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Research article

A conceptual model for evaluating readiness for lean practices using a fuzzy logic approach: A case study in Bangladeshi healthcare institutes

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ABSTRACT

In the realm of healthcare, an imperative necessity for all, institutions are increasingly recognizing the advantages of adopting lean strategies to enhance performance. Lean implementation in healthcare can lead to significant improvements in efficiency, patient care, and overall institutional performance. This paper aims to assess the readiness levels for implementing lean practices in healthcare institutes in Bangladesh, employing a fuzzy logic approach. The construction of a conceptual model is grounded in literature review and expert opinions, incorporating critical enablers, criteria, and attributes identified from extensive research. Factors measured include leadership commitment, workforce capability, operational processes, technological infrastructure, and organizational culture, each pivotal in determining readiness for lean implementation. The fuzzy logic approach is particularly useful in this context due to its ability to handle uncertainty and imprecision, which are common in complex environments like healthcare. This methodology not only provides a clear picture of current capabilities but also highlights specific areas that need enhancement, paving the way for more targeted and effective lean interventions. Data sourced from consultations with experts in three prominent hospitals in Bangladesh forms the basis of the analysis, enabling a detailed examination of readiness levels. The model's application of fuzzy logic facilitates a comprehensive assessment, revealing 12 critical attributes across the hospitals that require attention. Interestingly, the evaluation identifies varying levels of readiness, with two hospitals demonstrating moderate readiness and one showing a lower level. This conceptual approach has significant potential to assist top management in healthcare companies by providing a structured framework to prioritize crucial areas for improvement. By accurately assessing readiness levels and pinpointing weaker aspects before implementing lean strategies, this study aims to transform the healthcare industry. Ultimately, its implementation has the potential to enhance organizational performance and elevate standards in patient care, contributing to improved healthcare delivery in Bangladesh and beyond.

1. Introduction

Healthcare organizations worldwide are grappling with significant challenges due to the increasing demands of a growing population and the rising prevalence of chronic diseases such as diabetes and cancer. To maintain low costs while ensuring high-quality

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care and service, continuous and methodical improvement is essential in healthcare [1]. The value and accessibility of healthcare services vary significantly across different populations, socioeconomic levels, and geographic locations. Healthcare institutions need a new strategy to improve service quality while reducing costs [2].Over the past few decades, hospital utilization has increased due to a greater focus on preventive medicine and an aging population [3]. Within the healthcare section, Lean is widely used in strategic planning for the purpose of implementing sustainable growth [4]. Lean principles have been applied across various healthcare settings, including hospitals, clinics, diagnostic centers, healthcare facilities, and health maintenance organizations (HMOs) (for examples, see Refs. [5–7]. Lean offers a powerful model that enhances productivity by identifying and eliminating inefficiencies across diverse organizational processes [8]. The goal of the Lean approach is to maximize efficiency and decrease overhead expenses by minimizing non-value activities. Significant gains in quality care, patient safety, and staff and patient happiness have occurred from the use of Lean in the industry, specifically in hospitals [9,10].

Readiness, particularly lean readiness, is critical for successful implementation of Lean methodologies. It refers to an organization's capability, preparedness, and willingness to adopt Lean principles effectively. Lean readiness involves aligning organizational resources and leadership commitment with Lean principles, crucial for sustainability and operational success in the public sector [11]. This paper extends this concept to healthcare, emphasizing the link between readiness and organizational capacity to integrate Lean principles into healthcare delivery systems [12]. This paper categorizes inhibitors to the Lean journey, identifying organizational barriers that may hinder readiness [13]. This paper contains underscore the importance of organizational capabilities and cultural alignment for successful Lean adoption [14]. The paper provide insights from a case study on readiness assessment in healthcare institutions, highlighting specific challenges and readiness factors unique to healthcare settings [15].

Readiness is a collection of data indicating whether or not a medical professional is prepared to embrace the future. It is made up of the opinions, values, and motivations of the people who will be affected by strategic development, and it centers on the topic of whether or not the change can be successfully implemented [16]. Whether a business had to conduct a review of its level of performance, it could learn how enthusiastic its workforce is about bringing and executing change, how much potential exists inside the company, how to strengthen its internal processes, and how to better serve its customers [17] Members' change devotion and modification competence in carrying out the proclaimed organization are the most important factors in determining the organization's readiness to undergo transformation [18]. An organization's potential for successfully implementing the changes strategy can be assessed by identifying its level of readiness in the healthcare sector [19]. Several medical organizations fail in the long run because they put too much emphasis on their tools and techniques while contributing too little to their preparedness level [20]. When attempting to introduce Lean into a medical center, it is important to first assess its degree of preparedness for the transition. Organizational readiness encompasses the ability to seamlessly navigate through dynamic shifts in both internal and external landscapes, ensuring operational continuity amid evolving demands. The readiness factors inform management of the extent to which workers are prepared to adapt to how new Lean performed. This research endeavors to bridge this gap by employing an innovative and powerful approach: fuzzy logic. Fuzzy logic, known for its ability to handle uncertainty and ambiguity, becomes an invaluable tool in developing a robust model capable of making informed decisions even in unpredictable situations [21]. Fuzzy logic is increasingly being used in hospitals to evaluate readiness levels and obstacles to improving performance. It provides a mechanism to navigate complex and uncertain environments, offering a pathway to enhanced decision-making and adaptability. In this work, fuzzy logic is used to create a model for determining whether or not a healthcare institution in Bangladesh is prepared to deploy Lean practices. As a mathematical theory, fuzzy is mostly used in the realm of decision-making since it allows for the display of fuzziness and uncertainty through the use of numbers [21,22]. Some research has emphasized the significance of being prepared for Lean [23,24] while others have assessed the preparation for Lean six sigma (LSS) deployment with a key goal in the industries sector [25]. Extensive research has also focused on healthcare readiness for Lean performance, examining specific issues within various contexts such as hospital settings, primary care, public health agencies, and specialty care.

While it is acknowledged that several studies have indeed assessed lean readiness using fuzzy models in healthcare [15,25–29]. The current literature lacks a comprehensive model specifically tailored to evaluate readiness for lean practices in healthcare institutes in Bangladesh. Existing studies often focus on broader contexts or specific methodologies that may not fully address the unique challenges and dynamics present in Bangladeshi healthcare settings.

Moreover, the identified gap pertains specifically to the absence of a developed model that integrates multiple levels of analysis to comprehensively evaluate readiness levels and identify weaker areas within Bangladeshi healthcare institutes.

Therefore, the proposed research aims to fill this gap by developing and validating a new model that incorporates both qualitative and quantitative aspects, considering local contextual factors and providing actionable insights for healthcare improvement in Bangladesh. This approach seeks to build upon existing research while addressing the specific needs and challenges of healthcare institutes in Bangladesh, thereby contributing to the broader understanding and application of lean practices in diverse healthcare contexts.

This paper aims to achieve the following objectives.

(1) To create a conceptual model for assessing Lean Practices readiness in healthcare contexts.
(2) To identify the critical elements that influence lean readiness of healthcare institutions.

In two key areas, this research considerably adds to the body of knowledge on healthcare readiness. First, it recognizes and group crucial elements of healthcare institutes preparation into five different enablers. Understanding the various variables that affect readiness within healthcare organizations is made easier by this categorization. Second, a model of thought is created with features that may be used to gauge how ready hospitals are for lean practices in case situations. This study is particularly distinctive since it not

only offers a thorough conceptual model with indicators but also effectively measure healthcare lean practices readiness in healthcare settings using a fuzzy approach.

The study introduces a novel conceptual model using fuzzy logic to evaluate the readiness of Bangladeshi healthcare institutes for lean practices. The model is empirically validated through a real-world case study, demonstrating its practical applicability. It offers valuable insights and practical guidance for healthcare managers and policymakers in Bangladesh, helping them systematically prepare for lean implementation to improve healthcare quality and efficiency. This research also contributes to the lean healthcare literature, encouraging further studies in various contexts such as the education sector, manufacturing industry, public sector, service industry, non-profit organizations, transportation and logistics, construction industry, and agriculture sector. Through these objectives, the paper aims to contribute practical insights to healthcare practitioners, policymakers, and researchers, enhancing the understanding and successful application of Lean principles in the healthcare industry.

2. Literature review

To ensure a comprehensive and unbiased literature review, databases such as PubMed, Google Scholar, and IEEE Xplore were used. Keywords included "Lean Readiness," "Lean in Healthcare," "Fuzzy Logic Approach," "Readiness Assessment," "Readiness factors," and "Lean Implementation in Hospitals." The search aimed to cover a wide range of studies, ensuring none of the important and relevant research was missed. The authors systematically reviewed and included studies based on their relevance and contribution to the topic, mitigating author bias.

2.1. Lean and lean in healthcare

Lean methodologies have been instrumental in identifying process improvement opportunities and addressing eco-friendly production challenges [30]. Widely embraced by healthcare executives globally, Lean is valued for its capacity to lower costs while maintaining high service standards [31]. Research on the global adoption of lean manufacturing practices has underscored both successes and challenges, revealing fragmented implementation and varied impacts on organizational performance. Factors such as demand variability and organizational culture have been cited as contributors to mixed outcomes [32]. Across different sectors, including healthcare, lean principles have proven effective. Studies have highlighted perspectives from hospital managers regarding their efforts and challenges in adopting lean practices [33]. In hospital settings, particularly in emergency and surgical departments, lean methodologies have significantly enhanced productivity. Notably, the USA has been a leader in implementing these strategies. However, scholarly discourse often focuses on barriers and success factors rather than broader themes like sustainability and comprehensive measurement frameworks [34]. Moreover, investigations have explored the applicability of lean methodologies to the service industry, reflecting ongoing efforts to adapt lean principles beyond manufacturing contexts [35].

Several countries have implemented Lean methodologies in healthcare settings, including the USA, Canada, Japan, the UK, and various European nations. Several countries have implemented Lean methodologies in healthcare settings. However, the integration of fuzzy logic alongside Lean in healthcare applications remains limited in published studies.

As a result, they concluded that implementing Lean practices significantly reduced operating expenses while simultaneously improving service standards at the accommodations. User experience, specialist services, and self-sufficiency have all seen increases since the implementation of lean fundamentals in healthcare services [36]. The impact of lean principles on public health has also been underscored [37]. In medicine, lean projects need to be comprehensive. Experts warn that if lean developments are carried out in isolation, the result could be 'point optimization,' where improvements are made quickly and effectively but may inadvertently create bottlenecks elsewhere in the process, introducing new problems [38]. Structural equation modeling (SEM) was used to build a structured integrative framework of lean construction in the healthcare system and healthcare achievements [39]. Lean in hospitals is a methodology focused on improving efficiency by eliminating non-value-adding processes, such as delays and errors, to optimize the experience for customers/patients. A framework for evaluation, a data analysis methodology, and an index Improvement and Learning Level (ILL) to gauge excellence levels and improvement potential are developed based on the '4P Excellence Model.' The Improvement and Learning Level (ILL) is a concept often used in the context of organizational development, particularly in Lean management and continuous improvement frameworks. The ILL typically refers to the extent to which an organization or team is committed to and capable of ongoing improvement and learning. This approach is applicable not only within healthcare contexts but also serves as a means of evaluating and enhancing healthcare organizations [40].

2.2. Fuzzy logic

Fuzzy rules theory provides a method for representing information or data that encompasses various non-statistical uncertainties [41]. Unlike conventional binary logic, fuzzy logic allows for the expression of values between "true" and "false," or "good" and "bad," enabling the incorporation of uncertainty into decision-making processes to enhance robustness [41]. Soft tools such as fuzzy logic facilitate the creation, analysis, and validation of models more efficiently and objectively compared to alternative methods. Fuzzy logic aims to formalize human reasoning and decision-making abilities in uncertain and imprecise environments, bridging the gap between precise computation and human intuition [42]. Fuzzy logic, in its simplest form, allows for a specified amount of uncertainty in a framework due to things like skewed dimensions or a professional's subjective assessment of their own expertise. This approach accommodates imprecise input data and subjective assessments, enabling a more flexible consideration of variables and control limits [43,44]. With the goal of measuring the degree to which an National Health Service (NHS) has adopted lean practices an assessment

procedure have developed [26]. The healthcare institution is evaluated using a medical organization's continuous improvement index, and the results suggest that high-level interactive improvement (HLII) may be recommended by experts for both intercellular and intracellular applications [45]. Proposes a fuzzy logic-based decision-making system for home healthcare, particularly focusing on diabetes management, offering a potential solution to the challenges posed by an aging population and increasing chronic diseases within existing healthcare infrastructure. Using non-linear-linear [46], Using a non-linear approach [39], introduces a technique for assessing the integration of lean tools and instruments into a given supply network. This study aims to measure the leanness of hospitals using fuzzy logic, recognizing lean practices as essential for enhancing service quality and reducing costs in healthcare organizations [47] lays out a method for addressing issues arising from vague or ambiguous events. It does not assume freedom, applicability, or exclusivity, and it is flexible enough to accommodate ambiguity in definitions [48].

2.3. Readiness assessment

A proposed model for assessing factors preparedness has been developed in the healthcare industry [49]. This approach can be broken down into three categories: personality traits, social determinants, and analysis level. According to a study, key readiness variables include a great leader, an open and communicative workplace culture, and ample opportunities for learning and growth [50]. Development and testing of e-health readiness assessment tools for healthcare institutions in developing countries, with separate tools for managers and healthcare providers, aiming to assess preparedness for Information and Communications Technology (ICT) related program changes [51]. The paper presents a validated self-assessment model for evaluating organizational readiness to implement Green Lean initiatives, aiding practitioners in preemptively assessing feasibility and enhancing success rates [27]. Readiness assessment through critical success factors and exploratory factor analysis validates the readiness of an IT firm in Iran for implementing knowledge management, guiding promotional strategies [52]. This study pioneers a fuzzy logic-based framework to assess and enhance lean practices in healthcare organizations, identifying key factors and offering actionable insights to optimize operational efficiency and service quality [47]. This study applies fuzzy logic and ANFIS to assess leanness in an Indian SME. It introduces a model with five enablers, 30 criteria, and 90 attributes, yielding a fuzzy-based leanness index (4.47, 5.97, 7.55) and benchmarked with ANFIS (5.84). Practical implications for improving lean performance in SMEs are highlighted, offering original contributions to industrial leanness evaluation [53]. The purpose of this paper is to evaluate the key factors influencing the implementation of lean principles in healthcare organizations, aiming to enhance service delivery to patients and achieve competitive advantage through process improvement [54]. The success of a company-wide lean intervention hinges on internal and external factors, including lean support, clear goals, and regular communication [55]. The authors use big data to examine the impact of workers' actions and behaviors on the institution's willingness to adapt [56]. The research also develops a concept connecting employee preparedness with work satisfaction. This takes into account factors like salary, career advancement opportunities, loyalty to the company, and a sense of belonging to the company. Flexible effectiveness in hospital systems has been studied using an approach [57].

2.4. Lean readiness factors

This research introduces a lean readiness framework for healthcare institutions, employing stakeholder input and fuzzy-based methods to assess readiness and identify improvement areas before lean implementation [23]. To develop a readiness framework, it is necessary to identify readiness factors. This empirical quantitative study developed and validated a conceptual model of seven critical success factors for healthcare operations, utilizing questionnaire-based surveys and PLS-SEM analysis with SmartPLS3 software [58]. The literature on Lean readiness in healthcare organizations emphasizes several critical factors essential for successful implementation. Managerial accountability is crucial, involving top management responsibility for Lean initiatives, feedback mechanisms to integrate frontline and management perspectives [59,60]. Authority involvement in Lean performance significantly influences lean readiness by ensuring top-level support, resource allocation, and strategic alignment essential for successful Lean implementation and continuous improvement in organizational practices [61]. Increase employee trust fosters a supportive organizational culture where employees feel valued and empowered, crucial for enhancing collaboration, communication, and commitment to Lean principles, thereby boosting overall lean readiness and effectiveness in healthcare institutions [59]. Management Strategy involves the formulation and implementation of systematic approaches to align organizational goals with lean principles, aiming to eliminate waste, enhance quality, and optimize processes, thereby crucially influencing lean readiness in healthcare institutions [61]. Worker involvement emphasizes fostering a culture where employees actively participate in decision-making, collaborate across teams, and engage in continuous improvement efforts, which significantly enhances organizational readiness for lean implementation in healthcare settings [62]. Roadmap for organization goal & mission that involves clearly defining and aligning organizational objectives and missions with lean principles, providing a strategic direction that enhances readiness for lean implementation in healthcare institutions [63]. Employee devotion and faith refers to the level of commitment, loyalty, and belief employees have in the organization's goals and values, crucial for fostering a supportive environment essential for successful lean implementation in healthcare institutions [64]. Training and instruction encompass the systematic provision of education, guidance, and skill development opportunities to healthcare staff, vital for enhancing their readiness and competence in lean principles and practices, thereby facilitating effective implementation and continuous improvement efforts within the organization [64]. Lean tools and techniques refer to the methodologies, principles, and specific tools utilized within lean management practices, aimed at eliminating waste, improving efficiency, and enhancing overall operational performance in healthcare settings [65]. Lean Focus Emphasizes directing operational efforts towards optimizing processes and resources to meet patient needs efficiently in healthcare settings [65]. Organized Leadership Entails structured and effective leadership practices that ensure clarity in goals, efficient resource allocation, and supportive

environments for lean initiatives in healthcare organizations [59]. Good Communication Involves effective exchange of information and regular communication channels between stakeholders, facilitating smooth implementation and continuous improvement of lean practices in healthcare [59].

3. Methodology

In order to collect relevant research on lean performance, our study began with a thorough search of journal databases. This served as the basis for an extensive literature evaluation. We developed our own evaluation approach called Lean Practice Readiness Assessment in Healthcare Institutions (LPRAHI) by building on the knowledge gained from previous research with extensive opinion from experts [15,25–29]. In the literature, several alternative approaches for readiness assessment are discussed, including the Analytic Network Process (ANP), Failure Mode and Effects Analysis (FMEA), and various other calculation methods to derive priority values [66,67]. The ANP is a more general form of the Analytic Hierarchy Process (AHP) that allows for the consideration of interdependencies among decision criteria, offering a structured way to model complex decision-making scenarios [67].FMEA is a systematic technique for identifying potential failure modes, assessing their impact, and prioritizing them based on their severity, occurrence, and detection [66].Despite the strengths of these methods, fuzzy logic offers distinct advantages for readiness assessment, particularly in dealing with the inherent uncertainties and ambiguities in human judgment and decision-making processes [41].

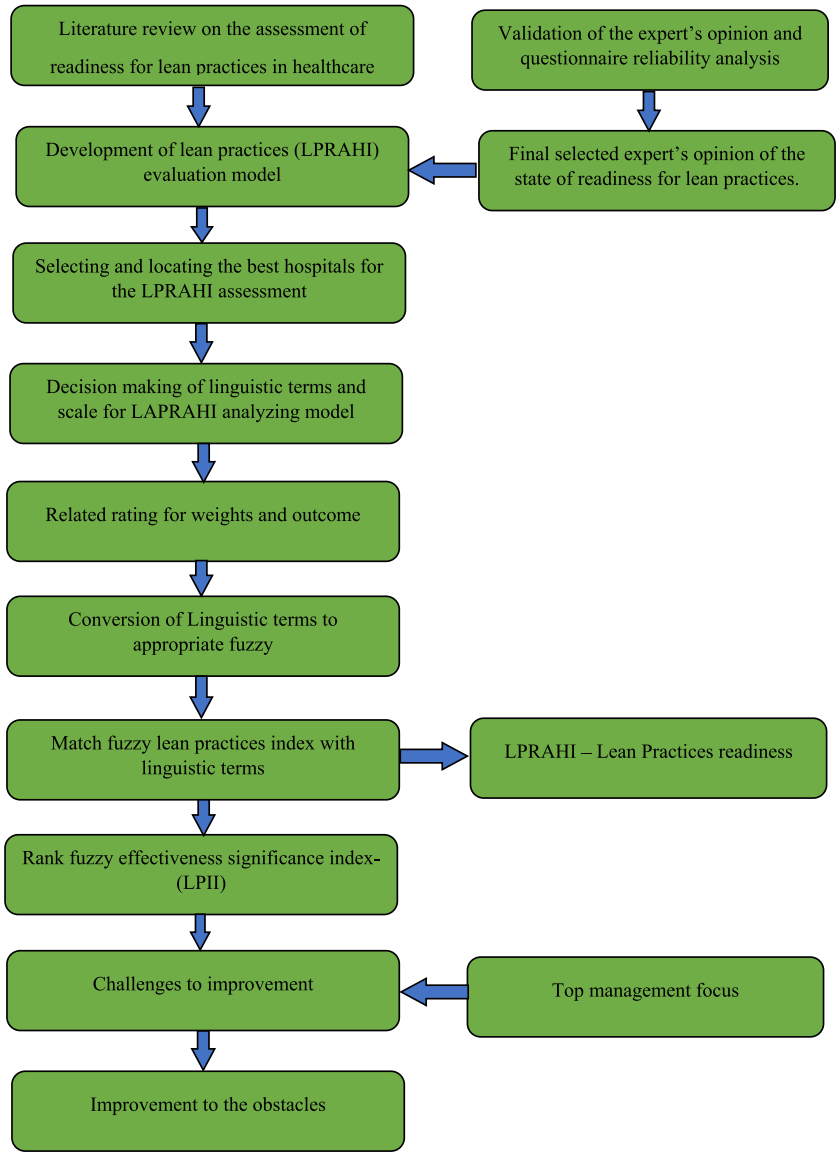

Figure-1. LPRAHI evaluation model road map.

Traditional methods like ANP and FMEA often rely on precise numerical inputs, which may not accurately capture the subjective and imprecise nature of real-world evaluations. Fuzzy logic, however, can handle imprecise and vague information by using linguistic variables and fuzzy sets, allowing for a more flexible and realistic assessment of readiness. Fuzzy logic systems can model the uncertainty and partial truth inherent in human assessments, providing a more robust framework for evaluating complex criteria. This approach is particularly useful in contexts where qualitative judgments are required, and precise numerical data is either unavailable or difficult to quantify. By incorporating fuzzy logic, the readiness assessment model can accommodate a wider range of inputs and provide a more comprehensive and nuanced evaluation, making it a valuable tool for assessing organizational readiness in various sectors. This unique model is based on our own framework and has been carefully designed with 13 criteria and 35 attributes. In order to determine the five most representative enablers and establish the foundation for a strong evaluation model, these criteria and features were carefully selected. Notably, our methodology customized the assessment to the particular context of healthcare systems, even as it took influence from other evaluation models already in existence, such as the leanness and agility evaluations. A key observation exposed a gap in the research on healthcare readiness despite plenty of material on lean practices, especially when considering Bangladesh. Our suggested model, which attempts to close the knowledge gap between comprehension and application, fills this gap in a novel way. Fig. 1 provides a visual representation of our lean practices evaluation strategy for hospitals, highlighting an organized and comprehensive approach. There are three main phases to the evaluation process. We start by doing a comprehensive literature review and consulting with specialists, which leads to the creation of a conceptual model. As a useful indicator of organizational preparation, three exemplary hospitals are then chosen and subjected to extensive testing for lean practices readiness level. The last phase entails a continuous and dynamic assessment of the hospital's readiness, providing an adaptation and iterative strategy for the successful implementation of lean practice concepts. This methodological framework addresses the lack of healthcare readiness research in Bangladesh by introducing an inventive and context-specific approach in addition to drawing from well-established evaluation methods. By going through this careful process, we hope to add insightful information to the field of lean practices in healthcare and provide a roadmap for successful implementation that is adapted to the particular difficulties faced by the healthcare system in Bangladesh.

Table 1
Indicators of the LPRAHI evaluation Model.

Enabler	Criteria	Attribute	References
Managerial accountability (LP_1)	Top management responsibility (LP_{11})	Feedback from front line and management (LP_{111})	[59,60]
		Authority involvement in Lean performance (LP_{112})	[61,68]
		Resource for implant Lean (LP_{113})	[69,70]
	Organized leadership (LP_{12})	Increase employee trust ($_{121}$)	[59]
		Organizing lean in healthcare (LP_{122})	[61,71]
		Support Level (LP_{123})	[72]
	Good communication (LP_{13})	Exchange of information (LP_{131})	[68,73]
		Periodic meetings (LP_{132})	[60,68]
		Knowledge about Lean Practices (LP_{133})	[74]
Organizing perspective (LP_2)	Management Strategy (LP_{21})	Elimination Waste (LP_{211})	[61]
		Statement of purpose (LP_{212})	[70,75]
		Quality Enhance (LP_{213})	[70]
	Worker involvement (LP_{22})	Teamwork and collaboration are encouraged and promoted (LP_{221})	[76]
		Official and casual communication (LP_{222})	[62]
		Judgment power (LP_{223})	[77]
	Roadmap for organization goal & mission (LP_{23})	Techniques for routine operations (LP_{231})	[63]
		Organization's assets and weaknesses (LP_{232})	[61,78]
		Professional understanding of the objectives and aims (LP_{233})	[79]
Employee Level (LP_3)	Employee devotion and faith (LP_{31})	A protected workplace ($_{LP311}$)	[80,81]
		Developing and growing (LP_{312})	[51,75]
		Workplace engagement (LP_{313})	[51,64]
	Training and instruction (LP_{32})	Job rotation system (LP_{321})	[64]
		Experts for guidelines and training (LP_{322})	[82]
	Honor system (LP_{33})	Boost efficiency (LP_{331})	[83]
		Motivating component (LP_{332})	[68] [70],
		Examining performance(LP_{333})	Expert Opinion
Lean practices level (LP_4)	Lean tools and technique (LP_{41})	Utilized basic equipment and methods (LP_{411})	[84], Expert Opinion
		Recognize the LP technique (LP_{412})	[61,79]
		Flexible tool set up (LP_{413})	[85]
	Execution style (LP_{42})	Organization's goal and the LP purpose (LP_{421})	[75,76]
		Changing process and operations (LP_{423})	[60]
Linking Lean to Hospital (LP_5)	Lean Focus (LP_{51})	Right Operation select (LP_{511})	[61,65]
		Linking Lean to the patient (LP_{512})	[86]
	Progress in technology (LP_{52})	Continuous investment in research and development (LP_{521})	Expert Opinion
		Adoption of cutting-edge technologies (LP_{522})	[87]

3.1. Representation of the LPRAHI evaluation model

The LPRAHI framework, which consists of three essential layers that clarify various aspects of organizational readiness, provides an effective structure for Lean practices readiness assessment in healthcare institutions.

Three stages are included in the LPRAHI evaluation model.

- The first layer embodies the five enablers that drive the performance of Lean.
- The second layer embodies the thirteen criteria.
- The third layer embodies the thirty-five attributes.

For developing an assessment model on readiness, it's necessary to know its whole at the management level, employee level, and organization level as an enabler. These three enablers are used to understand the organization's whole scenario on readiness. Then for the lean operation, we consider two enablers which are lean implementation level and linking lean to hospital. These two enablers are used to identify the healthcare organization's lean implementation current situation and link lean that helps to identify lean operation is connected with the hospital on which level. An evaluation of the review is created, leading to interviews with healthcare professionals from different hospitals, to obtain the assessment standards and traits that measure the preparedness for performing lean in the hospital in Bangladesh setting. Table 1 showcases a thorough explanation of the enablers, criteria, and attributes that have been determined within the hospital context.

The readiness assessment model used in this study is comprehensive, addressing key dimensions such as Managerial accountability, Organizing perspective, Employee Level, Lean practices level capabilities within healthcare institutes. It integrates multidimensional analysis including leadership commitment, workforce capabilities, Roadmap for organization goal & mission etc. ensuring a holistic evaluation. Methodologically rigorous with a focus on fuzzy logic, the model offers practical insights and recommendations for implementing lean practices. Validation through empirical studies supports its effectiveness in real-world settings, highlighting its comprehensive approach to assessing readiness for lean practices in healthcare.

The procedure is outlined in a step-by-step given below.

Step 1. Selection of enablers, criteria and attributes for assessing the readiness level for performing lean: The application of lean in healthcare organizations can bring about numerous benefits, such as improved quality of service, streamlined processes, and waste reduction. By doing so, healthcare systems can better meet the demands and competition in the industry, as well as enhance patient satisfaction, which is a crucial aspect of the healthcare sector [88]. Additionally, LSS enables continuous improvement in healthcare services and provides high-quality diagnosis and treatment for patients [89]. The successful deployment of LSS, however, is contingent upon effective management and a clear understanding of the critical success factors (CSFs) [90].

Step 2. Establishing the linguistic scale: The assessment of healthcare preparedness traits, standards, and key elements was conducted using terms to determine performance ratings and significance levels. The research employs the linguistic terminology obtained from Ref. [91].

Step 3. Collect information from experts about weightings and performance ratings: The next phase is to compile weights for importance and performance ratings for conceptual model all factors in order to assess whether or not Lean is ready to be performed. A questionnaire is administered to a group of five specialists, consisting of doctors, a director, and hospital management, who are responsible for formulating a new tactic and procedure aimed at enhancing the quality of healthcare services. The linguistic factors' point scale (0–10) is applied to rate performance. The parameters utilized have a rating scale of (0–1) for importance weights [25]. By using the expert responses, the average operation technique yields the combined performance rating and importance weighting [57].

Step 4. Transforming words into the right fuzzy sets: The conversion of variables into numbers is accomplished by leveraging the connection weights that establish the relationship between these terms. A collection of fuzzy numbers were created to assess agility and leanness [90,92]. Table 2 presents the numerical values utilized for calculating Lean Practices Readiness Assessment Health Index scores.

Step 5. Combining fuzzy weights with fuzzy ratings: The performance rating of the variables is transformed to criterion ratings [90], as described in equation (1). Subsequently, these criterion ratings are further modified into enabler ratings using equation (2).

Table 2
Identifying variables and their linguistic equivalents is essential for importance weighting and performance evaluation.

Performance Rating (Y_{ijk})		Importance Weighting (X_{ijk})	
Variable	Number	Variable	Number
Worst (W)	(0,0.50,1.50)	Very Low (VL)	(0,0.05,0.15)
Very Poor (VP)	(1.0,2.0,3.0)	Low (L)	(0.1,0.2,0.3)
Poor (P)	(2.0,3.0.5,50)	Fairly Low (FL)	(0.2,0.35,0.5)
Fair (F)	(3.0,5.0,7.0)	Medium (M)	(0.3,0.5,0.7)
Good (G)	(5.0,6.50,8.0)	Fairly High (FH)	(0.5,0.65,0.8)
Very Good (VG)	(7.0,8.0,9.0)	High (H)	(0.7,0.8,0.9)
Excellent (E)	(8.50,9.50,10.0)	Very High (VH)	(0.85,0.95,1)

$$LP_i = \frac{\sum_{j=1}^{i} \left(\mathrm{R}_{ij} * X_i\right)}{\sum_{j=1}^{i} X_{ij}} \tag{1}$$

$$LP_{ij} = \frac{\sum_{k=1}^{k} \left(R_{ijk} * X_{ijk}\right)}{\sum_{k=1}^{k} X_{ijk}} \tag{2}$$

The FRLPHI will then be determined in the following step using equation (3):

$$FRLPRI_i = \frac{\sum_{j=1}^{i} \left(\mathrm{R}_i * X_i\right)}{\sum_{j=1}^{i} X_i} \tag{3}$$

Step 6. Set the LPRI to the proper level: In order to compare the calculated LPRI to the generic linguistic term, the Euclidean distance approach is used, which is thought to be the most naturally occurring way for people to determine perceived proximity [90,93]. Table 3 displays the fuzzy interval that corresponds to the ready level for the performing of Lean.

Equation (4) is used to compute the Euclidean distance (D), as shown below.

$$\mathrm{D}(\mathrm{LPRI}, \mathrm{IIL}_{\mathrm{i})} = \sqrt{\sum \left(fLPRI(x) - fRIL_i(x)\right)^2} \tag{4}$$

Step 7. LPII is computed to recognize attributes that exhibit lower performance or weaker impact: Lean Practices Readiness and Health Index are utilized to assess an organization's readiness for lean implementation. It incorporates the performance rating and importance weight of each Lean component capacity to determine the overall readiness level. By analyzing the LPRAHI, major obstacles hindering improvement efforts can be identified and addressed. The degree of contribution decreases with decreased FPII of an LSS characteristic [90]. Equation (5) is used with the LPII (Lean Practices Importance Index) to determine the lower attributes, and equation (6) is used to get the ranking score. It consists of the following two steps: the LPII computation, which is first, is presented in equation (5)

$$LPII_{ijk} = R_{ijk} \otimes Y_{ijk} \tag{5}$$

$\mathrm{R_{ijk}}$= (1,1,1) - $\mathrm{Y_{ijk}}$. The subsequent step involves generating a rating score for each characteristic using the center approach. In this approach, the lower (a), middle (b), and upper (c) values of the triangular fuzzy number are employed to calculate the rating score, as shown in Equation (6) [25,93].

$$\text{Ranking Value} = (\mathrm{a} + 4\mathrm{b} + \mathrm{c})/6 \tag{6}$$

3.2. Data collection procedure

The framework is mainly survey based. For that reason, expert's opinions are taken into consideration for the purpose of understanding the impact of every lean practice factors (enablers, criteria and attributes) into healthcare systems. In order to assessing the enablers, criteria and attributes, a total of ten expert's opinions are collected. As illustrated in Table 4, the expert's profile and their work experiences related to their work field are described.

3.3. Pilot study of the assessment model

Before proceeding with a comprehensive survey, a pilot test was conducted to ensure content validity and reliability. Drawing from insights provided by academic researchers and healthcare industry professionals, the relevance and clarity of the enablers, criteria and

Table 3
Fuzzy intervals and readiness level.

Readiness level	Fuzzy intervals
Ready (R)	(7.0, 8.50, 10.0)
Close to Ready (CR)	(5.50, 7.0, 8.50)
Average Ready (AR)	(3.50, 5.0, 6.50)
Low Ready (LR)	(1.50, 3.0, 4.50)
Not Ready (NR)	(0, 1.50, 3.0)

Table 4
List of experts in healthcare systems.

Expert serial No.	Expert Belonging Hospital	Sectors	Designation	Work Experience
E1	A	Medical Doctor	Specialist	7 years
E2	A	Nurse	Registered	7 years
E3	A	Surgeons	General	10 years
E4	B	Academia	Professor	15 years
E5	B	Medical Doctor	Practitioner	3 years
E6	B	Pharmacist	Hospital	7 years
E7	C	Nurse	Registered	6 years
E8	C	Medical Doctor	Specialist	9 years
E9	C	Surgeon	Orthopedic	10 years
E10	C	Nurse	Practitioner	2 years

attributes were assessed. For the pilot study, we designed a series of questions to evaluate the importance and clarity of various enablers, criteria, and attributes for Lean implementation readiness in healthcare. Below are sample questions used in the study:

Section 1: Enablers.

Q1. How important do you consider "Managerial accountability" as an enabler for Lean implementation readiness in healthcare?

- 1 (Not important)
- 2 (Slightly important)
- 3 (Moderately important)
- 4 (Very important)
- 5 (Extremely important)

Q2. How clear and understandable is the description of "Managerial accountability" in the context of Lean readiness?

- 1 (Not clear)
- 2 (Slightly clear)
- 3 (Moderately clear)
- 4 (Very clear)
- 5 (Extremely clear)

Similar questions were asked for all other enablers, criteria, and attributes to ensure a comprehensive evaluation of Lean readiness factors. These questions were crafted to gather participants' perceptions regarding the criticality and clarity of each enabler, criterion, and attribute in the Lean readiness framework. By asking participants to rate the importance and clarity, we aimed to refine our evaluation criteria and ensure the reliability of the assessment model [94]. This comprehensive list ensures a thorough evaluation of Lean readiness factors. Initially, feedback was sought from ten experts specializing in healthcare systems to evaluate the enablers, criteria and attributes appropriateness and clarity. Subsequently, a pilot test involving 30 respondents was conducted to evaluate questionnaire reliability [94]. The primary aim of this pilot test was to confirm respondents' comprehension of each question and ensure the clarity and completeness of the enablers, criteria and attributes. Following their feedback and subsequent analysis, adjustments were made to the wording of several items, and redundant or unclear items were removed with new suggestions were included. Additionally, the construct reliability and validity were assessed based on respondents' input.

3.4. Data validity test and reliability analysis

A questionnaire was designed that contains essential questions addressing the prioritization of the lean practice factors (enablers, criteria and attributes) related to healthcare systems. The information was collected by means of Google survey tools. The collected expert opinions were evaluated for validity using the Cronbach α method, which yielded a result of 0.905 and so, the data was deemed to be within a good range [95]. Data analysis was carried out using IBM SPSS Statistics (Version 22.0), as per the chi-square test results, which showed that the questionnaires maintained the reliability range. The outcomes of the Chi-square test demonstrate that the questionnaires used in the study are reliable. For instance, one test on the question of "Top management responsibility" yielded a Chi-square statistic (χ^2) of 4.5 with 4 degrees of freedom and a p-value of 0.34. Since the p-value (0.34) is greater than the significance level of 0.05, there is no significant discrepancy between observed and expected response frequencies [96]. This validates the questionnaire by confirming that it consistently measures the intended enablers, criteria, and attributes for Lean implementation readiness in healthcare institutes, ensuring its effectiveness for further analysis. The data may be skewed due to the use of a survey-based technique. After data was collected, it was examined for reliability using the Biasness test. The replies were organized in chronological order based on the submission date. From every participant's response, two categories were formed: early responders and late responders. Two sets of data were compared using a Chi-square test. The statistical results suggest that the study corrected for the issue

of non-response bias [97].

4. Case Studies

Three different hospitals in Bangladesh tested the LPRAHI evaluation technique. The names of the hospitals are not given in this paper due to confidentiality agreements; instead, the hospitals mentioned in the context will be denoted as Hospital A, Hospital B, and Hospital C.

4.1. Hospital A

In a hospital in Khulna, the conceptual model is used for assessing the performance of Lean. The institute is presently operating with a team of highly trained medical professionals that have years of expertise in their specific fields. The chosen hospital must contend with problems with patient safety, concerns with quality, rising costs, and wasteful waste. By employing the present assessment model and identifying the weaker traits for improvement, the current research will assist hospital administrators in resolving all of the aforementioned problems. As illustrated in Table 5, data for importance weights for healthcare readiness for lean practices enablers (for hospital A) listed below. As illustrated in Table 6, Importance weights of criteria for healthcare readiness for lean practices (for hospital A) data are listed. Similarly, as illustrated in Table 7, data for Performance ratings and importance weights for attributes related to healthcare lean readiness (for hospital A) listed.

The average operational approach was used to compute the cumulative importance weights and performance rating.

$$\text{Determining the weights of various fuzzy factors} = [\text{H} + \text{FH} + \text{M} + \text{FH} + \text{H}]/5$$
$$= [(0.7, 0.8, 0.9) + (0.5, 0.65, 0.8) + (0.3, 0.5, 0.7) + (0.5, 0.65, 0.8) + (0.7, 0.8, 0.9)]/5 = (0.62, 0.74, 0.86)$$

$$\text{Determining the ratings of various fuzzy factors} = [\text{F} + \text{F} + \text{F} + \text{G} + \text{G}]/5$$
$$= [(3, 5, 7) + (3, 5, 7) + (3, 5, 7) + (5, 6.5, 8) + (5, 6.5, 8)]/5 = (3.8, 5.6, 7.4)$$

Table 8, gives a summary of the weighted relevance of attributes and the cumulative performance rating. Table 9, provides a cumulative importance weights for the various criteria and enablers.

The equation is used to construct the score of performance rating of criteria (LP_{ij}) (1). For instance, top management responsibility (LP_{11}), the following formula is used to calculate the criteria rating for L_{11} (LP_{11}).

$$L_1(LP_{11}) = \frac{[((3.04, 4.78, 0.68) \times (0.6, 0.74, 0.5)) + ((4.2, 5.39, 6.6) \times (0.58, 0.71, 0.84)) + ((2.97, 4.68, 6.41) \times (0.3, 0.47, 0.68))]}{[(0.6, 0.74, 0.5) + (0.58, 0.71, 0.84) + (0.3, 0.47, 0.68)]}$$

$$L_1(LP_{11}) = (3.48, 4.98, 6.55)$$

To assess the performance of enablers, Equation (2) is employed to determine the fuzzy index practices rating (LP_i) of each enabler. For example, the Managerial accountability enabler (L_1) is evaluated using this method to calculate its performance rating (LP_1).

$$L_1\ (LP_1) = \frac{[((3.8, 5.6, 7.4) \times (0.62, 0.74, 0.86)) + ((2.4, 4.1, 5.8) \times (0.68, 0.8, 0.54)) + ((3, 4.7, 6.4) \times\ (0.68, 0.8, 0.54))]}{[(0.62, 0.74, 0.86) + (0.58, 0.71, 0.84) + (0.68, 0.8, 0.54)]}$$

$$L_1\ (LP_1) = (3.04, 4.78, 6.68)$$

Evaluating Enabler Performance using the Same Formula In this case, the same formula is employed to evaluate the practices of the enabler (LP_i) and is displayed in Table 8. Calculating the LPRI, The next step is to calculate the LPRI using equation (3) after determining the enabler rating. This calculation results in the LPRI being computed. Table 9 indicates that Fuzzy Score of healthcare readiness for lean practices of Enabler Assessment and FLPRI (for hospital A). LPRI indicates the Lean practices readiness index.

Table 5
Importance weights for healthcare readiness for lean practices enablers (for hospital A).

Enabler (LP_i)	Importance weight (X_i)				
	S_1	S_2	S_3	S_4	S_5
LP_1	H	FH	M	FH	H
LP_2	H	VH	FH	M	H
LP_3	H	H	FH	FH	FH
LP_4	H	H	H	FH	H
LP_5	VH	VH	H	H	H

Table 6
Importance weights of criteria for healthcare readiness for lean practices (for hospital A).

Criteria (LP_{ij})	Importance weight ($^{(X}ij$)					OR_{ij}	^{X}ij				
	S_1	S_2	S_3	S_4	S_5		S_1	S_2	S_3	S_4	S_5
LP_{11}	VH	VH	FH	FH	M	LP_{32}	FH	FH	H	H	H
LP_{12}	FH	H	FH	H	FH	LP_{33}	H	FH	H	FH	H
LP_{13}	M	FH	M	L	M	LP_{41}	VH	VH	FH	H	H
LP_{21}	H	H	H	FH	H	LP_{42}	VH	VH	H	H	H
LP_{22}	H	M	H	M	M	LP_{51}	FH	FH	M	H	H
LP_{23}	FH	H	H	FH	FH	LP_{52}	FH	FH	M	VH	H
LP_{31}	FH	FH	H	H	M						

Table 7
Performance ratings and importance weights for attributes related to healthcare lean readiness (for hospital A).

LP_{ijk}	Performance ratings (X_{ijk})					Importance weights (Y_{ijk})				
	S_1	S_2	S_3	S_4	S_5	S_1	S_2	S_3	S_4	S_5
LP_{111}	H	H	FH	FH	H	F	F	F	G	G
LP_{112}	FH	FH	H	VH	VH	P	P	P	F	F
LP_{113}	M	VH	VH	H	H	P	P	F	F	G
LP_{121}	M	M	FH	FH	H	G	G	F	P	P
LP_{122}	VH	VH	FH	H	H	P	P	F	G	G
LP_{123}	FH	FH	VH	FH	H	G	G	P	P	F
LP_{131}	M	M	FH	H	VH	F	P	P	G	G
LP_{132}	VH	H	H	FH	FH	G	P	F	P	F
LP_{133}	H	H	VH	M	VH	F	F	F	P	P
LP_{211}	M	FH	H	FH	M	F	P	P	P	P
LP_{212}	H	M	FH	FH	M	P	P	F	F	P
LP_{213}	H	H	M	M	FH	F	F	F	G	F
LP_{221}	FH	H	H	FH	H	F	F	F	F	F
LP_{222}	M	FH	H	FH	VH	P	P	P	G	F
LP_{223}	H	H	FH	M	M	F	F	F	F	F
LP_{231}	FH	H	FH	M	VH	P	P	F	F	G
LP_{232}	M	VH	H	FL	FL	P	P	P	F	F
LP_{233}	H	H	FL	FL	FL	P	P	F	F	G
LP_{311}	H	H	H	VH	FH	P	P	P	F	F
LP_{312}	H	H	H	VH	H	P	P	F	F	G
LP_{313}	M	M	L	L	VL	VP	VP	W	P	P
LP_{321}	FL	M	FL	M	M	P	P	F	P	P
LP_{322}	H	FH	M	M	FH	F	F	G	G	P
LP_{331}	M	M	FH	FH	H	P	F	F	F	F
LP_{332}	H	FH	FH	VH	H	G	P	P	F	F
LP_{333}	H	M	L	M	L	P	P	G	F	F
LP_{411}	FH	H	FH	M	M	P	G	P	F	F
LP_{412}	M	M	FH	L	FL	G	G	F	F	F
LP_{413}	L	VL	M	L	L	P	VP	VP	P	F
LP_{421}	H	M	M	FH	FH	F	P	P	P	P
LP_{422}	FH	L	M	FH	FH	F	P	P	P	F
LP_{511}	FH	FH	FH	FH	FH	F	F	P	P	G
LP_{512}	FH	H	VH	FH	FH	P	P	P	F	G
LP_{521}	FH	H	L	M	M	P	P	P	W	VP
LP_{522}	FH	M	L	L	FH	P	P	F	P	W

Table 8
Fuzzy Score of healthcare readiness for lean practices of Criteria Assessment (for hospital A).

Healthcare Lean Criteria	Healthcare Lean Attribute	Attribute performance rating (X_{ijk}) -	Attributes importance average weight (Y_{ijk})	Criteria rating (LP_{ij})
LP_{11}	LP_{111}	(3.8,5.6,7.4)	(0.62,0.74,0.86)	(3.04,4.78,6.68)
	LP_{112}	(2.4,4.1,5.8)	(0.68,0.8,0.54)	
	LP_{113}	(3,4.7,6.4)	(0.68,0.8,0.54)	
LP_{12}	LP_{121}	(3.4,5,6.6)	(0.46,0.62,0.78)	(4.2,5.39,6.6)
	LP_{122}	(5,5,6.6)	(0.72,0.83,0.56)	
	LP_{123}	(3.4,5,6.6)	(0.61,0.74,0.68)	
LP_{13}	LP_{131}	(3.4,5,6.6)	(0.64,0.68,0.53)	(2.97,4.684,6.41)
	LP_{132}	(3,4.7,6.4)	(0.65,0.77,0.54)	
	LP_{133}	(2.6,4.4,6.2)	(0.68,0.8,0.54)	
LP_{21}	LP_{211}	(2.2,3.8,5.4)	(0.46,0.62,0.78)	(2.68,4.46,6.14)
	LP_{212}	(2.4,4.1,5.8)	(0.46,0.62,0.78)	
	LP_{213}	(3.4,5.3,7.2)	(0.5,0.65,0.8)	
LP_{22}	LP_{221}	(3,5,7)	(0.62,0.74,0.86)	(2.94,4.79,6.72)
	LP_{222}	(2.8,4.4,6)	(0.43,0.71,0.66)	
	LP_{223}	(3,5,7)	(0.5,0.65,0.8)	
LP_{23}	LP_{231}	(3,4.7,6.4)	(0.57,0.71,0.78)	(2.82,4.5,6.24)
	LP_{232}	(2.4,4.1,5.8)	(0.45,0.53,0.54)	
	LP_{233}	(3,4.7,6.4)	(0.4,0.53,0.66)	
LP_{31}	LP_{311}	(2.4,4.1,5.8)	(0.69,0.58,0.72)	(2.56,4.0,5.51)
	LP_{312}	(3,4.7,6.4)	(0.75,0.83,0.74)	
	LP_{313}	(1.2,2.3,3.5)	(0.16,0.38,0.43)	
LP_{32}	LP_{321}	(2.2,3.8,5.4)	(0.26,0.44,0.62)	(3.09,4.67,6.6)
	LP_{322}	(3.6,5.3,7.6)	(0.46,0.62,0.78)	
LP_{33}	LP_{331}	(2.8,4.7,6.6)	(0.46,0.62,0.780	(2.93,4.7,6.47)
	LP_{332}	(3,4.7,6.4)	(0.65,0.77,0.7)	
	LP_{333}	(3,4.7,6.4)	(0.3,0.44,0.58)	
LP_{41}	LP_{411}	(3,4.7,64)	(0.46,0.62,0.78)	(3.2,3.75,6.38)
	LP_{412}	(3.8,2.8,7.4)	(0.28,0.44,0.6)	
	LP_{413}	(1.8,3.2,4.6)	(0.12,0.32,0.35)	
LP_{42}	LP_{421}	(2.2,3.8,5.4)	(0.46,0.62,0.78)	(2.29,3.94,5.58)
	LP_{422}	(2.4,4.1,5.8)	(0.38,0.53,0.68)	
LP_{51}	LP_{511}	(3,4.7,6.4)	(0.5,0.65,0.8)	(4.1,4.54,6.21)
	LP_{512}	(2.8,4.4,6)	(0.61,0.74,0.68)	
LP_{52}	LP_{521}	(1.4,2.6,3.9)	(0.38,0.53,0.68)	(1.58,2.87,4.27)
	LP_{522}	(1.8,3.2,4.7)	(0.3,0.44,0.58)	

Table 9
Fuzzy Score of healthcare readiness for lean practices of Enabler Assessment and FLPRI (for hospital A).

Enabler	Criteria	Criteria rating (Y_{ij})	Criteria Weights (X_{ij})	Enabler Rating (LP_i)	Enabler Weights (X_i) – Average	Fuzzy Lean practices Readiness Index
LP_1	LP_{11}	(3.04,4.78,6.6)	(0.6,0.74,0.5)	(3.48,4.98,6.5)	(0.54,0.68,0.8)	(2.77,4.35,6.6)
	LP_{12}	(4.2,5.39,6.6)	(0.58,0.71,0.84)			
	LP_{13}	(2.97,4.68,6.4.)	(0.3,0.47,0.68)			
LP_2	LP_{21}	(2.68,4.40,6.1)	(0.66,0.77,0.88)	(2.79,4.54,6.5)	(0.61,0.74,0.86)	
	LP_{22}	(2.94,4.79,6.7)	(0.46,0.62,0.78)			
	LP_{23}	(2.82,4.5,6.24)	(0.58,0.71,0.84)			
LP_3	LP_{31}	(2.56,4.00,5.5)	(0.54,0.62,0.82)	(2.68,4.48,6.2)	(0.58,0.71,0.84)	
	LP_{32}	(3.09,4.67,6.6)	(0.62,0.74,0.86)			
	LP_{33}	(2.39,4.7,6.47)	(0.62,0.74,0.86)			
LP_4	LP_{41}	(3.2,3.75,6.38)	(0.72,0.83.0.56)	(3.04,3.85,5.7)	(0.66,0.77,0.88)	
	LP_{42}	(2.9,3.94,5.58)	(0.76,0.83,0.56)			
LP_5	LP_{51}	(4.1,4.54,6.21)	(0.54,0.68,0.82)	(2.8,3.68,5.34)	(0.76,0.86,0.94)	
	LP_{52}	(1.58,2.87,4.2)	(0.57,0.71,0.66)			

$$\mathrm{LPRI} = \frac{\begin{array}{c}[((3.48,4.98,6.55)\times(0.54,0.68,0.82))+\\((2.79,4.54,6.35)\times(0.61,0.74,0.86))+\\((2.68,4.48,6.02)\times(0.58,0.71,0.84))+\\((3.04,3.85,5.97)\times(0.66,0.77,0.88))+\\((2.08,3.68,5.34)\times(0.76,0.86,0.94))]\end{array}}{[(0.54,0.68,0.82)+(0.61,0.74,0.86)+(0.58,0.71,0.84)+(0.66,0.77,0.88)+(0.76,0.86,0.94)]}$$

$$\text{LPRI} = (2.77, 4.35, 6.06)$$

4.1.1. Calculating the Euclidean distance (for hospital A)

The Euclidean distance (D) for readiness label is calculated using equation (4) as illustrated below:

$$\text{D (LPRI, Ready)} = [(2.77\text{–}7)^2 + (4.35\text{–}8.5)^2 + (6.06\text{–}8.5)^2]^{1/2} = 6.75$$

$$\text{D (LPRI, Close to Ready)} = [(2.77\text{–}5.5)^2 + (4.35\text{–}7)^2 + (6.06\text{–}8.5)^2]^{1/2} = 4.54$$

$$\mathbf{D\ (LPRI,\ Average\ Ready) = [(2.77\text{–}3.5)^2 + (4.35\text{–}5)^2 + (6.06\text{–}6.5)^2]^{1/2} = 1.071}$$

$$\text{D (LPRI, Low Ready)} = [(2.77\text{-}1.5)^2 + (4.35\text{-}3)^2 + (6.06\text{-}4.5)]^{1/2} = 2.442$$

$$\text{D (LPRI, Not Ready)} = [(2.77\text{-}0)^2 + (4.35\text{-}1.5)^2 + (6.06\text{-}3)^2]^{1/2} = 5.015$$

Determining Readiness Label, By utilizing Euclidean distance calculation, linguistic label is paired with the lowest D value, revealing that the hospital's ready for performing the Lean index is "average ready." This information is visualized in Figure-2.

4.1.2. Identifying weak attributes with lean performance importance index (for hospital A)

The LPII is used to recognize weaker attributes and involves two steps. Firstly, the LPII is calculated using equation (5). Secondly, a rank for each element is developed through equation (6). A calculation of "Feedback from front line and management (LP_{111})" is presented below

$$R_{111} = (1,1,1) - Y_{111}.$$
$$= (1,1,1) - (0.62, 0.74, 0.86) = (0.38, 0.26, 0.14)$$

$$\text{LPII}_{111} = (3.8, 5.6, 7.4) \times (0.38, 0.26, 0.14) = (1.33, 1.45, 1.03)$$

$$\text{Rank score of } (\text{LPII}_{111}) = (1.33 + 4\,(1.45) + 1.03) \,/\, 6 = 1.36$$

According to Table 10, a ranking score has been assigned to each attribute and the management has established a threshold of 1.2. This means that any attribute falling below this value indicates a potential area for improvement or optimization within the hospital's operational framework. Hospital A faces deficiencies here are the areas listed in Table 11.

The Pareto principle dictates that 20 % of the attributes with the lowest scores need to be improved to increase the overall readiness for performing lean. The attributes with the lowest scores, ranging from 0.22 to 2.53, were discussed with the hospital management and they agreed that these attributes warrant extra attention to enhance the hospital's readiness.

Management sets thresholds based on their accumulated experience and insights from past projects and organizational contexts. This practical knowledge helps them establish realistic benchmarks for performance that align with strategic objectives. Additionally, decisions on thresholds are informed by relevant literature, organization standards, and best practices, ensuring that they reflect both practical feasibility and broader professional insights.

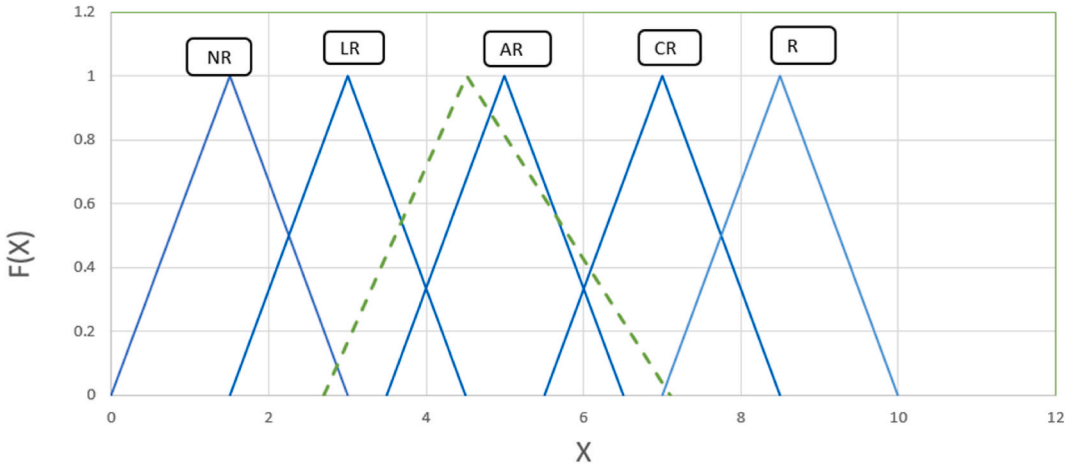

Figure-2. Linguistic levels to satisfy fuzzy ready for lean practices for hospital A.

Table 10
The Fuzzy Lean Practices Importance Index (LPII) measures healthcare readiness for lean practices (for hospital A).

Healthcare attributes	Performance rating (Y_{ijk})	$R_{ijk} = (1, 1, 1) - Y_{ijk.}$	LPII	Rank value
LP_{111}	(0.62,0.74,0.86)	(0.38,0.26,0.14)	(1.33,1.45,1.03)	1.36
LP_{112}	(0.68,0.8,0.54)	(0.32,0.20,0.46)	(0.76,0.82,2.6)	**1.11***
LP_{113}	(0.68,0.8,0.54)	(0.32,0.20,0.46)	(1.08,0.94,3.456)	1.38
LP_{121}	(0.46,0.62,0.78)	(0.54,0.38,0.22)	(1.83,1.9,1.84)	1.87
LP_{122}	(0.72,0.83,0.56)	(0.28,0.17,0.44)	(1.4,0.85,2.90)	1.28
LP_{123}	(0.61,0.74,0.68)	(0.39,0.26,0.32)	(1.326,1.3,2.11)	1.44
LP_{131}	(0.64,0.68,0.53)	(0.47,0.32,0.36)	(1.59,1.6,2.37)	1.72
LP_{132}	(0.65,0.77,0.54)	(0.35,0.23.0.46)	(1.05,1.08,2.94)	1.381
LP_{133}	(0.68,0.8,0.54)	(0.32,0.2,0.46)	(0.83,0.88,2.85)	1.2
LP_{211}	(0.46,0.62,0.78)	(0.54,0.35,0.22)	(1.18,1.33,1.18)	1.28
LP_{212}	(0.46,0.62,0.78)	(0.54,0.38,0.22)	(1.29,1.56,1.28)	1.47
LP_{213}	(0.5,0.65,0.8)	(0.5,0.35,0.2)	(0.25,0.23,0.16)	**0.22***
LP_{221}	(0.62,0.74,0.86)	(0.38,0.26,0.14)	(1.14,1.3,0.95)	1.22
LP_{222}	(0.43,0.71,0.66)	(0.57,0.29,0.44)	(1.6,1.28,2.64)	1.56
LP_{223}	(0.5,0.65,0.8)	(0.5,0.35,0.2)	(1.5,1.75,1.4)	1.65
LP_{231}	(0.57,0.71,0.78)	(0.43,0.29,0.21)	(1.29,1.36,1.34)	1.345
LP_{232}	(0.45,0.53,0.54)	(0.55,0.47,0.46)	(1.32,1.92,2.66)	1.94
LP_{233}	(0.4,0.53,0.66)	(0.6,0.47,0.34)	(1.2,2.20,2.17)	2.02
LP_{311}	(0.69,0.58,0.72)	(0.31,0.2,0.28)	(0.74,0.82,1.62)	**0.94***
LP_{312}	(0.75,0.83,0.74)	(0.25,0.17,0.26)	(0.75,0.79,1.66)	**0.92***
LP_{313}	(0.16,0.38,0.43)	(0.84,0.62,0.57)	(1.008,1.42,1.99)	1.44
LP_{321}	(0.26,0.44,0.62)	(0.74,0.56,0.38)	(1.628,2.13,3.25)	2.25
LP_{322}	(0.46,0.62,0.78)	(0.54,0.38,0.22)	(1.94,2.01,1.672)	1.94
LP_{331}	(0.46,0.62,0.780	(0.54,0.38,0.22)	(1.51,1.79,1.45)	1.68
LP_{332}	(0.65,0.77,0.7)	(0.35,0.33,0.3)	(1.05,1.55,1.92)	1.52
LP_{333}	(0.3,0.44,0.58)	(0.7,0.56,0.42)	(2.1,2.6,2.68)	2.53
LP_{411}	(0.46,0.62,0.78)	(0.54,0.38,0.22)	(1.62,1.78,1.4)	1.69
LP_{412}	(0.28,0.44,0.6)	(0.72,0.56,0.4)	(2.73,2.24,2.96)	2.35
LP_{413}	(0.12,0.32,0.35)	(0.88,0.68,0.65)	(1.57,2.17,2.99)	2.20
LP_{421}	(0.46,0.62,0.78)	(0.54,0.38,0.22)	(1.18,1.44,1.18)	1.35
LP_{422}	(0.38,0.53,0.68)	(0.62,0.47,0.32)	(1.148,1.92,1.82)	1.83
LP_{511}	(0.5,0.65,0.8)	(0.5,0.35,0.2)	(1.5,1.64,1.28)	1.55
LP_{512}	(0.61,0.74,0.68)	(0.39,0.26,0.22)	(1.70,1.44,1.32)	1.55
LP_{521}	(0.38,0.53,0.68)	(0.62,0.47,0.32)	(0.86,1.22,1.24)	**1.16***
LP_{522}	(0.3,0.44,0.58)	(0.7,0.56,0.42)	(1.26,1.79,1.97)	1.73

Note: Management threshold <1.2.

Table 11
Lists of Weaker attributes for hospital A.

Healthcare attributes	Weaker attributes
LP_{112}	Authority involvement in Lean performance
LP_{212}	Quality enhancement
LP_{311}	A protected workplace
LP_{312}	Development and growth
LP_{521}	Continuous investment in research and development

4.2. Hospital B

Hospital B, a renowned medical institution in Rajshahi, confronts challenges in patient safety, quality, rising costs, and operational efficiency. With a highly skilled medical team, the hospital recognizes the potential of Lean management to address these issues and meet elevated customer expectations for top-notch service. Following a methodology similar to Hospital A, data is collected and calculated to assess the hospital's readiness level for Lean implementation. The assessment spans organizational enablers, criteria, and attributes within the LPRAHI model, providing a diagnostic tool to pinpoint strengths and weaknesses. The goal is to exceed customer expectations and reinforce the hospital's position as a leader in healthcare excellence in Rajshahi.

Hence, acknowledging the necessity of the LPRAHI scheme, the hospital consented to conduct the assessment. Employing Equation (3), the LPRI score for hospital B is calculated as follows: LPRI (Hospital B) = (2.97, 4.37, 5.98)

4.2.1. Calculating the Euclidean distance for hospital B

The Euclidean distance (D) for readiness label is calculated using equation (4) as illustrated below:

$$D\ (\text{LPRI, Ready}) = [(2.79–7)^2 + (4.37–8.5)^2 + (5.98–8.5)^2]^{1/2} = 7.13$$

$$D\ (\text{LPRI, Close to Ready}) = [(2.79–5.5)^2 + (4.37–7)^2 + (5.98–8.5)^2]^{1/2} = 4.53$$

D (LPRI, Average Ready) = $[(2.79–3.5)^2+ (4.37–5)^2+ (5.98–6.5)^2]^{1/2} = 1.08$

D (LPRI, Low Ready) = $[(2.79\text{-}1.5)^2+ (4.37\text{-}3)^2+ (5.98\text{-}4.5)^2]^{1/2} = 2.39$

D (LPRI, Not Ready) = $[(2.79\text{-}0)^2+ (4.37\text{-}1.5)^2+ (5.98\text{-}3)^2]^{1/2} = 4.99$

Determining Label, By utilizing Euclidean distance calculation, the linguistic scale is paired with the lowest D score, revealing that hospital's ready for performing the Lean index is "average ready."

4.2.2. Identifying weak attributes with lean performance importance index for hospital B

In assessing the operational efficiency of Hospital B, a crucial metric lies in the evaluation of weaker attributes coupled with lean practices. Similar to Hospital A, an important index is computed to gauge the effectiveness of these practices. The LPII is used to recognize weaker attributes and involves two steps. Firstly, the LPII is calculated using equation (5). Secondly, a rank for each element is developed through equation (6). Now, the management has set a threshold value for this index at 1.2. Hospital B faces deficiencies here are the areas listed in Table 12. This means that any attribute falling below this value indicates a potential area for improvement or optimization within the hospital's operational framework.

4.3. Hospital C

Similar to Hospitals A and B, Hospital C is a medium-sized private medical facility in Khulna that uses Lean readiness assessment techniques. Taking on issues related to patient safety, quality, prices, and operational efficiency, Hospital C complies with hospitals norms by conducting a comprehensive evaluation of its state of readiness for Lean implementation. Following a methodology similar to Hospital A, data is collected and calculated to assess the hospital's readiness level for Lean implementation. Like its peers, Hospital C gathers and examines extensive data on organizational criteria, traits, and enablers that are part of the LPRAHI model. The objective is to pinpoint areas of strength and room for development in order to provide a customized road map for successful Lean initiatives.

Hence, acknowledging the necessity of the LPRAHI scheme, the hospital consented to conduct the assessment. Employing Equation (3), the LPRI score for hospital C is calculated as follows: LPRI (Hospital C) = (1.6, 2.52, 5.3)

4.3.1. Calculating the Euclidean distance for hospital C

The Euclidean distance (D) for readiness label is calculated using equation (4) as illustrated below:

D (LPRI, Ready) = $[(1.6–7)^2+ (2.52–8.5)^2+ (5.3–10)^2]^{1/2} = 9.32$

D (LPRI, Close to Ready) = $[(1.6–5.5)^2+ (2.52–7)^2+ (5.3–8.5)^2]^{1/2} = 6.74$

D (LPRI, Average Ready) = $[(1.6–3.5)^2+ (2.52–5)^2+ (5.3–6.5)^2]^{1/2} = 3.34$

D (LPRI, Low Ready) = $[(1.6\text{-}1.5)^2+ (2.52–3)^2+ (5.3\text{-}4.5)^2]^{1/2} = 0.93$

D (LPRI, Not Ready) = $[(1.6\text{-}0)^2+ (2.52\text{-}1.5)^2+ (5.3\text{-}3)^2]^{1/2} = 2.98$

Determining Label, By utilizing Euclidean distance calculation, linguistic label is paired with the lowest D value, revealing that the hospital's ready for performing the Lean index is "Low ready."

4.3.2. Identifying weak attributes with lean performance importance index for hospital C

In assessing the operational efficiency of Hospital C, a crucial metric lies in the evaluation of weaker attributes coupled with lean practices. Similar to Hospital A, an important index is computed to gauge the effectiveness of these practices. Now, the management has set a threshold value for this index at 1.2. This means that any attribute falling below this value indicates a potential area for improvement or optimization within the hospital's operational framework. Hospital C faces deficiencies here are the areas listed in Table 13.

4.4. Results

Hospitals in Bangladesh face many difficulties, including a wide range of medical services provided, regular modifications to

Table 12
Lists of Weaker attributes for hospital B.

Healthcare attributes	Weaker attributes
LP_{112}	Authority involvement in Lean performance
LP_{123}	Support level
LP_{331}	Workplace engagement
LP_{322}	Expertise for guidelines and training
LP_{521}	Continuous investment in research and development

Table 13
Lists of Weaker attributes for hospital C.

Healthcare attributes	Weaker attributes
LP_{112}	Authority involvement in Lean performance
LP_{113}	Resource for implant Lean
LP_{123}	Support level
LP_{131}	Exchange of information
LP_{212}	Quality enhancement
LP_{311}	A protected workplace
LP_{312}	Development and growth
LP_{331}	Workplace engagement
LP_{322}	Expertise for guidelines and training
LP_{521}	Continuous investment in research and development

medical protocols, the occurrence of operational inefficiencies that result in mistakes and delays, and changing patient expectations. Hospitals that wish to use the model are selected based on their desire to implement cutting-edge techniques to improve healthcare delivery procedures and maximize quality systems to satisfy patient demands. A unique framework for lean readiness is created specifically for healthcare institutions, incorporating fuzzy-based inputs and stakeholder theory to produce rankings that point out areas for development. This provides a new perspective for practitioners and scholars working on lean implementation initiatives [15]. Hence, the current LPRAHI evaluation model was constructed based on the Lean practices factors, lean readiness factors and expert suggestion, enablers, criteria, and attributes of Lean Practices (LP), and using fuzzy logic approach as methodology. As a result, Table 1's important elements, enablers, criteria, and attributes of Lean Practices (LP) served as the foundation for creating the present LPRAHI evaluation methodology. The model uses the centroid method, created with practitioners in mind, to rank the fuzzy member set (a, b, and c) [25]. This method was selected for its user-friendliness compared to other ranking techniques. To validate the proposed evaluation model, three Bangladeshi hospitals, particularly small to medium-sized ones, were chosen. Unlike many studies in the literature limited to a single hospital, the LPRAHI evaluation model underwent testing across three distinct hospitals, serving as case studies to validate the model's applicability and effectiveness. Before implementing the model, a comprehensive training session was conducted to ensure evaluators (experts) were well-versed in the concepts, ensuring the accuracy of results. During these sessions, linguistic variables, membership functions, and the assignment of relative importance to each element are thoroughly explained. A pilot study was carried out to verify content validity and reliability prior to moving on with a full survey. A healthcare lean practice prioritization questionnaire was administered via Google survey tools, with expert opinions validated for reliability (Cronbach's $\alpha = 0.905$) and further analysis conducted using IBM SPSS Statistics (Version 22.0), ensuring questionnaire reliability via chi-square tests, addressing potential skew-ness in data through biasness tests and non-response bias corrected through chronological comparison of early and late responders' data sets. Subsequently, a study involving hospital experts is conducted to determine linguistic terms corresponding to the importance weights and performance scores of each element (indicator, criterion, attribute). These scores are collectively determined by experts through discussion sessions and Google survey form. The importance weights and performance scores for Lean capabilities (indicator, criterion, attribute) are documented and presented in a Table 7. Then, by applying the relationship between linguistic terms and their membership functions, linguistic terms are transformed into fuzzy numbers. These fuzzy numbers are used to calculate the Lean index associated with each criterion LP_{ij} using equation (2). Additionally, the Lean practices index for each indicator LP_i is calculated using equation (1), thereby offering a comprehensive assessment of the hospital's performance in lean and quality improvement initiatives. Once the values LP_i have been calculated, the Fuzzy Lean Practices Readiness Index (FLPRI) can be determined using equation (3), with the results shown in Table 9. In our case study, the membership function of the FLPRI is (2.77; 4.35; 6.6) which is then converted back into a linguistic term to assess the Lean practices readiness level of Hospital A. Using the Euclidean distance method in equation (4), the readiness index for LP implementation is determined to be 'average ready,' indicating an intermediate state of readiness. So we needed to identify the weak attributes. To identify weak attributes, the Lean Practices Importance Index (FPII) is calculated using equation (5), and the score of each attribute is determined using equation (7), as presented in Table 10. Attributes with scores below 1.2 are considered critical barriers to improvement, with 5 attributes falling below this threshold in our calculations for hospital A.

4.5. Discussion of the findings

The evaluation of the LPRAHI model, encompassing three distinct hospitals as case studies, has yielded valuable insights into their readiness levels, pinpointing areas ripe for improvement. Each hospital's strengths and weaknesses were discussed in the context of the case studies, providing a more integrated and cohesive narrative.

4.5.1. Hospital A and Hospital B

Both hospitals have been classified as "average ready" based on the LPRAHI model. The readiness values (LPRI) for Hospital A stand at 2.77, 4.35, and 6.06, while Hospital B exhibits LPRI values of 2.79, 4.37, and 5.98. These values encapsulate the overall readiness levels of the hospitals, considering a spectrum of attributes.

4.5.2. Weaknesses

Leadership Commitment: There is a need for stronger leadership involvement and commitment to drive Lean initiatives effectively.
Workforce Capability: Enhancing the skills and capabilities of the workforce is crucial for successful Lean implementation.
Operational Processes: Streamlining operational processes to reduce inefficiencies and errors is essential.
Technological Infrastructure: Upgrading technological infrastructure to support Lean practices is necessary.
Organizational Culture: Fostering a culture that supports continuous improvement and Lean principles is vital.

4.5.3. Hospital C

Hospital C demonstrates a lower readiness level compared to the other two hospitals, with LPRI values of 1.62, 2.52, and 5.3. This indicates a need for significant improvements in readiness for Lean performance.

4.5.4. Weaknesses

Leadership Commitment: Enhancing leadership commitment to Lean initiatives.
Workforce Capability: Developing the workforce's skills and capabilities.
Operational Processes: Improving operational processes to minimize errors and inefficiencies.
Technological Infrastructure: Investing in technological upgrades.
Organizational Culture: Building a supportive organizational culture for Lean practices.

To overcome these obstacles, strategic measures such as engaging senior management in Lean initiatives, establishing quality improvement teams, ensuring a safe working environment, and fostering employee growth are essential focuses. These actions are feasible as they leverage existing leadership structures and organizational commitment, promoting alignment with Lean principles from top management down to operational levels. Additionally, investing in research infrastructure, implementing efficient communication channels, enhancing support systems, and fostering a positive work environment are recommended. These actions are feasible through phased implementation, starting with pilot projects and scaling up based on demonstrated success and organizational capacity. Developing subject matter experts and allocating resources for Lean implementation are also critical. Feasibility is ensured by prioritizing training and development programs that build internal expertise gradually, aligning with long-term organizational goals. By approaching these strategic measures with a phased implementation strategy, organizations can enhance readiness levels for Lean practices effectively while ensuring sustainability and continuous improvement.

The LPRAHI model aids in assessing the current readiness level of the hospital before embarking on improvement initiatives. Comparing our findings with a study conducted, where 4 enablers, 12 criteria, and 38 attributes of healthcare readiness for change were utilized across a hospital, revealed readiness level as average ready. Identified areas for improvement included "Degree of support" and "Positive environment for change" [98] Conversely, in a study by pertaining to manufacturing models, the importance of "resistance of employees to changes, the lack of time to launch LSS projects, as well as the low maturity of the clothing SME sector, and the lack of knowledge of the tools and techniques of Lean Six Sigma." was highlighted [25].

In our investigation, we've identified key weakness, including Authority involvement in Lean performance, Resource for implant Lean, Support level, Expertise for guidelines and training, Continuous investment in research and development. Overall, the findings from the LPRAHI model evaluation offer a roadmap for hospital administrators to strategically plan and prioritize areas for improvement. By addressing these weaker attributes, hospitals can elevate their readiness levels, optimize operational efficiency, and enhance patient care outcomes. The insights garnered serve as a valuable guide for administrators to navigate the intricacies of Lean implementation effectively.

5. Practical implication

The LPRAHI model evaluation across three diverse hospitals provides crucial insights for hospital administrators seeking to enhance Lean implementation. The findings underscore the importance of active top management involvement, emphasizing leadership commitment to inspire organizational adherence to Lean principles. Establishing seamless communication channels among healthcare professionals is vital, promoting collaboration and informed decision-making. Allocating resources strategically for robust support systems, including guidance, training, and mentorship, contributes to effective Lean implementation. Fostering a positive work environment, characterized by employee participation, collaboration, and recognition of contributions, cultivates a culture of continuous improvement. Prioritizing continuous learning through training programs and career advancement opportunities equips healthcare professionals with the necessary skills for successful Lean practices. Robust quality improvement strategies, including safety assessments and data-driven decision-making, are essential for enhancing patient care quality. Additionally, nurturing a dynamic learning culture that encourages innovation, knowledge sharing, and continuous professional development creates an environment conducive to Lean success. By addressing these practical implications, administrators can fortify their readiness for Lean implementation, resulting in improved operational efficiency, enhanced patient care, and overall organizational excellence. The LPRAHI evaluation model serves as a valuable tool for administrators to strategically plan and prioritize areas of improvement, ushering in transformative changes within healthcare organizations. Embracing Lean principles holds the potential to revolutionize healthcare, fostering a more sustainable and patient-centric healthcare system.

6. Conclusions

This study aimed to assess hospital readiness at three levels for implementing Lean techniques, focusing on identifying weaknesses

and necessary strategies for success. Through the research, several key objectives were achieved: understanding current readiness levels, pinpointing areas of improvement, and proposing strategies to enhance readiness. This involved creating a unique framework that uses fuzzy logic approach to identify readiness level with areas for improvement. The study aimed to achieve these objectives through a comprehensive literature review, expert consultations, development of evaluation criteria, pilot testing, and case studies across three Bangladeshi hospitals. These steps ensured that the model was robustly designed and validated to measure readiness levels effectively. The study contributes significantly to existing literature by providing a detailed analysis of hospital readiness specifically tailored for Lean implementation. It highlights the importance of addressing identified weaknesses, such as leadership commitment, workforce capabilities, and operational processes, authority involvement in Lean performance, and resource support levels to effectively overcome challenges in Lean adoption. Key findings indicate that many hospitals struggle with insufficient training programs, lack of staff engagement, and inadequate technological infrastructure. To address these issues, it is crucial to develop comprehensive training initiatives, foster a culture of continuous improvement, and invest in advanced technologies that support Lean methodologies. Ensuring robust communication frameworks and leadership alignment with Lean principles is also essential for driving successful implementation. Key learnings from the study underscore the critical role of hospital leaders in driving Lean initiatives and fostering a supportive organizational culture. Healthcare practitioners emphasize the need for strategic investments in infrastructure, improved communication channels, and ongoing professional development to enhance readiness and sustain Lean practices.

In conclusion, this study provides actionable insights and strategic recommendations to strengthen hospital readiness for Lean techniques, contributing to improved efficiency and patient care outcomes in healthcare organizations.

7. Limitations and future research directions

This study has several limitations that should be acknowledged. First, the research was conducted solely within Bangladesh due to time constraints, which may limit the generalizability of the findings to broader contexts. The relatively small sample size of hospitals used as case studies further constrains the applicability of the results to the wider healthcare sector. Additionally, the reliance on self-reported data introduces the potential for biases or inaccuracies. The study also provides only a snapshot of hospital readiness, lacking longitudinal data to track progress over time. External factors and regional variations that influence Lean readiness may not have been fully considered.

Despite these limitations, this research offers valuable insights into hospital readiness for Lean implementation in healthcare. For future research, it is recommended to encompass a more diverse range of healthcare settings and include a larger sample size to enhance the generalizability of the findings. Employing correlation analysis for ranking readiness attributes and conducting comparative analyses across different regions will provide a more nuanced understanding. Adopting a longitudinal approach and incorporating diverse stakeholder perspectives will contribute to a more comprehensive understanding of Lean readiness in healthcare, thereby fostering informed strategies for successful implementation.

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Ethics statement

Written informed consent was obtained from all participants prior to their involvement in this study. The study was conducted in compliance with the ethical standards and the Helsinki Declaration of 1975, as revised in 2000. The research protocol was reviewed and approved by Office of the Director for Research & Extension, KUET with the approval number: KUET/DRE/2024/12(02). Participants were informed about the study's purpose, procedures, their rights to withdraw at any time, and the measures taken to ensure the confidentiality and anonymity of their data. All collected data were anonymized and securely stored to protect participant privacy.

Data availability statement

Data associated with this study has not been deposited into a publicly available repository. However, the data will be made available upon request.

CRediT authorship contribution statement

Kazi Md Tanvir Anzum: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Md Golam Kibria:** Writing – review & editing, Validation, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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