implementation in healthcare supply chain: a scoping review. *Journal of Health Organization and Management*.

Brito, M. F., Ramos, A. L., Carneiro, P., & Gonçalves, M. A. (2019). A continuous improvement assessment tool, considering lean, safety and ergonomics. *International Journal of Lean Six Sigma*, *11*(5), 879–902.

Cardinal Health Hospital. (2018). *Hospital Supply Chain Survey*. https://newsroom.cardinalhealth.com/2018-03-28-Survey-Finds-40-Percent-of-Health-Care-Providers-Have-Canceled-Surgical-Cases-Due-to-Lack-of-Supplies

Castro, C., Pereira, T., Sá, J. C., & Santos, G. (2020). Logistics reorganization and management of the ambulatory pharmacy of a local health unit in Portugal. *Evaluation and Program Planning*, *80*, 101801.

Chakraborty, S., & Gonzalez, J. A. (2018). An integrated lean supply chain framework for U.S. hospitals. *Operations and Supply Chain Management*, *11*(2), 98–109. https://doi.org/10.31387/oscm0310206

Costa, F., Portioli-Staudacher, A., Alemsan, N., & Tortorella, G. L. (2024). Readiness level assessment for lean Six Sigma implementation in the healthcare sector. *International Journal of Lean Six Sigma*, *15*(1), 131–152. https://doi.org/10.1108/IJLSS-02-2023-0031

Damián Sanz, M., Yagüe-Fabra, J. A., & Gracia Matilla, R. (2019). Use of lean techniques in health care in Spain to improve involvement and satisfaction of workers. *International Journal of Health Planning and Management*, *34*(1), 274–290.

Das, S. K., Rakesh, &, & Shrivastava, L. (2018). Evaluation of Critical Success Factors for Indian Healthcare Industry. *AJHM ADMAA Amity Journal of Healthcare Management*, *2*(1), 50–58.

De Beer, M. (2015). Supply chain integration with corporate strategy for selected companies in the fast moving consumer goods industry in KwaZulu-Natal, South Africa.

De Lima, F., Da Silva, A., Godinho Filho, M., & Dias, E. M. (2018). Systematic review: resilience enablers to combat counterfeit medicines. *Supply Chain Management: An International Journal*, *12*(3), 117–135.

Dewi, F. C., Sari Hartanti, L. P., Sari Dewi, D. R., Mulyono, J., & Mulyana, I. J. (2024). Readiness assessment of lean six sigma implementation in the manufacturing industry as a way to ensure sustainability. *E3S Web of Conferences*, *475*. https://doi.org/10.1051/e3sconf/202447505001

Dombrowski, U., Wullbrandt, J., & Fochler, S. (2019). Center of excellence for lean enterprise 4.0. *Procedia Manufacturing*, *31*, 66–71.

Duque-Uribe, V., Sarache, W., & Gutiérrez, E. V. (2019). Sustainable supply chain management practices and sustainable performance in hospitals: a systematic review and integrative framework. *Sustainability*, *11*(21), 5949.

Eamranond, P. P., Bhukhen, A., DiPalma, D., Kunuakaphun, S., Burke, T., Rodis, J., & Grey, M. (2020). Interprofessional, multitiered daily rounding management in a high-acuity hospital. *International Journal of Health Care Quality Assurance*, *33*(6), 447–461.

Fainshmidt, S., Wenger, L., Pezeshkan, A., & Mallon, M. R. (2019). When do dynamic capabilities lead to competitive advantage? The importance of strategic fit. *Journal of Management Studies*, *56*(4), 758–787.

Farooque, M., Zhang, A., Thürer, M., Qu, T., & Huisingh, D. (2019). Circular supply chain management: A definition and structured literature review. *Journal of Cleaner Production*, *228*, 882–900.

Fathollahi-Fard, A. M., Ahmadi, A., & Karimi, B. (2022). Sustainable and robust home healthcare logistics: A response to the COVID-19 pandemic. *Symmetry*, *14*(2), 193.

Ferreira, D. C., Nunes, A. M., & Marques, R. C. (2020). Operational efficiency vs clinical safety, care appropriateness, timeliness, and access to health care: The case of Portuguese public hospitals. *Journal of Productivity Analysis*, *53*, 355–375.

Fournier, P. L., & Jobin, M. H. (2018). Medical commitment to Lean: an inductive model development. *Leadership in Health Services*.

García-Villarreal, E., Bhamra, R., & Schoenheit, M. (2019). Critical success factors of medical technology supply chains. *Production Planning and Control*, *30*(9), 716–735. https://doi.org/10.1080/09537287.2019.1572248

Garza-Reyes, J. A., Betsis, I. E., Kumar, V., & Radwan Al-Shboul, M. D. A. (2018). Lean readiness–the case of the European pharmaceutical manufacturing industry. *International Journal of Productivity and Performance Management*, *67*(1), 20–44. https://doi.org/10.1108/IJPPM-04-2016-0083

Ghobakhloo, M., & Fathi, M. (2019). Corporate survival in Industry 4.0 era: the enabling role of lean-digitized manufacturing. *Journal of Manufacturing Technology Management*.

Gholizadeh, L., Asl, I. M., Hajinabi, K., & Dehkordi, P. R. (2018). Lean management in hospitals: Key factors for successful implementation: (an investigation of factors affecting lean management in public hospitals in kohgiluyeh and boyerahmad and bushehr provinces). *Journal of Advanced Pharmacy Education and Research*, *8*, 88–92.

Gilson I.A., L. and A. (2018). Strengthening health system leadership for better governance: what does it take? *Health Policy and Planning*, *33*, 1–4. https://doi.org/10.1093/heapol/czy052

Gohr, C. F., Cabral, N. G. C., & Santos, L. C. (2019). Success factors for lean healthcare implementation: Exploratory case study in a Brazilian hospital. *Rahis*, *16*(2), 126–138.

Govender, C., Kader, A., & Proches, S. (2018). Examining leadership as a strategy to enhance health care service delivery in regional hospitals in South Africa. *Journal of Multidisciplinary Healthcare*, *11*, 157. https://doi.org/10.2147/JMDH.

Govindan, K., Mina, H., & Alavi, B. (2020). A decision support system for demand management in healthcare supply chains considering the epidemic outbreaks: A case study of coronavirus disease 2019 (COVID-19). *Transportation Research Part E: Logistics and Transportation Review*, *198*, 101967.

Gupta, S. (2018). Key supply chain integration factors for success of medical device startups. *Asia Graduate School of Business*. https://dspace.mit.edu/handle/1721.1/117921

Hallam, C. R., & Contreras, C. (2018). Lean healthcare: scale, scope and sustainability. *International Journal of Health Care Quality Assurance*, *31*(7), 684–696.

Harris, G., Stone, K. B., Mayeshiba, T., Componation, P. J., & Farrington, P. A. (2014). Transitioning from teaching lean tools to teaching lean transformation. *Journal of Enterprise Transformation*, *4*(3), 191–204.

Helten, K., & Lindemann, U. (2012). Formulation of a Questionnaire to Assess the Success of the Introductory Phase of Lean Development. DS 72: Modelling and Management of Engineering Processes-Concepts, Tools and Case Studies. 115–126.

Honda, A. C., Bernardo, V. Z., Gerolamo, M. C., & Davis, M. M. (2018). How lean six sigma principles improve hospital performance. *Quality Management Journal*, *25*(2), 70–82.

Horwitz, L. I., Kuznetsova, M., & Jones, S. A. (2019). Creating a learning health system through rapid-cycle, randomized testing. *N Engl J Med*, *381*(12), 1175–1179.

Ingelsson, I., Snyder, K., & Bäckström, K. (2020). Adapting a Lean leadership-training program within a health care organisation through co-creation. *Int. J. Qual. Serv. Sci*, *12*, 15–28.

Iswanto, A. H. (2019). Lean Implementation in Hospital Departments: How to Move from Good to Great Services. CRC Press.

Ivanov, D. (2022). Viable supply chain model: integrating agility, resilience and sustainability perspectives—lessons from and thinking beyond the COVID-19 pandemic. *Annals of Operations Research*, *319*(1), 1411–1431.

Jain, V., & Ajmera, P. (2019). Modelling of the factors affecting lean implementation in healthcare using structural equation modelling. *International Journal of System Assurance Engineering and Management*, *10*(4), 563–575. https://doi.org/10.1007/s13198-019-00770-4

Janatyan, N., Zandieh, M., Alem-Tabriz, A., & Rabieh, M. (2018). Designing sustainable distribution network in pharmaceutical supply chain: A case study. *International Journal of Supply and Operations Management*, *5*(2), 122–133.

Jasti, N. V. K., & Kodali, R. (2019). An empirical investigation on lean production system framework in the Indian manufacturing industry. *Benchmarking: An International Journal*, *26*(1), 296–316.

Kaupa, F., & Naude, M. J. (2020). Critical success factors in the supply chain management of essential medicines in the public health-care system in Malawi. *Journal of Global Operations and Strategic Sourcing*, *14*(3), 454–476. https://doi.org/10.1108/JGOSS-01-2020-0004

Kelendar, H., Faisal, M., & Mohammed, A. M. (2020). The Need for Lean Thinking in the Kuwaiti Healthcare System iMedPub Journals The Need for Lean Thinking in the Kuwaiti Healthcare System Abstract. *Health Science Journal*, *September*, 1–6. https://doi.org/10.36648/1791-809X.14.2.700

Khorasani, S. T., Cross, J., & Maghazei, O. (2020). Lean supply chain management in healthcare: a systematic review and meta-study. *International Journal of Lean Six Sigma*, *11*(1), 1–34.

Kuiper, A., Lee, R. H., van Ham, V. J., & Does, R. J. (2022). A reconsideration of Lean Six Sigma in healthcare after the COVID-19 crisis. *International Journal of Lean Six Sigma*, *13*(1), 101–117.

Lee, J., & Joo, H. Y. (2020). The impact of top management's support on the collaboration of green supply chain participants and environmental performance. *Sustainability*, *12*(21), 9090.

Leite, H., Lindsay, C., & Kumar, M. (2020). COVID-19 outbreak: Implications on healthcare operations. *The TQM Journal*, *33*(1), 247–256.

Linderman, K., Schroeder, R. G., & Sanders, J. (2010). A knowledge framework underlying process management. *Decision Sciences*, *41*(4), 689–719.

Maphumulo, W. T., & Bhengu, B. R. (2019). Challenges of quality improvement in the healthcare of South Africa post-apartheid: A critical review. *Curationis*, *42*(1), 1–9.

Marolla, G., Rosa, A., & Giuliani, F. (2022). Addressing critical failure factors and barriers in implementing Lean Six Sigma in Italian public hospitals. *International Journal of Lean Six Sigma*, *13*(3), 733–764.

Mathur, B., Gupta, S., Meena, M. L., & Dangayach, G. S. (2018). Healthcare supply chain management: literature review and some issues. *Journal of Advances in Management Research*, *15*(3), 265–287. https://doi.org/10.1108/JAMR-09-2017-0090

McBride, S., & Tietze, M. (2021). Health Information Technology and Electronic Health Records. In *In Nurses Contributions to Quality Health Outcomes*. Cham: Springer International Publishing.

McDermott, O., Antony, J., Bhat, S., Jayaraman, R., Rosa, A., Marolla, G., & Parida, R. (2022). Lean six sigma in healthcare: A systematic literature review on challenges, organisational readiness and critical success factors. *Processes*, *10*(10), 1945.

Miake-Lye, I. M., Delevan, D. M., Ganz, D. A., Mittman, B. S., & Finley, E. P. (2020). Unpacking organizational readiness for change: an updated systematic review and content analysis of assessments. *BMC Health Services Research*, *20*(1), 1–13.

MIT. (2001). LESAT, The Lean Enterprise Self Assessment Tool.

Murphy, K. R., & Davidshofer, C. O. (2005). *Psychological testing: Principles and applications* (6th ed.). Pearson Education.

Moons, K., Waeyenbergh, G., & Pintelon, L. (2019). Measuring the logistics performance of internal hospital supply chains–a literature study. *Omega*, *82*, 205–217.

Moradi, M., & Jolai, F. (2018). Purchasing planning and order allocation in the pharmaceutical sustainable supply chain using the theoretical-graph (GT-MP- DM) (case study: Supplying the clotting factor for patients with hemophilia). *International Journal of Supply and Operations Management*, *5*(4), 361–378.

Musamba, C., Getrude, B., & Mwanza, M. (2025). Enhancing Pharmaceutical Supply Chain Efficiency of Medicine Through the Utilization of Lean Practices : A Survey of Hospitals and Clinics in Ndola District , Zambia. https://doi.org/10.59413/ajocs/v6.i3.9

Naidoo Z., L. and F. (2019). Critical success factors for the successful initiation of Lean in public hospitals in KwaZulu-Natal: a factor analysis and structural equation modelling study. *Human Resources for Health*, *17*, 69. https://doi.org/10.1186/s12960-019-0405-1

Naidoo, L. (2021). Critical success factors and practical considerations for Lean readiness and implementation in health-care: a literature review. *Journal of Contemporary Management*, *18*(1), 407–432.

Naidoo, L., & Fields, Z. (2019). Critical success factors for the successful initiation of Lean in public hospitals in KwaZulu-Natal: a factor analysis and structural equation modelling study. *Human Resources for Health*, *17*(1), 1–11.

Naidoo, Logandran, & Fields, Z. (2019). Knowledge and Experience of Lean Thinking amongst Senior Health Care Managers in Selected South African Public Hospitals. *Spoudai*, *69*(4), 21–37. https://search.ebscohost.com/login.aspx?direct=true&db=eoh&AN=1852702&lang=pl&site=ehost-live

Narayanamurthy, G., & Gurumurthy, A. (2018). Is the hospital lean? A mathematical model for assessing the implementation of lean thinking in healthcare institutions. *Operations Research for Health Care*, *18*, 84–98.

Narayanamurthy, G., Gurumurthy, A., Subramanian, N., & Moser, R. (2018). Assessing the readiness to implement lean in healthcare institutions–A case study. *International Journal of Production Economics*, *197*, 123-142.

Nasrabadi, E. M., & Mohammadipour, E. (2022). A conceptual model of critical success factors in improving the resilience of the health tourism supply chain: a case study. *Journal of Health Administration*, *25*(2), 9–25.

Niñerola, A., Sánchez-Rebull, M. V., & Hernández-Lara, A. B. (2020). Quality improvement in healthcare: Six Sigma systematic review. *Health Policy*, *124*(1), 438–445.

Osman, A. A., Rahamaddulla, S. R., Kamar, A. N. N., Norismail, N., & Nordin, N. (2025). *Measuring Lean Culture – Validating a Research Instrument*. *17*(1), 205–215.

Patri, R., Suresh, M., & Prasad, R. (2021). Modelling the leadership characteristics for organizational readiness: a context of lean implementation in healthcare. *Leadership in Health Services*.

Patri, Rojalin, & Suresh, M. (2018). Factors influencing lean implementation in healthcare organizations: An ISM approach. *International Journal of Healthcare Management*, *11*(1), 25–37. https://doi.org/10.1080/20479700.2017.1300380

Pereira, L., & Tortorella, G. (2018). Identification of the relationships between critical success factors, barriers and practices for lean implementation in a small company. *Brazilian Journal of Operations & Production Management*, *15*(2), 232–246. https://doi.org/10.14488/bjopm.2018.v15.n2.a6

Podsakoff, P. M., & Podsakoff, N. P. (2019). Experimental designs in management and leadership research: Strengths, limitations, and recommendations for improving publishability. *The Leadership Quarterly*, *30*(1), 11–33.

Prasad, D. S., Pradhan, R. P., Gaurav, K., Chatterjee, P. P., Kaur, I., Dash, S., & Nayak, S. (2018). Analysing the critical success factors for implementation of sustainable supply chain management: An Indian case study. *Decision*, *45*(1), 3–25. https://doi.org/10.1007/s40622-017-0171-7

Primadasa, S., & Alfarisi, R. (2018). Lean supply chain management (LSCM) framework for palm oil industry in Indonesia". In Proceedings of the The 1st International Conference on Computer Science and Engineering Technology Universitas Muria Kudus, EAI, (pp. 225–232).

Polit, D. F., & Beck, C. T. (2006). The content validity index: are you sure you know what's being reported? Critique and recommendations. Research in nursing & health, 29(5), 489-497.

Quan, N. H. K., Adegoke, A. O., Wankasi, M. M., & Nnatuanya, I. N. (2020). International Integration of Pharmaceutical Supply Chains in Vietnam: An Overview of Challenges and Opportunities at Hospitals in Ho Chi Minh City. *International Journal of Medical and Health Sciences Research*, *7*(1), 37–48.

Raju, R., & Antony, J. (2019). Assessment of Lean Six Sigma Readiness (LESIRE) for manufacturing industries using fuzzy logic. *International Journal of Quality & Reliability Management*.

Régis, T. K. O., Santos, L. C., & Gohr, C. F. (2019). A case-based methodology for lean implementation in hospital operations. *Journal of Health Organization and Management*, *33*(6), 656–676.

Rojas, F., Wanke, P., Leiva, V., Huerta, M., & Martin-Barreiro, C. (2022). Modeling Inventory Cost Savings and Supply Chain Success Factors: A Hybrid Robust Compromise Multi-Criteria Approach. *Mathematics*, *10*(16), 1–18. https://doi.org/10.3390/math10162911

Rosa, A., Capolupo, N., Romeo, E., McDermott, O., Antony, J., Sony, M., & Bhat, S. (2024). Assessing Lean Six Sigma and quality performance improvement in Italian public healthcare organizations: a validated scale. *TQM Journal*. https://doi.org/10.1108/TQM-10-2023-0350

Santos, L. C. (2020). Success Factors for Lean Healthcare Implementation : Exploratory Case Study in a Brazilian Hospital an Fatores De Sucesso Para Implementação Do Lean Healthcare : Um Estudo De Caso Exploratório Em Um Hospital Brasileiro Factores Exitosos Para La Implementa. 16, 126–138.

Sharma, N., Herrnschmidt, J., Claes, V., Bachnick, S., De Geest, S., Simon, M., & Group., M. (2018). Organizational readiness for implementing change in acute care hospitals: An analysis of a cross-sectional, multicentre study. *Journal of Advanced Nursing*, *74*(12), 2798–2808.

Shung-King L. and Mbachu, C. and Molyneux, S. and Muraya, K.W. and Uguru, N. and Govender, V., M. and G. (2018). Leadership experiences and practices of South African health managers: what is the influence of gender? -a qualitative, exploratory study. *International Journal for Equity in Health*, *17*, 148. https://doi.org/10.1186/s12939018-0859-0

Sohal, A., de Vass, T., Singh, P., Al Balushi, S., Al Hajri, A. S., Al Farsi, Y., & Al Arbi, R. (2021). Assessing readiness for lean thinking in healthcare settings: the case for Oman. *Industrial Management and Data Systems*, *121*(11), 2338–2361. https://doi.org/10.1108/IMDS-02-2021-0120

Sohal, A., De Vass, T., Vasquez, T., Bamber, G. J., Bartram, T., & Stanton, P. (2022). Success factors for lean six sigma projects in healthcare. *Journal of Management Control*, *33*(2), 215–240. https://doi.org/10.1007/s00187-022-00336-9

Sony, M., Antony, J., & Tortorella, G. L. (2023). Critical Success Factors for Successful Implementation of Healthcare 4.0: A Literature Review and Future Research Agenda. *International Journal of Environmental Research and Public Health*, *20*(5). https://doi.org/10.3390/ijerph20054669

Sulistyoa, A. B., Karningsih, P. D., & Alvandic, S. (2024). Developing an Industry-Specific Lean 4.0 Readiness Assessment Tool: A Case for the Chemical Sector. *Jurnal Optimasi Sistem Industri*, *23*(2), 283–298. https://doi.org/10.25077/josi.v23.n2.p283-298.2024

Sundram, V. P. K., Bahrin, A. S., Abdul Munir, Z. B., & Zolait, A. H. (2018). The effect of supply chain information management and information system infrastructure: The mediating role of supply chain integration towards manufacturing performance in Malaysia. *Journal of Enterprise Information Management*, *31*(5), 751–770.

Swarnakar, V., Bagherian, A., & Singh, A. R. (2021). Modeling critical success factors for sustainable LSS implementation in hospitals: an empirical study. *International Journal of Quality & Reliability Management*, *39*(5), 1249–1280.

Swarnakar, V., Bagherian, A., & Singh, A. R. (2022). Prioritization of critical success factors for sustainable Lean Six Sigma implementation in Indian healthcare organisations using best-worst-method. *TQM J*.

Tidwell, M. (2020). An exploration of success factors in the healthcare supply chain. 1(August).

Toledo, J. C., Gonzalez, R. V. D., Lizarelli, F. L., & Pelegrino, R. A. (2018). Lean production system development through leadership practices. *Management Decision*.

Tortorella, R., Fettermmann, D. C., Tlapa, D., & Giglio, G. (2018). Lean supply chain practices: an exploratory study on their relationship. *The International Journal of Logistics Management*, *29*(3), 1049–1076. https://doi.org/10.1108/IJLM-062017-0141

Tavakol, M., & Dennick, R. (2011). Making sense of Cronbach's alpha. International journal of medical education, 2, 53.

Uhl-Bien, M., & Arena, M. (2018). Leadership for organizational adaptability: A theoretical synthesis and integrative framework. *The Leadership Quarterly*, *29*(1), 89–104.

Vaishnavi, V., & Suresh, M. (2020). Modelling of readiness factors for the implementation of Lean Six Sigma in healthcare organizations. *International Journal of Lean Six Sigma*.

Vaishnavi, V., Suresh, M., & Dutta, P. (2019). A study on the influence of factors associated with organizational readiness for change in healthcare organizations using TISM. *Benchmarking: An International Journal*.

Vito, R. (2019). Self-directed teams as an organizational change strategy to empower staff: A teaching/learning case study. *Human Service Organizations: Management, Leadership & Governance*, *43*(2), 146–151.

Waqas, M., Yu, Z., Khan, S. A. R., Tanveer, M., & Ahmad, A. R. (2023). Promoting Healthcare Technologies Through Sustainable Supply Chain Operations: an Empirical Analysis of Key Success Factors Using the Ism-Micmac Approach. *Logforum*, *19*(1), 91–126. https://doi.org/10.17270/J.LOG.2023.722

Willis, M. A. (2019). Improving Lean Healthcare Effectiveness Marge A. Willis Oregon Health & Science University. 1–26.

Woodnutt, S. (2018). Is Lean sustainable in today's NHS hospitals? A systematic literature review using the meta-narrative and integrative methods. *International Journal for Quality in Health Care*, *30*(8), 578–586.

Yadav, R., Singh, S., & Shankar, N. (2021). Hierarchy of Critical Success Factors (CSF) for Lean Six Sigma (LSS) in Quality 4.0. *Int. J. Global Bus. Compet*, *16*, 1–14.

Yadav, V., Jain, R., Mittal, M. L., Panwar, A., & Sharma, M. K. (2018). An appraisal on barriers to implement lean in SMEs. *Journal of Manufacturing Technology Management*.

Yu, W., Liu, Q., Zhao, G., & Song, Y. (2021). Exploring the effects of data-driven hospital operations on operational performance from the resource orchestration theory perspective. *IEEE Transactions on Engineering Management*.

Zepeda-Lugo, C., Limon-Romero, J., Tlapa, D., & Baez-Lopez, Y. (2018). Critical factors of lean healthcare: An overview. *ACM International Conference Proceeding Series*, 1–7. https://doi.org/10.1145/3242789.3242837

Zhu, Q., Johnson, S., & Sarkis, J. (2018). Lean six sigma and environmental sustainability: A hospital perspective. *Supply Chain Forum*, *19*(1), 25–41. https://doi.org/10.1080/16258312.2018.1426339