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A hybrid multi-criteria decision-making approach for hospitals' sustainability performance evaluation under fuzzy environment

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Abstract

Purpose – Hospital structures serve to protect and improve public health; however, they are recognized as a major source of environmental degradation. Thus, an effective performance evaluation framework is required to improve hospital sustainability. In this context, this study presents a holistic methodology that integrates the sustainability balanced scorecard (SBSC) with fuzzy Delphi method and fuzzy multi-criteria decision-making approaches for evaluating the sustainability performance of hospitals.

Design/methodology/approach – Initially, a comprehensive list of relevant sustainability evaluation criteria was considered based on six SBSC-based dimensions, in line with triple-bottom-line sustainability dimensions, and derived from the literature review and experts' opinions. Then, the weights of perspectives and their respective criteria are computed and ranked utilizing the fuzzy analytic hierarchy process. Subsequently, the hospitals' sustainable performance values are ranked based on these criteria using the Fuzzy Technique for Order of Preference by Similarity to Ideal Solution.

Findings – A numerical application was conducted in six public hospitals to exhibit the proposed model's applicability. The results of this study revealed that "Patient satisfaction," "Efficiency," "Effectiveness," "Access to care" and "Waste production," respectively, are the five most important criteria of sustainable performance.

Practical implications – The new model will provide decision-makers with management tools that may help them identify the relevant factors for upgrading the level of sustainability in their hospitals and thus improve public health and community well-being.

Originality/value – This is the first study that proposes a new hybrid decision-making methodology for evaluating and comparing hospitals' sustainability performance under a fuzzy environment.

Keywords Hospitals, Performance evaluation, Sustainability performance, MCDM, FAHP, FTOPSIS

Paper type Research paper

1. Introduction

The healthcare sector is one of the most significant sectors of the world's economy and among the predominant factors of social well-being and community development. According to the World Health Report, a hospital is considered the main provider of care and a principal factor in the equitable distribution of healthcare services in health systems (Shaw, 2003).

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It contributes to public health services by providing continuous services to address difficult health scenarios (Davis *et al.*, 2013). Moreover, public health systems attain their ultimate goals at a broader level through enhanced hospital performance. However, this institution also carries a significant sustainability-related burden as it has huge negative side effects on the economy, environment and society (De Soete *et al.*, 2017). More specifically, hospitals consume the greatest bulk of health system expenditures in both developed and developing countries (Amiri *et al.*, 2020). In 2013, the healthcare industry consumed an average of 10% of the gross domestic product (De Soete *et al.*, 2017), whereas the volume of hospital waste has dramatically increased (Ansari *et al.*, 2019). Healthcare waste is considered the fourth largest producer of mercury in the environment in some areas and the generator of around 5% of the national CO2 footprint in China and India, which are members of the Organization for Economic Co-operation and Development countries (Pichler *et al.*, 2019). In addition, the workplace risk factors in hospitals are greater than those in other occupational sectors and may adversely harm the health of their workers and patients (Weisz *et al.*, 2011). In light of the aforementioned issues, various stakeholders, such as patients, legislators, government and community, have pressured hospitals to embrace more sustainable practices within their operations. Bieker and Waxenberger (2002) ascertained that by adopting sustainable practices, an organization raises its value and encourages sustainable development.

Sustainability performance evaluation systems for hospitals are one of the crucial deciding tools for implementing new strategies and transitioning progress toward sustainability objectives. To date, a continuously growing number of sustainability assessment frameworks have been conducted in various areas such as oil companies (Rabbani *et al.*, 2014), banking services (Raut *et al.*, 2017) and the semiconductor industry (Hsu *et al.*, 2011). However, the healthcare sector has attracted very little attention, and the majority of existing models for evaluating the sustainability performance of hospitals are limited. Existing models focus on evaluating the environmental and economic performances separately while ignoring the social dimension (Blass *et al.*, 2017; Pasqualini *et al.*, 2016). Most importantly, they do not consider the relative prioritization of these dimensions and criteria in an uncertain environment (Grigoroudis *et al.*, 2012; Gurd and Gao, 2007). Thus, it is necessary for hospitals' evaluation framework to be expanded further to incorporate social criteria such as patient health, access to care and the well-being of employees to achieve real sustainable hospitals. According to the triple-bottom-line (TBL) concept, all three facets of sustainability (economic, social and environmental) are considered crucial and should be considered in the evaluation process (Rabbani *et al.*, 2014). To bridge the existing gap, this study aims to develop a novel quantitative method that helps to evaluate hospitals' sustainability performance based on TBL dimensions.

Different methods have been developed for measuring the sustainability performance of organizations, such as the data envelopment analysis (DEA) (Omrani *et al.*, 2018), balanced scorecard (BSC) (Khalid *et al.*, 2019), fuzzy analytic hierarchy process (FAHP) (Shahbod *et al.*, 2017), fuzzy technique for order of preference by similarity to ideal solution (FTOPSIS) (Carnero, 2020), fuzzy set approach (Lin *et al.*, 2013), etc. However, these techniques have been criticized for not fully considering all three sustainability dimensions, i.e. economic, environmental and social dimensions (HASSINI *et al.*, 2012). Regarding these issues, Figge *et al.* (2002) combined the conventional BSC method with the idea of sustainable development to establish a sustainability balanced scorecard (SBSC) model that covers economic, environmental and social aspects. SBSC-based performance measurement is one of the unique techniques that provide a comprehensive and multidimensional view of the overall organization's performance (Rabbani *et al.*, 2014). Since it is argued that prioritizing performance criteria may yield a most constructive framework for evaluating sustainable development (Ahmad and Wong, 2019; Hsu *et al.*, 2011; Rabbani *et al.*, 2014), the new idea developed in the paper is to create an integrated approach that combines SBSC with FAHP and FTOPSIS. This integrated approach for hospital performance evaluation has never been proposed. First, the sustainability evaluation criteria based on the six dimensions of SBSC (financial, stakeholder, internal business process, learning and development, environmental, and social) are derived from the literature and adjusted through the fuzzy Delphi method and experts' opinions. Yet, it must be mentioned that the evaluation of the sustainability performance of hospitals is a complicated task requiring several conflicting criteria to be considered simultaneously. Consequently, it is a multi-criteria decision-making (MCDM) problem that can be measured by both qualitative and quantitative factors. Furthermore, the utilization of qualitative criteria for such evaluation is influenced by fuzziness, primarily owing to the intrinsic uncertainty in assessing qualitative criteria. In such a case, fuzzy logic combined with MCDM methods can be a useful approach in dealing with the vagueness associated with experts' subjective judgments while analyzing MCDM problems (Busi and Bititci, 2018; Chatterjee and Kar, 2016, 2018; Dania *et al.*, 2022). Therefore, this study has developed a hybrid MCDM model using a combination of FAHP and FTOPSIS to evaluate and rank the performance of hospitals from a sustainability perspective. Fuzzy AHP is used to obtain the importance weights of the identified criteria and perspectives, and fuzzy TOPSIS is used to compute the sustainable performance of each alternative and select the best-performing hospital in a specific context. As such, the sustainability evaluation framework can be used in determining the benchmark scorecard of the hospitals. This scorecard may show a hospital's sustainability performance compared to the hospital that ranks higher. Finally, this study presents a case study based on data from six leading Moroccan hospitals to reveal the applicability of the proposed framework.

The novelty and uniqueness of the methodology are as follows: (1) It integrates TBL criteria with the SBSC method to develop an integrated framework that allows a holistic and comprehensive assessment of all aspects of sustainability in a hospital context. (2) It develops a system that enables the aggregation of diverse categories of economic, environmental and social evaluation criteria with different units and provides useful and interpretable results for evaluating and comparing hospitals' sustainability performance under uncertain conditions. Thus, the model proposed herein will provide healthcare managers with decision-making tools that can help them detect significant areas that require enhanced strategies to achieve improved levels of sustainability in their hospitals.

The remainder of this paper is organized as follows. Section 2 covers the literature review associated with the present research. The developed hybrid fuzzy MCDM model, including fuzzy Delphi, fuzzy AHP and fuzzy TOPSIS methods, is depicted in Section 3. Section 4 explains the usefulness and applicability of the developed framework by means of a case study. A discussion of the results, results comparison, sensitivity analysis and managerial implications, respectively, constitute Section 5, Section 6, Section 7 and Section 8. The paper's conclusion highlights the scope for future related research.

2. Literature review

A well-structured literature review of previous studies in this field is necessary to identify research developments and gaps. Research papers related to this study from 2001 to 2022 were collected from various databases, such as Scopus and Emerald. The keywords used for paper selection were "Sustainable healthcare," "Hospital performance evaluation," "Sustainability evaluation," "SBSC" and "MCDM techniques." The search was refined by considering only articles written in English. Then, these keywords were investigated in the abstract and main text of published studies. Thus, relevant articles were analyzed for their contributions to this work. From the relevant articles retrieved, an in-depth analysis and discussion were performed in the following subsections.

2.1 Performance evaluation in hospitals

Healthcare structures play a crucial role in protecting and promoting public health; however, they are also acknowledged as intensive consumers of natural resources and major sources of environmental degradation. Therefore, it is paramount that healthcare organizations work toward sustainability to address the environmental and social challenges that public health systems face and to achieve optimal performance. To improve sustainability, it is essential to assess the organization's sustainability performance. In recent times, sustainability evaluation has become one of the most widely discussed issues in the area of performance management. Various sustainability performance assessment frameworks have been developed in numerous studies; however, little attention has been paid to the healthcare industry and to hospitals in particular (Hussain *et al.*, 2018). The evaluation of sustainability performance in hospitals is still in its infancy, and the majority of the research carried out in this field focuses on specific areas, such as environmental performance, service quality, patient satisfaction, cost management, productivity and efficiency (Ansari *et al.*, 2019; Blass *et al.*, 2017; Miszczynska and Miszczyński, 2022; Pasqualini *et al.*, 2016; Sumaedi *et al.*, 2016a, b). For example, Pink *et al.* (2001) have considered hospital performance evaluation from four perspectives: patient satisfaction, clinical utilization and outcomes, financial performance, and system integration and change. Karra and Papadopoulos (2005) have studied hospital performance from different viewpoints and proposed four dimensions to establish a scorecard for hospitals, which includes management, stakeholder, internal process, and learning and growth. In another study, Rouyendegh *et al.* (2019) have employed the FAHP method to refine the computation results of a DEA model in hospital efficiency evaluation. Similarly, Omrani *et al.* (2018) have studied the efficiency of Iran's hospitals using a hybridization method that integrates the cooperative game approach and DEA method. Irwandy *et al.* (2020) have provided a methodology to assess the productivity and efficiency of Indonesian hospitals based on the frontier analysis approach. Elsewhere, an extensive framework using a combination of the fuzzy set theory and key performance indicators has been proposed for assessing the financial performance of hospitals (Muriana *et al.*, 2016). Pink *et al.* (2007) have defined four determinants to assess hospitals' financial performance: profitability, liquidity, capital, and efficiency and human resources. Davis *et al.* (2013) have considered the three dimensions of equity, effectiveness and efficiency to evaluate and rank 35 public hospitals in New Zealand during the period of 2001–2009. Gholamzadeh Nikjoo *et al.* (2013) present another study in which they have considered access equity, quality effectiveness and efficiency financing as the three major areas to evaluate hospital performance. Amiri *et al.* (2020) have formed a new hybrid model of fuzzy preference programming and the best-worst method (BWM) to evaluate the performance of Iranian hospitals under the fuzzy environment, which considers five criteria: bed occupancy, number of patients, number of patient beds, Length of stay and bed turnover. Recently, Gartner and Lemaire (2022) have conducted a literature review to identify the different dimensions of hospital performance used over the past decade. The authors have found nine dimensions, including access to care, effectiveness, efficiency, characteristics of staff, quality, safety, research process and innovation, appropriateness, and continuity and coordination. Pasqualini *et al.* (2016) have formed a new framework to assess the environmental performance of hospitals using literature review, actual legislation and feedback from field studies. Similarly, Blass *et al.* (2017) have defined the most relevant indicators for measuring and reporting the environmental performance of Brazilian hospitals based on a process approach. Akdag *et al.* (2014) have utilized a combination of fuzzy MCDM techniques and Yager's min-max method to assess the service quality of some Turkish hospitals. Chang's work has studied the evaluation of service quality of Taiwan's hospitals based on fuzzy VIseKriterijumska Optimizacija I Kompromisno Resenje (FVIKOR) technique (Chang, 2014). Similarly, Fei *et al.* (2020) have considered 33 different performance indicators to assess hospital service quality and categorized them under six main dimensions: hospital equipment, service attitude, pharmacy and medical treatment, professional capability, administrative policy, and hospital sanitation and environment. Additionally, more studies focusing on evaluating patient satisfaction in hospital settings have been conducted by Black *et al.* (2021), Graham (2016), Radu *et al.* (2022) and Sumaedi *et al.* (2016a). These research works are summarized in Table 1.

A review of the literature shows that significant research has been focused on the economic and environmental dimensions of sustainability, but the social aspect has been given less attention. Yet, the primary goal of sustainability is grounded in the concept of TBL, which in turn, requires the full and equal involvement of social, economic and environmental dimensions. In this vein, Hussain *et al.* (2018) have highlighted the gap in the current literature on issues surrounding the consideration of social parameters in the overall sustainability evaluation of healthcare organizations. Thus, there is a need to shift traditional and single-dimension-oriented performance evaluation methods to a more systematic framework that satisfies the requirements of the various stakeholders in hospitals.

Researcher (Year)	Dimensions of sustainability			Solution methodology/ Technique used	Application
	Economic	Environmental	Social		
Pink *et al.* (2001)	✓			BSC	Hospitals in Ontario
Karra and Papadopoulos (2005)	✓			BSC	Public hospitals in Greece
Pink *et al.* (2007)	✓			BSC	Hospitals in Ontario
Davis *et al.* (2013)	✓		✓	BSC	Public hospitals in New Zealand
Gholamzadeh Nikjoo *et al.* (2013)	✓		✓	BSC	Public hospitals in Iran
Akdag *et al.* (2014)	✓	✓		Hybrid MCDM	Turkish hospitals
Chang (2014)	✓			FVIKOR	Taiwan's hospitals
Muriana *et al.* (2016)	✓			Fuzzy sets	Hospitals in Italy
Pasqualini *et al.* (2016)		✓			Brazilian hospitals
Sumaedi *et al.* (2016a)	✓			Structural equation modeling	Indonesian healthcare institutions
Blass *et al.* (2017)		✓		Process approach	Brazilian hospitals
Omrani *et al.* (2018)	✓			Cooperative game approach and DEA	Iran's hospitals
Ansari *et al.* (2019)	✓	✓		Environmental performance index	Hospitals from India, China, Pakistan, Brazil and Iran
Rouyendegh *et al.* (2019)	✓			FAHP and DEA	Turkish hospitals
Amiri *et al.* (2020)	✓			Fuzzy preference programming and the BWM	Iranian hospitals
Fei *et al.* (2020)	✓			Extended BWM	Hospitals in China
Irwandy *et al.* (2020)	✓			DEA	Indonesian public hospitals
Miszczynska and Miszczyński (2022)	✓			DEA	Polish healthcare institutions
This study	✓	✓	✓	SBSC, FDM and hybrid FMCDM	Moroccan public hospitals

Source(s): Authors' own creation

Table 1. Previous works on evaluating the performance of hospitals

2.2 Sustainability evaluation methods

Different models and approaches to evaluate the sustainability performance of organizations have been reported in the literature. One of the main systematic and strategic methods used in this area is the SBSC introduced by Figge *et al.* (2002). SBSC is an effective management technique that allows the incorporation of environmental and social concerns into the performance evaluation system, as well as the improvement of the value-added potentials evolved from social and/or ecological aspects (Bieker and Waxenberger, 2002; Lu *et al.*, 2018). Due to these advantages, it has aroused considerable attention in the field of sustainability performance evaluation (Junior *et al.*, 2018; Lin *et al.*, 2016; Nikolaou and Tsalis, 2013). For example, Hubbard (2009) has developed a conceptual model to measure a firm's organizational performance based on stakeholder theory, SBSC and the organizational sustainability performance index. Although SBSC has some advantages in sustainability assessment issues, two weak points gradually hinder its functionality. First, this approach fails to aggregate multiple performance indicators into a single overall score, which leads to impractical, incomparable and inexpressive results. In addition, the approach is deficient in specifying the relative preferences of different criteria (qualitative and quantitative) and thus objectively assessing performance.

In this case, MCDM methods are integrated with the SBSC framework to address such weaknesses (Rabbani *et al.*, 2014). Ahmad and Wong (2019) have pointed out that the utilization of weighted indicators promotes the maturity level of sustainability assessment because it is more convenient to provide a generic model with weighted sustainability indicators that are specific to the type of industry and the economic development of a country. Moreover, many authors have recommended enhancing the SBSC model with MCDM approaches (Lu *et al.*, 2018; Salomon *et al.*, 2015) to increase the accuracy of the evaluation framework, as sustainability assessment models embed indicators that are often in conflict with one another (Hsu *et al.*, 2011; Rabbani *et al.*, 2014). For instance, Hsu *et al.* (2011) have proposed a framework for measuring the sustainable performance of the semiconductor industry in Taiwan based on the combination of SBSC, fuzzy Delphi and analytic network process (ANP) methods. Later, Rabbani *et al.* (2014) have constituted a new method for sustainable performance evaluation of oil-producing companies using SBSC, ANP and complex proportional assessment (COPRAS) techniques. Recently, Raut *et al.* (2017) have established a conceptual framework for assessing the achievement of sustainable development objectives in banking services, which combines fuzzy AHP, fuzzy TOPSIS and the BSC model. Lu *et al.* (2018) have designed a decision framework for evaluating the sustainability performance of international airports by combining the SBSC, DEMATEL-based ANP and VIKOR models.

After examining the relevant literature, it was inferred that no earlier study has addressed the simultaneous integration of the economic, environmental and social dimensions into the SBSC model to evaluate sustainability performance in hospitals. In addition, no prior attempt has been made to develop a hospital's sustainability evaluation framework by combining the SBSC approach with fuzzy MCDM tools. Thus, the present study sought to fill these gaps by developing a fuzzy decision tool to evaluate the comprehensive performance of hospitals according to TBL by integrating the fuzzy Delphi, fuzzy AHP and FTOPSIS methods along with the SBSC approach.

3. Methods

3.1 The proposed methodology

In this section, the proposed methodology for evaluating the sustainability performance of hospitals based on the SBSC model, fuzzy Delphi technique and fuzzy hybrid MCDM methods is introduced in detail. As seen in Figure 1, the analytical structure of the new

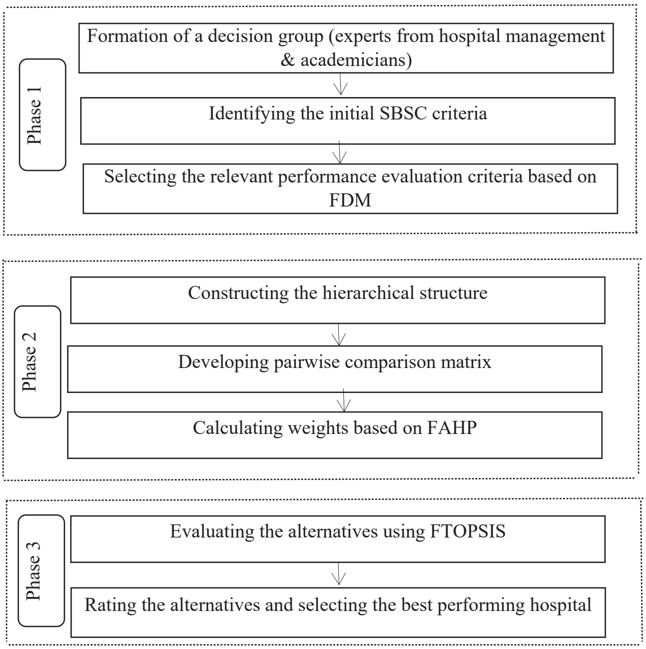

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Figure 1. Schematic diagram of the proposed performance evaluation framework

approach is divided into three phases: (1) identifying the relevant hospitals' performance evaluation criteria based on SBSC and fuzzy Delphi approach, (2) determining the weights of evaluation criteria and perspectives through fuzzy AHP and (3) ranking the performance values of hospitals using fuzzy TOPSIS. In the first phase, the initial evaluation criteria influencing the sustainable performance of hospitals have been identified through an extensive literature review and consultations with experts in the field. A total of 34 criteria covering six perspectives have been retrieved (Table 2). Since the collected criteria are numerous, and the experts are not capable of handling pairwise comparisons with several elements in FAHP, it is recommended to recognize the most relevant factors that affect and expedite the progress toward sustainability for hospitals. Thus, the fuzzy Delphi technique is used for screening the appropriate criteria for our model. In the second phase, FAHP is employed to obtain the relative importance weights of all levels of the hierarchical structure. The weights obtained from the second phase are used as inputs in the fuzzy TOPSIS model. Finally, according to the results of the FTOPSIS method, hospitals are ranked in descending order of performance, and the best one is identified. A detailed description of the steps for each model is as follows.

3.2 Fuzzy Delphi method

The fuzzy Delphi approach is a combination of the Delphi technique and fuzzy set theory and was first developed by Ishikawa to address the ambiguity of the traditional model (Murray *et al.*, 1985). It is widely used to obtain expert judgments on each criterion's significance level through questionnaire survey. In this study, the FDM is employed to refine the valid criteria affecting sustainability performance in hospitals. Triangular fuzzy numbers (TFNs) are used as membership functions to handle fuzziness in the common understanding between experts

SBSC perspectives	Initial evaluation criteria	References
Financial (D1)	Personnel expenses (IC1)	(Pink *et al.*, 2007; Regragui *et al.*, 2018)
	Material cost (IC2)	Regragui *et al.* (2018)
	Investment costs (IC3)	(Grigoroudis *et al.*, 2012; Pink *et al.*, 2001)
	Revenue (IC4)	(Grigoroudis *et al.*, 2012; Gurd and Gao, 2007)
	Liquidity (IC5)	(Grigoroudis *et al.*, 2012; Pink *et al.*, 2001, 2007)
	Debt (IC6)	(Grigoroudis *et al.*, 2012; Karra and Papadopoulos, 2005)
Stakeholder (D2)	Patient satisfaction (IC7)	(Grigoroudis *et al.*, 2012; Lucadamo *et al.*, 2020; Radu *et al.*, 2022; Regragui *et al.*, 2018)
	Patient retention (IC8)	Gurd and Gao (2007)
	Acquisition of new patients (IC9)	Gurd and Gao (2007)
	Employee satisfaction (IC10)	(Grigoroudis *et al.*, 2012; Karra and Papadopoulos, 2005)
	Market share (IC11)	Trotta *et al.* (2013)
Internal business process (D3)	Efficiency (IC12)	(Gurd and Gao, 2007; Irwandy *et al.*, 2020; Ramanathan and Ramanathan, 2011; Rouyendegh *et al.*, 2019)
	Effectiveness (IC13)	(Davis *et al.*, 2013; Grigoroudis *et al.*, 2012; Ramanathan and Ramanathan, 2011)
	Resource utilization (IC14)	(Grigoroudis *et al.*, 2012; Gurd and Gao, 2007)
	Time intervals (IC15)	(Karra and Papadopoulos, 2005; Moons *et al.*, 2019; Regragui *et al.*, 2018)
	Flexibility (IC16)	Purbey *et al.* (2007)
	Use of information technology (IC17)	Purbey *et al.* (2007)
Learning and Growth (D4)	Employee training (IC18)	(Grigoroudis *et al.*, 2012; Regragui *et al.*, 2018)
	Research and development (IC19)	(Grigoroudis *et al.*, 2012; Regragui *et al.*, 2018)
	Technological growth (IC20)	(Grigoroudis *et al.*, 2012; Regragui *et al.*, 2018)
	Collaboration with other institutions (IC21)	(Grigoroudis *et al.*, 2012; Karra and Papadopoulos, 2005)
Environmental (D5)	Water consumption (IC22)	(Blass *et al.*, 2017; Pasqualini *et al.*, 2016; Romero, 2017)
	Energy consumption (IC23)	(Blass *et al.*, 2017; Pasqualini *et al.*, 2016)
	Materials consumption (IC24)	(Blass *et al.*, 2017; Pasqualini *et al.*, 2016)
	Transport (IC25)	(Pasqualini *et al.*, 2016; Romero, 2017)
	Waste production (IC26)	(Blass *et al.*, 2017; Pasqualini *et al.*, 2016; Romero, 2017)
	Accidents or environmental incidents (IC27)	Pasqualini *et al.* (2016)
	Green purchasing (IC28)	(Pasqualini *et al.*, 2016; Romero, 2017)
	Noise inside/outside the hospital (IC29)	(Pasqualini *et al.*, 2016; Romero, 2017)
Social (D6)	Access to care (IC30)	(Grigoroudis *et al.*, 2012; Ramanathan and Ramanathan, 2011)
	Safety and health of patient (IC31)	(Grigoroudis *et al.*, 2012; Hussain *et al.*, 2018)
	Safety and health of employees (IC32)	Gurd and Gao (2007)
	Well-being of employees (IC33)	(Hussain *et al.*, 2018; Karra and Papadopoulos, 2005)
	Philanthropy (IC34)	Hussain *et al.* (2018)

Source(s): Authors' own creation

Table 2.
Extensive summary of initial evaluation criteria of a sustainability balanced scorecard emphasized by selected references

when making group decisions. The basic definition and arithmetic operations of TFN are further explained in Sabaghi *et al.* (2016). In TFN, the three points of a symmetric triangle, i.e. the left, middle and right points of the base of a triangle, indicate each membership function (see Figure 2). The lower (l) and upper (u) bounds are the highest maximum and lowest values of the fuzzy number, respectively. The value of m is the most probable value of fuzzy numbers.

The FDM procedure is as follows:

Step 1: Collecting opinions from decision groups. For the selection of relevant appraisal criteria, expert groups, including managers and academic professionals, were invited to score the degree of importance of each criterion through a questionnaire using the linguistic variables depicted in Table 3.

Step 2: Establishing TFNs. Transform the linguistics variables gathered from questionnaires to fuzzy numbers, as suggested in Table 3. This study uses the geometric mean method to obtain agreement with group decisions. The procedure is as follows:

$$\widetilde{w}_j = (l_j, m_j, u_j) \tag{1}$$

$$l_j = \min\{l_{ij}\}, i = 1, \ldots, n; j =, \ldots, m \tag{2}$$

$$m_j = \left(\prod_{i=1 j=1}^{n,m} m_{ij} \right)^{1/n} i = 1, \ldots, n; j =, \ldots, m \tag{3}$$

$$u_j = \max\{u_{ij}\}, i = 1, \ldots, n; j =, \ldots, m \tag{4}$$

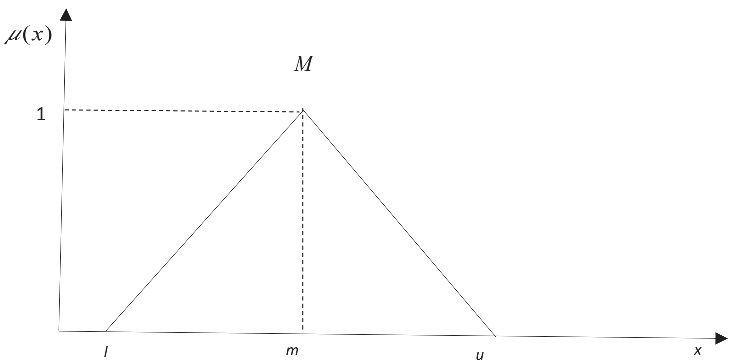

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Figure 2. Membership function of the TFN

Table 3. Linguistic variables and triangular fuzzy numbers

Linguistic variables	Triangular fuzzy numbers
Very Important (VI)	(0.75, 1.00, 1.00)
Important (I)	(0.50, 0.75, 1.00)
Moderately Important (MI)	(0.25, 0.50, 0.75)
Some Important (SI)	(0.00, 0.25, 0.50)
Not Important (NI)	(0.00, 0.00, 0.25)

Source(s): Authors' own creation

where in $\widetilde{w}_j$ is the fuzzy weighting of element j given by expert i; n is the number of experts; m is the number of indicators; l_{ij}, m_{ij} and u_{ij} define the bottom, geometric mean and ceiling, respectively, of all the experts' appraisal values for indicator j.

Step 3: Conducting the process of defuzzification. The center of gravity method is used to defuzzify the fuzzy weight $\widetilde{wj}$ of each evaluation indicator, where S_j denotes the crisp value. It is determined as follows:

$$S_j = \frac{l_j + m_j + u_j}{3} j = 1, \ldots, m \quad (5)$$

Step 4: Selecting the relevant appraisal criteria. The important criteria for the performance evaluation of hospitals are screened by comparing the weights of each criterion with the threshold α. The value of α is fixed by experts according to the 20/80 rule, and it is set to 0.7. The screening principles are described as follows:

If $S_j \geq \alpha$, then the criterion j is accepted.

If $S_j < \alpha$, then the criterion j is rejected.

3.3 Fuzzy AHP

The AHP methodology, devised by Saaty (1977), has been recognized by the international scientific community as a powerful and flexible MCDM technique (Lombardi *et al.*, 2021) to deal with complex decision situations. This technique helps to organize and structure complicated, multi-person and multi-attribute problems hierarchically and determines the relative importance weights of various parameters and decision factors based on pairwise comparisons provided by a group of decision-makers. Despite the universality of AHP, it has been criticized by numerous scholars for its deficiency in handling the uncertainty and vagueness of personal subjective judgments and preferences (Belhadi *et al.*, 2017; Kumar *et al.*, 2022b; Silva Júnior *et al.*, 2022). To address this issue, an integration of fuzzy theory with AHP, known as fuzzy AHP, has been developed as a way of solving the weaknesses of hierarchical fuzzy problems and improving it further to provide a more accurate judgment during the decision-making process (Sharfuddin Ahmed Khan *et al.*, 2019). Thus, fuzzy AHP has been extensively used in a diverse array of decision-making situations, such as hospital quality assessments (Torkzad and Beheshtinia, 2019), university performance measurement (Zangoueinezhad and Moshabaki, 2011), medical staff scheduling (Chen *et al.*, 2016) and project prioritization in portfolio management (Chatterjee *et al.*, 2018). In particular, it has been successfully employed to cope with the vague nature of sustainability assessment problems (Liu *et al.*, 2019; Raut *et al.*, 2017). The present study proposes the application of FAHP to structure the problem of hospitals' sustainability evaluation in a hierarchical manner and determine the importance weights of the sustainable criteria and sub-criteria. The fuzzy extension of the AHP approach suggested by Chang (1996) is preferred when compared to other FAHP approaches due to the simplicity of its implementation and its similarity to the conventional AHP. The steps of this phase are as follows:

Step 1: Building a hierarchical model for a sustainable performance evaluation system for hospitals. The problem should be stated clearly and broken down into a rational hierarchy of interrelated elements (criteria and sub-criteria). At the highest level of the hierarchy, we find the goal, while the elements contributing to obtaining the goal are set at lower levels.

Step 2: Formulating pairwise comparison of all the sustainability criteria and the SBSC perspectives. Through expert questionnaires, each expert is asked to assign linguistic terms by TFN (as shown in Table 4) to the pairwise comparisons by selecting which of the two criteria is more important, as in the following matrix A.

$$A = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ x_{n1} & a_{n2} & \dots & 1 \end{bmatrix} \tag{6}$$

where

$$A_{ij} = \begin{cases} 1 & i = j \\ 1, 3, 5, 7, 9 \; or \dots 1^{-1}, 3^{-1}, 5^{-1}, 7^{-1} 9^{-1} & i \neq j \end{cases}$$

Step 3: Calculating the weights of the perspectives and criteria through Chang's extent analysis FAHP method (Chang, 1996). The steps of the extent analysis are given as follows:

According to Chang's method, each object is taken, and an extent analysis for each goal is performed, respectively. Consequently, m extent analysis values for each object can be attained with the following notation: $M_{gi}^1, M_{gi}^2, \dots, M_{gi}^m, i = 1, 2, 3, \dots, n$ where all the $M_{gi}^j (j = 1, 2, \dots, m.)$ are TFNs.

The fuzzy synthetic extent value with respect to the ith object is defined as

$$S_i = \sum_{j=1}^{m} M_{gi}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j \right]^{-1} \tag{7}$$

To obtain $\sum_{j=1}^{m} M_{gi}^j$, the fuzzy addition operation of m extent analysis values for a particular matrix is performed such that

$$\sum_{j=1}^{m} M_{gi}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \tag{8}$$

and the value of $[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi}^j]^{-1}$ is obtained by performing the fuzzy addition operation of M_{gi}^j (j = 1, 2, . . ., m) as

Linguistic variable	Fuzzy number	Triangular fuzzy number (TFN)
Equal importance	$\tilde{1}$	(1, 1, 1)
Moderate importance	$\tilde{3}$	(2, 3, 4)
Strong importance	$\tilde{5}$	(4, 5, 6)
Very strong importance	$\tilde{7}$	(6, 7, 8)
Extreme importance	$\tilde{9}$	(8, 9, 10)

Source(s): Authors' own creation

Table 4. Linguistic parameters and TFNs

$$\sum_{i=1}^{n}\sum_{j=1}^{m}M_{gi}^{j}=\left(\sum_{i=1}^{n}l_i,\sum_{i=1}^{n}m_i,\sum_{i=1}^{n}u_i\right) \tag{9}$$

Then the inverse of the above vector is calculated as follows:

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m}M_{gi}^{j}\right]^{-1}=\left(\frac{1}{\sum_{i=1}^{n}u_i},\frac{1}{\sum_{i=1}^{n}m_i},\frac{1}{\sum_{i=1}^{n}l_i}\right) \tag{10}$$

The possibility degree of $M_2=(l_2,m_2,u_2)\geq M_1=(l_1,m_1,u_1)$ is expressed as follows:

$$V_{(M_2\geq M_1)}=\sup_{y\geq x}\left[\min\left(\mu_{M_1}(x),\mu_{M2}(y)\right)\right] \tag{11}$$

and can be also expressed as follows:

$$V(M_2\geq M_1)=\mu_{M_2}(d)=\begin{cases}1, & \text{if} m_2\geq m_1,\\ 0, & \text{if}, l_1\geq u_2,\\ \dfrac{l_1-u_2}{(m_2-u_2)-(m_1-l_1)}, & \text{Otherwise}\end{cases} \tag{12}$$

where d is the ordinate of the highest intersection point D between μ_{M_2} and μ_{M_2} as shown in Figure 3.

The values of $V(M_2\geq M_1)$ and $V(M_1\geq M_2)$ must be calculated in order to compare M_1 and M_2.

The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i(i=1,2,\ldots,k)$ is determined by

$$V(M\geq M_1,M_2,\ldots,M_k)=V[(M\geq M_1)and(M\geq M_2)and\ldots and(M\geq M_k)]$$
$$=\min V(M\geq M_i), i=1,2,3,\ldots,k$$

$$\text{Assume that } d'(A_i)=\min V(S_i\geq S_k) \text{ for } k=1,2,\ldots,n;\ k\neq i. \tag{13}$$

Then, the weight vector is given by $W'=(d\prime(A_1),d\prime(A_2),\ldots,d\prime(A_n))^T$, where $A_i(i=1,2,,\ldots,n)$ are the n elements.

The weight vectors after normalization are defined as

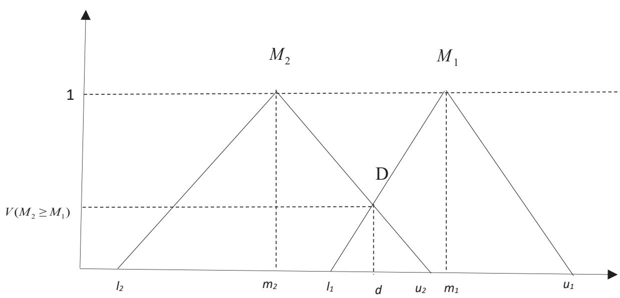

Figure 3. The intersection of the triangular fuzzy numbers M1 and M2

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$$W = (d(A_1), d(A_2), \ldots, d(A_n))^T$$

where W is a non-fuzzy number.

3.4 Fuzzy TOPSIS

The FTOPSIS technique, initially developed by Hwang and Yoon (1981), is a classical MCDM approach and is largely used for ranking and/or sorting solutions from a finite pool of alternatives. The underlying logic of this method is based on the principle that a selective alternative should simultaneously have the shortest distance from the fuzzy positive ideal solution (FPIS) and the furthest distance from the fuzzy negative ideal solution (FNIS) (Kumar *et al.*, 2022a). This study uses the FTOPSIS method developed by Chen (2000) to rank the sustainability performance values of different hospitals and, therefore, select the most sustainable hospital among the determined current alternatives in a fuzzy environment. The FTOPSIS stages are outlined as follows:

Step 1: Determining the weights of the evaluation criteria, which have already been determined in the previous step using FAHP.

Step 2: Constructing the fuzzy decision matrix (D).

Let $A = \{A_i \backslash i = 1, \ldots, m\}$ be m possible alternatives that are evaluated against n criteria $C = \{C_j \backslash j = 1, \ldots, n\}$ by a group of K experts $(E_1, E_2, \ldots, E_k)$.

The fuzzy decision matrix (D) is constructed as follows:

$$D = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{14}$$

where x_{ij} is the rating of the alternative A_i against criteria C_j, and $W = [w_1, w_2, \ldots, w_n]$ is the set of weights of the criteria C_j. Using the triangle Fuzz number, the linguistic variables can be illustrated as $x_{ij} = (a_{ij}, b_{ij}, c_{ij})$.

Step 3: Aggregating the weights of ratings of alternatives.

We consider the fuzzy ratings of the Kth decision-maker x_{ijK} as a TFN $(a_{ijK}, b_{ijK}, c_{ijK})$ then the aggregated fuzzy weights of alternatives with respect to each criterion are denoted by $x_{ij} = (a_{ij}, b_{ij}, c_{ij})$ and can be determined as follows:

$$a_{ij} = \min_N\{a_{ijk}\}, b_{ij} = \sqrt{\prod_{n=1}^{N} b_{ijk}}, c_{ij} = \max_N\{c_{ijk}\}, \tag{15}$$

Step 4: Normalizing the fuzzy decision matrix.

The normalized fuzzy decision matrix denoted by R is expressed as follows:

$$R = [r_{ij}]_{m \times n} \tag{16}$$

$$r_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \tag{17}$$

and $c_j^* = \max c_{ij}$ (benefit criteria)

$$r_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \tag{18}$$

and $a_j^- = \min a_{ij}$ (cost criteria).

Step 5: Constructing weighted fuzzy normalized decision matrix.

$$V = [v_{ij}]_{m \times n} = r_{ij} \otimes w_j, i = 1, 2, 3, \ldots, m; j = 1, 2, 3, \ldots, n. \tag{19}$$

where w_j is the weight of the criteria j.

Step 6: Determining the FPIS and the FNIS, according to the following equations:

$$FPIS = A^+ = \{v_1^+, \ldots, v_n^+\}, \text{ where } v_j^+ = \{\max(v_{ij}) if j \in J; \min(v_{ij}) if j \in J'\}, \quad j = 1, 2, 3, 4, 5, \ldots, n \tag{20}$$

$$FNIS = A^- = \{v_1^-, \ldots, v_n^-\}, \text{ where } v_j^- = \{\min(v_{ij}) if j \in J; \min(v_{ij}) if j \in J'\}, \quad j = 1, 2, 3, 4, 5, \ldots, n \tag{21}$$

Step 7: Calculating the distance of each alternative from the fuzzy positive and negative ideal solutions.

The distance of each alternative from FPIS (d_i^+) and FNIS (d_i^-) is calculated, respectively, as follows:

$$d_i^+ = \sum_{j=1}^{n} d\left(v_{ij}, v_j^+\right), i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \tag{22}$$

$$d_i^- = \sum_{j=1}^{n} d\left(v_{ij}, v_j^-\right), i = 1, 2, \ldots, m; j = 1, 2, \ldots, n \tag{23}$$

where $d(.,.)$ express the distance between the two fuzzy numbers. For TFNs, it is computed as in Eq. (24).

$$d(x, y) = \sqrt{\frac{1}{3}\left[(a_x - a_y)^2 + (b_x - b_y)^2 + (c_x - c_y)^2\right]} \tag{24}$$

Step 8: Computing the closeness coefficient (CC_i) of each alternative using the following equation:

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad i = 1, 2, \ldots, m \tag{25}$$

Step 9: Ranking the alternatives.

The alternatives are ranked according to the CC_i in a descending order. In other words, the best alternative is the one with the maximum CC_i.

4. Application of the proposed methodology

Recently, the Moroccan Ministry of Health has signed a cooperation strategy with the World Health Organization to adhere to a sustainable development approach in response to the increasing awareness of environmental and social issues. This approach leads to the integration of sustainable development initiatives into the strategies of the Moroccan health system. For an efficient implementation approach, hospital decision-makers (DMs) must focus on factors that have more influence on sustainable development. In the present study, we propose a methodology that prioritizes important criteria that will foster the transition to sustainability, as well as tools to monitor and compare performance from a new perspective of sustainable development. Thus, hospitals would be encouraged to improve their performance to achieve a "sustainable hospital." To demonstrate the applicability of the proposed evaluation framework, six metropolitan public hospitals in Morocco (five university hospital centers and one regional hospital center) are chosen as empirical examples because they are leading Moroccan hospitals in the healthcare sector. In the following sections, we present an application of the three phases of the developed methodology.

4.1 Identifying the relevant evaluation criteria

In the first step, a questionnaire was sent to 20 experts to screen for relevant criteria. Of the 20 distributed questionnaires, 18 were completed and returned. The panel of experts was carefully selected and consists of four hospital directors, three heads of administrative affairs departments, two hospital and ambulatory care managers of the Ministry of Health, four occupational health and safety managers, three environmental managers and two academicians. All selected experts have at least ten years of work experience and adequate knowledge of performance evaluation and sustainability. The experts were interviewed face to face, and the responses were processed using the FDM technique. Subsequently, these indicators were grouped into six perspectives: financial, stakeholder, internal business process, learning and development, environmental, and social. Table 5 presents the results of the selected evaluation criteria for measuring the sustainability performance of hospitals.

4.2 Determining the weights of evaluation criteria and perspectives through fuzzy AHP

After identifying the relevant criteria from the previous step, a hierarchical structure was established. The structure of the decision problem contains three levels: as shown in Figure 4, "selecting the best performing hospital" is considered the main goal and placed at the highest level; in the second level, six perspectives are listed; and in the third level, 24 performance criteria fitting every perspective are introduced. After creating the hierarchical structure, pairwise comparisons of these perspectives and performance criteria were performed via questionnaires distributed to nine experts: four hospital directors, three heads of administrative affairs departments and two academicians with background knowledge in healthcare management and sustainable development. The experts were requested to express their preferences regarding the relative importance weight of each perspective and criterion, using the linguistic variables included in Table 6. After gathering the questionnaires, group decision-making was utilized to avoid any decision-maker bias during the decision process. Thus, this method aggregates multiple assessments into a single TFN to synthesize multiple opinions. Table A1 in Appendix displays the evaluation of the perspectives with respect to the goal. Table A2 in Appendix displays the evaluation of criteria with respect to the financial perspective, whereas Table A3 in Appendix shows the evaluation of criteria with respect to the stakeholder perspective. Similarly, Tables A4–A7 in Appendix display pairwise comparisons with respect to perspectives such as financial, internal process, learning and growth, environmental, and social perspectives, respectively. The final results of the fuzzy AHP methodology are reported in Table 6, based on which we can conclude that the most important criterion is "Stakeholders perspective (0.196)" followed by "Internal business process (0.189)," "Environmental perspective (0.171)," "Social

Table 5. Fuzzy Delphi analysis results of evaluation criteria

Perspectives	Criteria	Fuzzy calculation Min	Geometric mean	Max	S_j	Accepted/ Rejected
Financial	Personnel expenses	0.5	0.85	1	0.78	Accepted
	Material cost	0.5	0.87	1	0.79	Accepted
	Investment costs	0.25	0.85	1	0.70	Accepted
	Revenue	0.5	0.85	1	0.78	Accepted
	Liquidity	0	0.28	0.5	0.26	Rejected
	Debt	0	0.34	0.75	0.36	Rejected
Stakeholder	Patient satisfaction	0.5	0.94	1	0.81	Accepted
	Patient retention	0	0.16	0.75	0.30	Rejected
	Acquisition of new patients	0.5	0.79	1	0.76	Accepted
	Employee satisfaction	0.25	0.85	1	0.70	Accepted
	Market share	0.5	0.77	1	0.76	Accepted
Internal business process	Efficiency	0.5	0.91	1	0.80	Accepted
	Effectiveness	0.5	0.84	1	0.78	Accepted
	Resource utilization	0.5	0.77	1	0.76	Accepted
	Time intervals	0	0.39	0.75	0.38	Rejected
	Flexibility	0	0.32	0.75	0.36	Rejected
	Use of information technology	0.5	0.79	1	0.76	Accepted
Learning and growth	Employee training	0.25	0.85	1	0.70	Accepted
	Research and development	0.5	0.75	1	0.75	Accepted
	Technological growth	0.25	0.77	1	0.67	Rejected
	Collaboration with other institutions	0.5	0.75	1	0.75	Accepted
Environmental	Water consumption	0.5	0.79	1	0.76	Accepted
	Energy consumption	0.5	0.77	1	0.76	Accepted
	Materials consumption	0.25	0.89	1	0.71	Accepted
	Transport	0	0.35	0.75	0.37	Rejected
	Waste production	0.5	0.91	1	0.80	Accepted
	Accidents or environmental incidents	0	0.38	0.75	0.38	Rejected
	Green purchasing	0	0.45	1	0.48	Rejected
	Noise inside/outside the hospital	0	0.45	1	0.48	Rejected
Social	Access to care	0.5	0.88	1	0.79	Accepted
	Safety and health of patient	0.5	0.81	1	0.77	Accepted
	Safety and health of employees	0.25	0.86	1	0.70	Accepted
	Well-being of employees	0.25	0.84	1	0.70	Accepted
	Philanthropy	0.25	0.85	1	0.70	Accepted

Source(s): Authors' own creation

perspective (0.162)" and "Financial perspective (0.151)." In the next level, it is seen that "Patient satisfaction (C5)" has the maximum weightage value (0.08016) and has been considered the most important criterion in the overall performance of hospitals. This is followed by "Efficiency (0.07673)," "Effectiveness (0.06728)," "Access to care (0.05621)," "Waste production (0.05605)" and "Use of information technology (0.00151)," which has the weakest weightage value.

4.3 Ranking alternatives using fuzzy TOPSIS

In the following step, three DMs (head doctors in hospitals) were selected to evaluate six renowned metropolitan public hospitals in Morocco. To evaluate the level of performance in

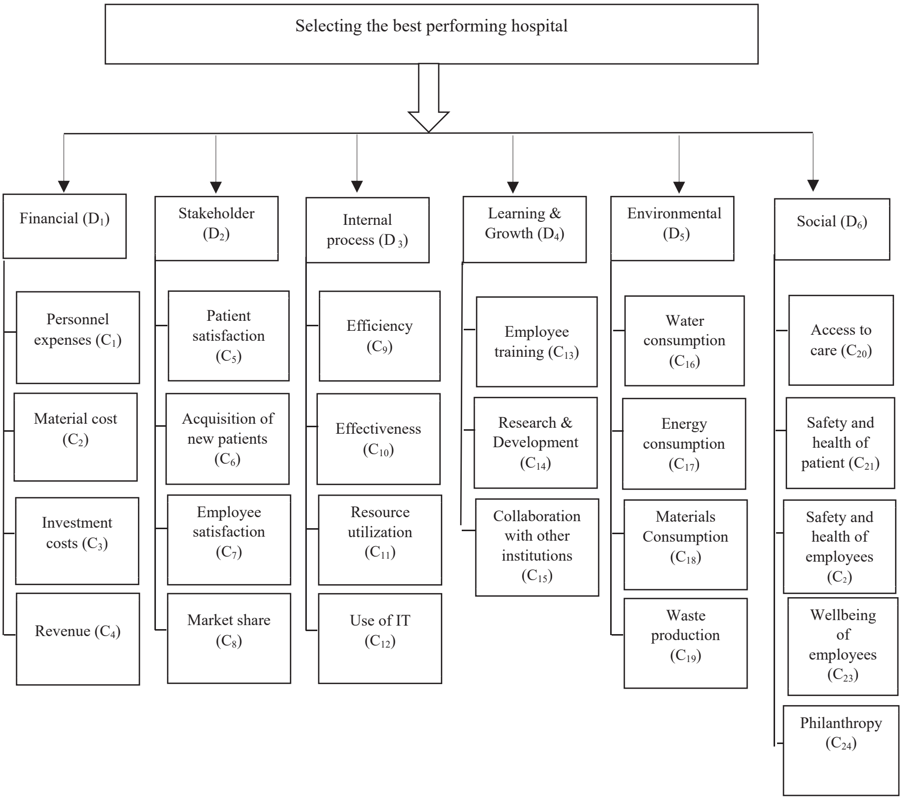

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Figure 4.
Hierarchical framework of performance criteria of an SBSC

each hospital, DMs were asked to assign linguistic variables to each hospital in terms of this indicator. The linguistic variables used for the alternatives' ratings are as follows: {Very good (7, 9, 9), Good (5, 7, 9), Fair (3, 5, 7), Poor (1, 3, 5), and Very poor (1, 1, 3)}. Subsequently, the linguistic terms were converted into fuzzy triangular numbers. Using Eq. (15), we combined the individual fuzzy matrix of all DMs to obtain the aggregated fuzzy decision matrix, and the results are presented in Table 7. The fuzzy decision matrix of the alternatives has been normalized using Eqs. (17) and (18) and is presented in Table 8.

In the next step, the weighted normalized fuzzy decision matrix was computed using Eq. (19) and the weights of the criteria. The fuzzy weighted decision matrix is shown in Table 9. Consequently, the FPIS and the FNIS of each criterion are defined based on Eqs. (20) and (21), respectively. Then, the distance of each alternative from the FPIS and FNIS, in accordance with each criterion, is calculated using Eq. (24). FPIS (A^+) and FNIS (A^-) are defined as $\tilde{v}^+ = (1, 1, 1)$ and $\tilde{v}^- = (0, 0, 0)$, respectively, for all criteria. Table 10 summarizes the results.

The Closeness Coefficient (CC) of each alternative was calculated using Eq. (25). Finally, as seen in Table 11, the CC_i values of the six hospitals with respect to the 24 evaluation criteria were obtained as (H1 = 0.0269), (H5 = 0.02639), (H6 = 0.0259), (H4 = 0.0255), (H2 = 0.0247) and (H3 = 0.0241), respectively. Regarding the results obtained from Table 11, it can be seen that "Hospital 1" has both the maximum value of the negative ideal solution and the lowest

Perspectives	Weights	Criteria	Local weights	Global weights	Ranking
Financial perspective (D1)	0.151	C1	0.323	0.04877	9
		C2	0.352	0.05315	7
		C3	0.119	0.01796	22
		C4	0.204	0.03080	17
Stakeholder perspective (D2)	0.196	C5	0.409	0.08016	1
		C6	0.222	0.04351	13
		C7	0.233	0.04566	12
		C8	0.134	0.02626	20
Internal business process (D3)	0.189	C9	0.406	0.07673	2
		C10	0.356	0.06728	3
		C11	0.228	0.04309	14
		C12	0.008	0.00151	24
Learning and growth (D4)	0.130	C13	0.422	0.05487	6
		C14	0.367	0.04775	10
		C15	0.210	0.02738	19
Environmental perspective (D5)	0.171	C16	0.217	0.03712	16
		C17	0.163	0.02789	18
		C18	0.292	0.04993	8
		C19	0.327	0.05605	5
Social perspective (D6)	0.162	C20	0.347	0.05621	4
		C21	0.283	0.04584	11
		C22	0.231	0.03742	15
		C23	0.116	0.01879	21
		C24	0.020	0.00324	23

Source(s): Authors' own creation

Table 6.
Summary weights of perspectives and evaluation criteria

Criteria	H1	H2	H3	H4	H5	H6
C1	(3, 6.26, 9)	(3, 5.00, 7)	(3, 5.00, 7)	(3, 5.39, 9)	(3, 5.13, 7)	(3, 5.17, 9)
C2	(3, 6.26, 9)	(3, 6.26, 9)	(3, 5.00, 7)	(1, 5.81, 9)	(1, 5.66, 7)	(3, 5.48, 9)
C3	(3, 5.59, 9)	(3, 5.59, 9)	(1, 3.98, 9)	(1, 4.99, 9)	(1, 4.81, 5)	(1, 4.57, 9)
C4	(1, 3.56, 7)	(3, 5.00, 7)	(3, 6.26, 9)	(3, 5.00, 7)	(3, 6.26, 9)	(3, 5.00, 7)
C5	(1, 5.00, 7)	(3, 5.00, 7)	(1, 3.56, 7)	(3, 5.00, 7)	(3, 6.26, 9)	(3, 5.00, 7)
C6	(3, 6.26, 9)	(3, 5.00, 7)	(1, 3.56, 7)	(3, 6.26, 9)	(5, 8.28, 9)	(1, 3.98, 9)
C7	(3, 5.00, 7)	(1, 1.71, 7)	(1, 3.56, 7)	(1, 3.56, 7)	(1, 3.56, 7)	(1, 3.56, 7)
C8	(3, 5.00, 7)	(3, 5.00, 7)	(3, 5.00, 7)	(3, 5.00, 7)	(3, 5.00, 7)	(3, 6.26, 9)
C9	(3, 5.00, 7)	(3, 5.00, 7)	(3, 5.00, 7)	(5, 7.67, 9)	(5, 7.67, 9)	(1, 4.22, 7)
C10	(3, 6.26, 9)	(3, 6.26, 9)	(3, 5.00, 7)	(3, 6.84, 9)	(3, 7.40, 9)	(3, 5.65, 9)
C11	(5, 8.20, 9)	(5, 7.40, 9)	(3, 5.40, 7)	(3, 6.60, 9)	(5, 7.40, 9)	(5, 7.40, 9)
C12	(3, 5.50, 9)	(1, 3.00, 5)	(1, 2.03, 5)	(1, 3.00, 5)	(1, 4.50, 7)	(1, 4.50, 7)
C13	(3, 5.00, 7)	(1, 1.71, 7)	(1, 3.56, 7)	(1, 1.71, 7)	(1, 3.56, 7)	(1, 3.56, 7)
C14	(1, 3.67, 7)	(1, 1.67, 3)	(1, 3.00, 5)	(1, 1.44, 5)	(1, 2.33, 5)	(1, 3.67, 7)
C15	(3, 6.26, 9)	(1, 1.71, 7)	(1, 3.56, 7)	(1, 1.71, 7)	(1, 3.56, 7)	(3, 5.00, 7)
C16	(1, 3.56, 7)	(1, 3.56, 7)	(3, 5.00, 7)	(1, 1.71, 7)	(3, 5.00, 7)	(3, 5.00, 7)
C17	(1, 3.56, 7)	(1, 3.56, 7)	(3, 5.00, 7)	(3, 5.00, 7)	(3, 5.00, 7)	(1, 3.56, 7)
C18	(1, 3.56, 7)	(1, 3.56, 7)	(1, 3.56, 7)	(3, 5.00, 7)	(3, 5.00, 7)	(1, 3.56, 7)
C19	(1, 3.56, 7)	(1, 3.56, 7)	(1, 3.56, 7)	(1, 4.33, 7)	(1, 3.56, 7)	(1, 3.56, 7)
C20	(1, 3.50, 7)	(1, 2.41, 7)	(1, 3.50, 7)	(1, 4.5, 7)	(1, 2.50, 5)	(3, 5.50, 7)
C21	(5, 7.00, 9)	(1, 3.56, 7)	(3, 6.26, 9)	(3, 5.67, 7)	(5, 7.67, 9)	(3, 4.33, 7)
C22	(1, 3.56, 7)	(1, 3.56, 7)	(1, 3.67, 7)	(3, 5.00, 7)	(3, 6.26, 9)	(3, 5.67, 9)
C23	(1, 3.56, 7)	(1, 2.71, 7)	(3, 5.00, 7)	(3, 5.65, 7)	(3, 5.65, 8)	(3, 5.00, 7)
C24	(3, 5.65, 9)	(3, 5.00, 7)	(1, 4.31, 7)	(1, 1.71, 7)	(2, 4.31, 7)	(1, 3.56, 7)

Source(s): Authors' own creation

Table 7.
Fuzzy aggregated decision matrix for hospitals

Table 8. Normalized fuzzy decision matrix

Criteria	H1	H2	H3	H4	H5	H6
C1	(0.33, 0.48, 1.00)	(0.43, 0.60, 1.00)	(0.43, 0.60, 1.00)	(0.33, 0.56, 1.00)	(0.33, 0.58, 1.00)	(0.33, 0.58, 1.00)
C2	(0.33, 0.48, 1.00)	(0.33, 0.48, 1.00)	(0.43, 0.60, 1.00)	(0.33, 0.52, 1.00)	(0.33, 0.53, 1.00)	(0.33, 0.55, 1.00)
C3	(0.11, 0.18, 0.33)	(0.11, 0.18, 0.33)	(0.11, 0.25, 1.00)	(0.11, 0.20, 1.00)	(0.11, 0.21, 1.00)	(0.11, 0.22, 1.00)
C4	(0.11, 0.78, 0.40)	(0.33, 0.56, 0.78)	(0.33, 0.70, 1.00)	(0.33, 0.56, 0.78)	(0.33, 0.70, 1.00)	(0.33, 0.56, 0.78)
C5	(0.11, 0.56, 0.78)	(0.33, 0.56, 0.78)	(0.11, 0.40, 0.78)	(0.33, 0.56, 0.78)	(0.33, 0.70, 1.00)	(0.33, 0.56, 0.78)
C6	(0.33, 0.70, 1.00)	(0.33, 0.56, 0.78)	(0.11, 0.40, 0.78)	(0.33, 0.70, 1.00)	(0.56, 0.92, 1.00)	(0.11, 0.44, 1.00)
C7	(0.43, 0.71, 1.00)	(0.14, 0.24, 1.00)	(0.14, 0.51, 1.00)	(0.14, 0.51, 1.00)	(0.14, 0.51, 1.00)	(0.14, 0.51, 1.00)
C8	(0.33, 0.56, 0.78)	(0.33, 0.56, 0.78)	(0.33, 0.56, 0.78)	(0.33, 0.56, 0.78)	(0.33, 0.56, 0.78)	(0.33, 0.70, 1.00)
C9	(0.33, 0.56, 0.78)	(0.33, 0.56, 0.78)	(0.33, 0.56, 0.78)	(0.56, 0.85, 1.00)	(0.56, 0.85, 1.00)	(0.11, 0.47, 0.78)
C10	(0.33, 0.70, 1.00)	(0.33, 0.70, 1.00)	(0.33, 0.56, 0.78)	(0.33, 0.76, 1.00)	(0.33, 0.82, 1.00)	(0.33, 0.63, 0.89)
C11	(0.56, 0.91, 1.00)	(0.56, 0.82, 1.00)	(0.33, 0.60, 0.78)	(0.33, 0.73, 1.00)	(0.56, 0.82, 1.00)	(0.33, 0.82, 1.00)
C12	(0.33, 0.61, 1.00)	(0.11, 0.33, 0.56)	(0.11, 0.23, 0.56)	(0.11, 0.33, 0.56)	(0.11, 0.50, 0.78)	(0.11, 0.50, 0.78)
C13	(0.43, 0.71, 1.00)	(0.14, 0.24, 1.00)	(0.14, 0.51, 1.00)	(0.14, 0.24, 1.00)	(0.14, 0.51, 1.00)	(0.14, 0.51, 1.00)
C14	(0.14, 0.52, 1.00)	(0.14, 0.24, 0.71)	(0.14, 0.43, 0.71)	(0.14, 0.21, 0.71)	(0.14, 0.33, 0.71)	(0.14, 0.52, 1.00)
C15	(0.33, 0.70, 1.00)	(0.11, 0.19, 0.78)	(0.11, 0.40, 0.78)	(0.11, 0.19, 0.78)	(0.11, 0.40, 0.78)	(0.33, 0.56, 0.78)
C16	(0.14, 0.51, 1.00)	(0.14, 0.51, 1.00)	(0.43, 0.71, 1.00)	(0.14, 0.24, 1.00)	(0.43, 0.71, 1.00)	(0.43, 0.71, 1.00)
C17	(0.14, 0.51, 1.00)	(0.14, 0.51, 1.00)	(0.43, 0.71, 1.00)	(0.43, 0.71, 1.00)	(0.43, 0.71, 1.00)	(0.14, 0.51, 1.00)
C18	(0.14, 0.51, 1.00)	(0.14, 0.51, 1.00)	(0.14, 0.51, 1.00)	(0.43, 0.71, 1.00)	(0.43, 0.71, 1.00)	(0.14, 0.51, 1.00)
C19	(0.14, 0.51, 1.00)	(0.14, 0.51, 1.00)	(0.14, 0.51, 1.00)	(0.14, 0.62, 1.00)	(0.14, 0.51, 1.00)	(0.14, 0.51, 1.00)
C20	(0.29, 0.50, 1.00)	(0.14, 0.34, 1.00)	(0.14, 0.50, 1.00)	(0.14, 0.64, 1.00)	(0.14, 0.36, 0.71)	(0.43, 0.79, 1.00)
C21	(0.56, 0.78, 1.00)	(0.11, 0.40, 0.78)	(0.33, 0.70, 1.00)	(0.33, 0.63, 0.78)	(0.56, 0.85, 1.00)	(0.33, 0.48, 0.78)
C22	(0.11, 0.40, 0.78)	(0.11, 0.40, 0.78)	(0.11, 0.41, 0.78)	(0.33, 0.56, 0.78)	(0.33, 0.70, 1.00)	(0.33, 0.63, 1.00)
C23	(0.25, 0.45, 0.88)	(0.13, 0.34, 0.88)	(0.38, 0.63, 0.88)	(0.38, 0.71, 0.88)	(0.38, 0.71, 1.00)	(0.38, 0.63, 0.88)
C24	(0.33, 0.63, 1.00)	(0.33, 0.56, 0.78)	(0.22, 0.48, 0.78)	(0.11, 0.19, 0.78)	(0.22, 0.48, 0.78)	(0.11, 0.40, 0.78)

Source(s): Authors' own creation

Table 9.
Weighted normalized fuzzy decision matrix

Criteria	H1	H2	H3	H4	H5	H6
C1	(0.016, 0.023, 0.049)	(0.021, 0.029, 0.049)	(0.021, 0.029, 0.049)	(0.016, 0.027, 0.049)	(0.016, 0.029, 0.049)	(0.016, 0.028, 0.049)
C2	(0.018, 0.025, 0.053)	(0.018, 0.025, 0.053)	(0.023, 0.032, 0.053)	(0.018, 0.027, 0.053)	(0.018, 0.028, 0.053)	(0.018, 0.029, 0.053)
C3	(0.002, 0.003, 0.006)	(0.002, 0.003, 0.006)	(0.002, 0.005, 0.018)	(0.002, 0.004, 0.018)	(0.002, 0.004, 0.018)	(0.002, 0.004, 0.018)
C4	(0.003, 0.012, 0.024)	(0.010, 0.017, 0.024)	(0.010, 0.021, 0.031)	(0.010, 0.017, 0.024)	(0.010, 0.021, 0.031)	(0.010, 0.017, 0.024)
C5	(0.009, 0.045, 0.062)	(0.027, 0.045, 0.062)	(0.009, 0.032, 0.062)	(0.027, 0.045, 0.062)	(0.027, 0.056, 0.080)	(0.027, 0.045, 0.062)
C6	(0.015, 0.030, 0.044)	(0.015, 0.024, 0.034)	(0.005, 0.017, 0.034)	(0.015, 0.030, 0.044)	(0.024, 0.040, 0.044)	(0.005, 0.019, 0.044)
C7	(0.020, 0.033, 0.046)	(0.007, 0.011, 0.046)	(0.007, 0.023, 0.046)	(0.007, 0.023, 0.046)	(0.007, 0.023, 0.046)	(0.007, 0.023, 0.046)
C8	(0.009, 0.020, 0.015)	(0.009, 0.015, 0.020)	(0.009, 0.015, 0.020)	(0.009, 0.015, 0.020)	(0.009, 0.015, 0.020)	(0.009, 0.018, 0.026)
C9	(0.026, 0.043, 0.060)	(0.026, 0.043, 0.060)	(0.026, 0.043, 0.060)	(0.043, 0.065, 0.077)	(0.043, 0.065, 0.077)	(0.009, 0.036, 0.060)
C10	(0.022, 0.047, 0.067)	(0.022, 0.047, 0.067)	(0.022, 0.037, 0.052)	(0.022, 0.051, 0.067)	(0.022, 0.055, 0.067)	(0.022, 0.042, 0.060)
C11	(0.024, 0.039, 0.043)	(0.024, 0.035, 0.043)	(0.014, 0.026, 0.034)	(0.014, 0.032, 0.043)	(0.024, 0.035, 0.043)	(0.014, 0.035, 0.043)
C12	(0.001, 0.001, 0.002)	(0.000, 0.001, 0.001)	(0.000, 0.000, 0.001)	(0.000, 0.001, 0.001)	(0.000, 0.001, 0.001)	(0.000, 0.001, 0.001)
C13	(0.024, 0.039, 0.055)	(0.008, 0.013, 0.055)	(0.008, 0.028, 0.055)	(0.008, 0.013, 0.055)	(0.008, 0.028, 0.055)	(0.008, 0.028, 0.055)
C14	(0.007, 0.025, 0.048)	(0.007, 0.011, 0.034)	(0.007, 0.020, 0.034)	(0.007, 0.010, 0.034)	(0.007, 0.016, 0.034)	(0.007, 0.025, 0.048)
C15	(0.009, 0.019, 0.027)	(0.003, 0.005, 0.021)	(0.003, 0.011, 0.021)	(0.003, 0.005, 0.021)	(0.003, 0.011, 0.021)	(0.009, 0.015, 0.021)
C16	(0.005, 0.019, 0.037)	(0.005, 0.019, 0.037)	(0.016, 0.027, 0.037)	(0.005, 0.009, 0.037)	(0.016, 0.027, 0.037)	(0.016, 0.027, 0.037)
C17	(0.004, 0.014, 0.028)	(0.004, 0.014, 0.028)	(0.012, 0.020, 0.028)	(0.012, 0.020, 0.028)	(0.012, 0.020, 0.028)	(0.004, 0.014, 0.028)
C18	(0.007, 0.025, 0.050)	(0.007, 0.025, 0.050)	(0.007, 0.025, 0.050)	(0.021, 0.036, 0.050)	(0.021, 0.036, 0.050)	(0.007, 0.025, 0.050)
C19	(0.008, 0.029, 0.056)	(0.008, 0.029, 0.056)	(0.008, 0.029, 0.056)	(0.008, 0.035, 0.056)	(0.008, 0.029, 0.056)	(0.008, 0.029, 0.056)
C20	(0.016, 0.028, 0.056)	(0.008, 0.019, 0.056)	(0.008, 0.028, 0.056)	(0.008, 0.036, 0.056)	(0.008, 0.020, 0.040)	(0.024, 0.044, 0.056)
C21	(0.025, 0.036, 0.046)	(0.005, 0.018, 0.036)	(0.015, 0.032, 0.046)	(0.015, 0.029, 0.036)	(0.025, 0.039, 0.046)	(0.015, 0.022, 0.036)
C22	(0.004, 0.015, 0.029)	(0.004, 0.015, 0.029)	(0.004, 0.015, 0.029)	(0.012, 0.021, 0.029)	(0.012, 0.026, 0.037)	(0.012, 0.024, 0.037)
C23	(0.005, 0.008, 0.016)	(0.002, 0.006, 0.016)	(0.007, 0.012, 0.016)	(0.007, 0.013, 0.016)	(0.007, 0.013, 0.019)	(0.007, 0.012, 0.016)
C24	(0.001, 0.002, 0.003)	(0.001, 0.002, 0.003)	(0.001, 0.002, 0.003)	(0.000, 0.001, 0.003)	(0.001, 0.002, 0.003)	(0.000, 0.001, 0.003)

Source(s): Authors' own creation

value of the positive ideal solution. Thus, this hospital is determined as the best performing hospital in terms of sustainability and therefore can serve as the benchmark for the other hospitals with a purpose of performance improvement. While, hospital H3, which has the longest distance from the positive ideal solution and the shortest distance from the negative ideal solution, is the worst hospital based on the 24 performance criteria.

5. Discussion of the results

The hybrid fuzzy-MCDM method based on SBSC provides a systematic way to prioritize the evaluation criteria and rank the performance values of hospitals. According to the results shown in Table 6, the ranking of perspectives, respectively, is as follows: "Stakeholders perspective" with the highest weights value (0.196), "Internal business process (0.189)," "Environmental perspective (0.171)," "Social perspective (0.162)," "Financial perspective (0.151)" and finally "Learning and Growth (0.130)." The above results allow us to claim that the social dimension does not hold much importance compared to the environmental dimension. This is due to the social dimension having recently emerged in hospitals' strategies, as it requires more time to reach a certain level of maturity. On the other hand, the environmental dimension had great importance in the hospitals' strategic plans and can be explained by two main reasons. First, the last few decades have witnessed a surge in interest in shielding the environment, especially with the rise of the UK Environmental Protection Law in 1990 (Tudor *et al.*, 2005). Second, new environmental movements have emerged, such as Practice GreenHealth, Hospitals for a Healthy Environment and Health Care Without Harm (Unger *et al.*, 2016). Moreover, the findings on the weights of criteria highlight that the top five important criteria for hospital evaluation performance are "Patient satisfaction," "Efficiency," "Effectiveness," "Access to care" and "Waste production," whereas "Use of information technology" has the weakest weighting value. Based on the current results, we can conclude that experts pay more attention and give more importance to patients' satisfaction compared to all other criteria. This result is expected because the primary mission of hospitals is to fulfill the requirements of patients. The "Use of information technology" criterion was given the lowest weight by experts because most Moroccan hospital departments still use a paper format, which contributes to the lack of interest in this criterion. According to Table 11, hospital H1 has the best performance, whereas hospital H3 has the weakest performance. H1 is an academic hospital center that has been strengthening its sustainable management policy since 2012 (https://www.chumarrakech.ma/wp-content/dd/politique.pdf), which explains its high performance. Conversely, other hospitals have recently begun to implement a sustainable development approach. Therefore, resistance to change resulting from new shifts hinders project success. It can be deduced that Hospital 3's performance value under all criteria has the poorest value compared to the other alternatives, thus making it the worst alternative. As a result, DMs should make greater efforts in areas that have high priorities in performance uplift.

The findings of this study diverge from those of previous works that have studied the framework of sustainability performance evaluation in various industries and services, such as the automotive component manufacturing industry (Swarnakar *et al.*, 2021) and the food manufacturing industry (Ahmad and Wong, 2019). However, no previous works exist that evaluate the sustainability performance of hospitals according to the TBL perspectives. Therefore, the research contributes to filling this gap. Moreover, to the best of our knowledge, this is the first study that proposes a framework for evaluating the sustainability performance of hospitals by integrating fuzzy Delphi, FAHP and FTOPSIS methods with the SBSC approach. This framework is useful for healthcare institution managers to assess their specific performance with regard to sustainability, benchmark with their peers, and propose measures to improve their performance.

Criteria	d^+						d^-					
	H1	H2	H3	H4	H5	H6	H1	H2	H3	H4	H5	H6
C1	0.971	0.967	0.967	0.969	0.969	0.969	0.033	0.035	0.035	0.034	0.034	0.034
C2	0.968	0.968	0.964	0.967	0.967	0.967	0.036	0.036	0.038	0.036	0.036	0.036
C3	0.996	0.996	0.992	0.992	0.992	0.992	0.004	0.004	0.011	0.011	0.011	0.011
C4	0.987	0.983	0.979	0.983	0.979	0.983	0.016	0.018	0.022	0.018	0.022	0.018
C5	0.962	0.956	0.966	0.956	0.946	0.956	0.045	0.047	0.041	0.047	0.058	0.047
C6	0.971	0.976	0.981	0.971	0.964	0.978	0.032	0.025	0.022	0.032	0.037	0.028
C7	0.967	0.979	0.975	0.975	0.975	0.975	0.034	0.027	0.030	0.030	0.030	0.030
C8	0.985	0.985	0.985	0.985	0.985	0.982	0.015	0.015	0.015	0.015	0.015	0.019
C9	0.957	0.957	0.957	0.939	0.939	0.965	0.045	0.045	0.045	0.063	0.063	0.041
C10	0.955	0.955	0.963	0.953	0.952	0.959	0.049	0.049	0.039	0.050	0.052	0.044
C11	0.965	0.966	0.975	0.970	0.966	0.969	0.036	0.035	0.026	0.032	0.035	0.033
C12	0.999	0.999	1.000	0.999	0.999	0.999	0.001	0.001	0.001	0.001	0.001	0.001
C13	0.961	0.975	0.970	0.975	0.970	0.970	0.041	0.033	0.036	0.033	0.036	0.036
C14	0.974	0.983	0.980	0.983	0.981	0.974	0.031	0.021	0.023	0.021	0.022	0.031
C15	0.982	0.990	0.988	0.990	0.988	0.985	0.020	0.013	0.014	0.013	0.014	0.016
C16	0.982	0.982	0.992	0.979	0.992	0.992	0.022	0.022	0.009	0.025	0.009	0.009
C17	0.987	0.987	0.994	0.994	0.994	0.987	0.017	0.017	0.007	0.007	0.007	0.017
C18	0.976	0.976	0.976	0.989	0.989	0.976	0.030	0.030	0.030	0.012	0.012	0.030
C19	0.974	0.974	0.974	0.975	0.974	0.974	0.034	0.034	0.034	0.034	0.034	0.034
C20	0.967	0.972	0.969	0.967	0.977	0.959	0.037	0.035	0.037	0.039	0.026	0.044
C21	0.964	0.980	0.969	0.973	0.963	0.976	0.037	0.023	0.033	0.028	0.038	0.026
C22	0.984	0.984	0.984	0.979	0.975	0.976	0.019	0.019	0.019	0.022	0.027	0.027
C23	0.990	0.992	0.988	0.988	0.987	0.988	0.011	0.010	0.012	0.013	0.014	0.012
C24	0.998	0.998	0.998	0.999	0.998	0.999	0.002	0.002	0.002	0.002	0.002	0.002

Source(s): Authors' own creation

Table 10.
Distance for hospitals

Alternatives	d_i^+	d_i^-	CC_i	Ranking
H1	23.42130	0.64755	0.02690413	1
H2	23.48146	0.59657	0.02477642	5
H3	23.48768	0.58076	0.02412954	6
H4	23.45003	0.61489	0.02555123	4
H5	23.42135	0.63497	0.02639495	2
H6	23.44745	0.62420	0.02593087	3

Source(s): Authors' own creation

Table 11.
Ranking of the hospitals

Although this work provides a novel framework for the sustainability evaluation of hospitals, it has some limitations. Indeed, in the case presented in the paper, the selection of evaluation criteria and the assignment of relative weights are determined based on data and information obtained from Moroccan hospitals, which may limit the generalization of the framework. Thus, similar work should be conducted in other regions and hospitals in the world, and possible additional adjustments or modifications might be required in the case.

6. Results comparison

In order to verify the efficiency and strengths of the proposed fuzzy-based methodology, a comparative analysis is performed. To do so, three conventional MCDM ranking methods, including fuzzy VIKOR (Chang, 2014), fuzzy multi-objective optimization by ratio analysis (FMULTIMOORA) (Rani *et al.*, 2021; Yapıcı Pehlivan and Gürsoy, 2019) and fuzzy weighted aggregated sum product assessment (FWASPAS) (Kul *et al.*, 2020) are used for the evaluation of sustainability performance of the six alternatives, where all these models are based on the same weights and the fuzzy decision matrix. These techniques, similar to FTOPSIS, address fuzzy environments to tackle the vagueness inherent in decision-makers' judgments. The comparison results are presented in Table 12.

As seen in Table 12, the ranks of the six alternatives determined by FVIKOR, FMULTIMOORA and FWASPAS are consistent with the ranks obtained by FTOPSIS. Hospital H1 is the best performer from the sustainability viewpoint for all the fuzzy MCDM methods. In addition, Spearman's rank correlation coefficient (ρ_r) is applied to compare the ranking consistency with the other three techniques (Patil and Majumdar, 2021). The results of the ranking comparisons conducted with the Spearman coefficient are displayed in Table 13.

The findings indicate that there is a substantial statistical correlation between the rankings of the MCMD techniques. The correlation coefficients that exceed 0.8 indicate a highly significant correlation, and those above 0.6 indicate a strong correlation (Yu *et al.*, 2022). It can be inferred from the correlation coefficients being higher than 0.8 that there is a strong correlation in our case. Therefore, it can be said that the proposed methodology is reliable.

7. Sensitivity analysis

Sensitivity analysis has been applied to verify the stability of the proposed methodology as well as to investigate and depict the extent to which the ranking of hospitals is affected by changing the weights of the evaluation criteria. In this study, we have performed sensitivity analysis based on a set of 26 experiments. Table 14 exhibits more details about the experiments. Sensitivity analysis is conducted by changing the weight of one criterion to its maximum, while the remaining criteria are set to the same weights. For example, in the first computation, the weight of the first criterion C_1 is changed to (8, 9, 10), while the other remaining criteria C2–C24 are kept at the weight (1, 1, 1). The same process was applied to the rest of the experiments until experiment 24. In the 25th and 26th experiments, all criteria are assigned equal weights to (1, 1, 1) and (4, 5, 6), respectively. Figure 5 depicts the changes in the final ranking of the performance values when the weights of the sustainability criteria are changed. From Table 14 and Figure 5, one can easily see that H1 has the highest CC_i value in most of the experiments. Eventually, we can conclude that the ranking of alternatives is not highly sensitive to the variation of the criteria weights, which demonstrates the robustness of the applied approach and the relevance of the model for hospitals' sustainability performance evaluation.

8. Managerial implications

The present study provides relevant managerial implications for healthcare managers and DMs involved in monitoring and improving the all-inclusive performance of hospitals. This paper has covered various managerial implications that can be summarized as follows:

(1) The healthcare industry in Morocco is lagging behind other industries in terms of practicing sustainability. Furthermore, healthcare managers have limited knowledge of ways to incorporate sustainable practices and of ways to assess their sustainability performance. In this vein, our model provides a framework for assisting healthcare managers in developing a strategy map that enables the involvement of new sustainable development objectives and thus can be a reference for a new government-driven plan.

(2) The suggested approach will provide administrators with a shortlist of sustainable performance criteria and their importance weights, which will allow them to measure and track any progress toward sustainability goals and sustainable hospitals.

(3) The integrated framework is developed in an uncertain environment, permitting managers to evaluate the overall performance of hospitals, even if the data are fuzzy, imprecise and incomplete.

(4) The proposed methodology is expected to help healthcare managers evaluate their hospitals' performance from the TBL viewpoint and provide an opportunity to compare their performance with other hospitals, which will eventually help them gain valuable feedback about forthcoming improvements.

(5) The present framework will also assist DMs in enhancing social sustainability in their hospitals, which is currently the subject of trends, by focusing on factors that have a great influence on social performance. Accordingly, DMs have a decision tool that assists them in detecting areas requiring more attention to obtain the desired performance.

9. Conclusion

The development of public health is necessary for improving the nation's health and maintaining public welfare. Therefore, an appropriate sustainability performance evaluation system for hospitals has become of utmost importance. In this context, this study proposes an integrated approach based on a combination of SBSC and hybrid fuzzy MCDM techniques to evaluate the sustainability performance of hospitals. The findings highlight that the top five most important evaluation criteria for the hospital evaluation performance from most important to least important are "Patient satisfaction," "Efficiency," "Effectiveness," "Access to care" and "Waste production," respectively. "Use of information technology" has the weakest weightage value. Finally, a case study was conducted in six renowned metropolitan hospitals in Morocco. According to the results of FTOPSIS, hospital H1 performed the best, while hospital H3 performed the worst. The practical contribution of the suggested approach lies in its ability to provide hospital managers with a strategic management tool for decision-making. As the importance weights of each evaluation criterion are computed, the aspects with more impact on performance will be emphasized, which helps decision-makers focus

Table 12. Comparison of the proposed methodology outcome with other methods for the alternative ranks

Alternatives	Fuzzy TOPSIS	FVIKOR	FMULTIMOORA	FWASPAS
H1	1	1	1	1
H2	5	5	5	5
H3	6	6	6	6
H4	4	4	4	4
H5	2	2	2	2
H6	3	3	3	3

Source(s): Authors' own creation

Table 13. Spearman's rank correlation coefficients

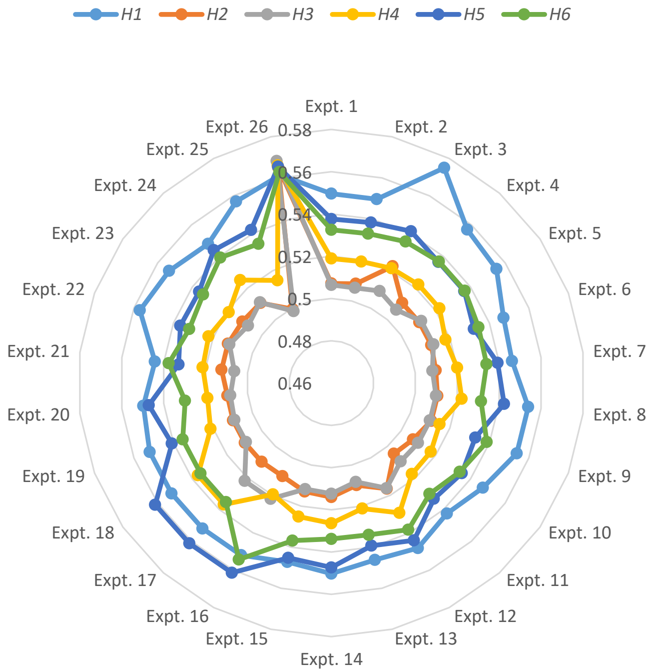
Spearman's coefficients	Fuzzy TOPSIS	FVIKOR	FMULTIMOORA	FWASPAS
ρ_r	–	1	1	1

Source(s): Authors' own creation

Expt. no.	Definition	Overall scores (CC_i) H1	H2	H3	H4	H5	H6	Ranking
Expt. 1	C_1=(8,9,10), the others=(1,1,1)	0.549	0.507	0.506	0.518	0.537	0.532	H1<H5<H6<H4<H2<H3
Expt. 2	C_2=(8,9,10), the others=(1,1,1)	0.549	0.508	0.506	0.519	0.538	0.532	H1<H5<H6<H4<H2<H3
Expt. 3	C_3=(8,9,10), the others=(1,1,1)	0.575	0.522	0.509	0.521	0.541	0.535	H1<H5<H6<H2<H4<H3
Expt. 4	C_4=(8,9,10), the others=(1,1,1)	0.557	0.510	0.506	0.522	0.536	0.536	H1<H5<H6<H4<H2<H3
Expt. 5	C_5=(8,9,10), the others=(1,1,1)	0.555	0.510	0.511	0.522	0.536	0.536	H1<H5<H6<H4<H2<H3
Expt. 6	C_6=(8,9,10), the others=(1,1,1)	0.547	0.510	0.511	0.517	0.532	0.534	H1<H6<H5<H4<H3<H2
Expt. 7	C_7=(8,9,10), the others=(1,1,1)	0.546	0.509	0.508	0.520	0.539	0.534	H1<H5<H6<H4<H2<H3
Expt. 8	C_8=(8,9,10), the others=(1,1,1)	0.553	0.510	0.509	0.522	0.542	0.531	H1<H5<H6<H4<H2<H3
Expt. 9	C_9=(8,9,10), the others=(1,1,1)	0.553	0.510	0.509	0.514	0.532	0.538	H1<H6<H5<H4<H3<H2
Expt. 10	C_{10}=(8,9,10), the others=(1,1,1)	0.547	0.507	0.509	0.517	0.535	0.533	H1<H5<H6<H4<H3<H2
Expt. 11	C_{11}=(8,9,10), the others=(1,1,1)	0.542	0.504	0.509	0.517	0.533	0.530	H1<H5<H6<H4<H3<H2
Expt. 12	C_{12}=(8,9,10), the others=(1,1,1)	0.548	0.516	0.516	0.529	0.544	0.538	H1<H5<H6<H4<H2<H3
Expt. 13	C_{13}=(8,9,10), the others=(1,1,1)	0.546	0.509	0.508	0.521	0.539	0.534	H1<H5<H6<H4<H2<H3
Expt. 14	C_{14}=(8,9,10), the others=(1,1,1)	0.550	0.514	0.512	0.526	0.547	0.533	H1<H5<H6<H4<H2<H3
Expt. 15	C_{15}=(8,9,10), the others=(1,1,1)	0.547	0.512	0.511	0.525	0.545	0.536	H1<H5<H6<H4<H2<H3
Expt. 16	C_{16}=(8,9,10), the others=(1,1,1)	0.552	0.509	0.521	0.519	0.561	0.554	H5<H6<H1<H3<H5<H2
Expt. 17	C_{17}=(8,9,10), the others=(1,1,1)	0.552	0.509	0.521	0.536	0.561	0.535	H5<H1<H4<H6<H3<H2
Expt. 18	C_{18}=(8,9,10), the others=(1,1,1)	0.552	0.509	0.509	0.536	0.561	0.535	H5<H1<H4<H6<H2<H3
Expt. 19	C_{19}=(8,9,10), the others=(1,1,1)	0.552	0.509	0.509	0.521	0.540	0.535	H1<H5<H6<H4<H2<H3
Expt. 20	C_{20}=(8,9,10), the others=(1,1,1)	0.549	0.509	0.508	0.519	0.547	0.529	H1<H5<H6<H4<H2<H3
Expt. 21	C_{21}=(8,9,10), the others=(1,1,1)	0.544	0.512	0.506	0.521	0.532	0.537	H1<H6<H5<H4<H2<H3
Expt. 22	C_{22}=(8,9,10), the others=(1,1,1)	0.557	0.512	0.511	0.522	0.536	0.532	H1<H5<H6<H4<H2<H3
Expt. 23	C_{23}=(8,9,10), the others=(1,1,1)	0.553	0.511	0.507	0.519	0.536	0.533	H1<H5<H6<H4<H2<H3
Expt. 24	C_{24}=(8,9,10), the others=(1,1,1)	0.548	0.510	0.511	0.525	0.544	0.539	H1<H5<H6<H4<H3<H2
Expt. 25	$C_{1\text{-}24}$=(1,1,1)	0.557	0.499	0.498	0.515	0.542	0.534	H1<H5<H6<H4<H2<H3
Expt. 26	$C_{1\text{-}24}$=(4,5,6)	0.561	0.565	0.568	0.566	0.565	0.563	H3<H4<H5<H2<H6<H1

Source(s): Authors' own creation

Table 14.
Ranking of alternatives in sensitivity analysis



Source(s): Author's own creation

Figure 5.
Results of sensitivity analysis

their efforts on those elements. In addition, it would assist DMs to have a more holistic view of their own hospitals' sustainability performance. Furthermore, DMs can compare the performance of their hospitals using the proposed model, which allows them to detect the strengths and weaknesses of their organizational performance and thereby develop necessary actions to address the performance gaps in weak areas. In turn, the proposed measurement model can be an appropriate tool for healthcare administrators searching to evaluate the efficacy of their sustainability strategies. This study also has some limitations that may drive future work. Firstly, in the current study, 24 evaluation criteria of sustainability are considered based on data and information obtained from Moroccan hospitals. To ascertain the broader applicability of the proposed framework, further investigations should be carried out in different regions and hospitals, with possible supplementary modifications or adaptations that might be needed in the case. Secondly, the importance weight of responders is assumed to be equal, although in real cases, experts detain different weights because they have different competences, professional occupations and experiences. Using the Linguistic Weighted Geometric Averaging technique for aggregating individual preferences into a group decision also merits further exploration. Moreover, accounting for the eventual relationship of mutual dependence among the criteria can be viewed as an appropriate avenue for future research. Furthermore, the comparison of this methodology with different MCDM models, such as DEMATEL, FPP-ANP, ELECTRE and COPRAS, constitutes interesting research directions.

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Further reading

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(The Appendix follows overleaf)

Appendix

Table A1. Aggregate fuzzy decision matrix and weights calculation of perspectives

	D1	D2	D3	D4	D5	D6
D1	(1,1,1)	(0.14,0.40,3)	(0,16.0,40.3)	(0.14,1.51,5)	(0.16,0.51,4)	(0.2,0.36,1)
D2	(0.33,2.44,7)	(1,1,1)	(1, 2.48,6)	(2,4.24,6)	(1,3.48,6)	(1,3.08,6)
D3	(0.33,2.44,6)	(0.16,0.40,1)	(1,1,1)	(1,1.51,5)	(0.16,0.51,4)	(0.20,0.36,1)
D4	(0.20,0.65,7)	(0.16,0.23,0.5)	(0.16,0.26,1)	(1,1,1)	(0.16,0.31,1)	(0.16,0.31,1)
D5	(0.25,1.93,6)	(0.16,0.28,1)	(0.16,0.28,1)	(1,3.19,6)	(1,1,1)	(0.33,2.37,6)
D6	(1,2.74,5)	(0.16,0.32,1)	(0.16,0.30,1)	(1,3.19,6)	(0.16,0.42,3)	(1,1,1)

Source(s): Authors' own creation

Table A2. Aggregate fuzzy decision matrix and weights calculation of criteria (D1)

	C1	C2	C3	C4
C1	(1,1,1)	(0.20,0.48,4)	(2,3.27,6)	(1,3.68,6)
C2	(0.25,2.06,5)	(1,1,1)	(1, 4.41,6)	(2,3.85,6)
C3	(0.17,0.31,0.50)	0.17,0.23,1	(1,1,1)	(0.25,0.52,1)
C4	(0.17,0.27,17)	(0.17,0.26,0.50)	(1,1.94,4)	(1,1,1)

Source(s): Authors' own creation

Table A3. Aggregate fuzzy decision matrix and weights calculation of criteria (D2)

	C5	C6	C7	C8
C5	(1,1,1)	(3,5.62,7)	(1,3.52,6)	(4,6.08,8)
C6	(0.14,0.18,0.33)	(1,1,1)	(0.17,0.53,5)	(1,1.17,5)
C7	(0.17,0.28,1)	(0.20,1.89,6)	(1,1,1)	(0.25,1.52,3)
C8	(0.13,0.16,0.25)	(0.20,0.86,1)	(0.33,0.66,4)	(1,1,1)

Source(s): Authors' own creation

Table A4. Aggregate fuzzy decision matrix and weights calculation of criteria (D3)

	C9	C10	C11	C12
C9	(1,1,1)	(1,2.96,5)	(2,4.46,6)	(2, 5.63,8)
C10	(0.20,0.34,1)	(1,1,1)	(2,3.93,7)	(2, 5.20,7)
C11	(0.17,0.22,0.50)	(0.14,0.25,0.50)	(1,1,1)	(3,4.10,6)
C12	(0,3,0.18,0.50)	(0.14,0.19,0.50)	(0.17,0.24,0.33)	(1,1,1)

Source(s): Authors' own creation

	C13	C14	C15
C13	(1,1,1)	(0.33, 2.47,7)	(1, 3.74,6)
C14	(0.14,0.4,3)	(1,1,1)	(1,2.96,5)
C15	(0.17,0.27,1)	(0,20,0.34,1)	(1,1,1)

Source(s): Authors' own creation

Table A5. Aggregate fuzzy decision matrix and weights calculation of criteria (D4)

	C16	C17	C18	C19
C16	(1,1,1)	(0.33,0.73,3)	(0.25,0.43,4)	(0.17,0.36,1)
C17	(0.33,1.36,3)	(1,1,1)	(0.17,0.25,0.50)	(0.17,0.26,0.5)
C18	(0.25,2.35,4)	(2, 3.97,6)	(1,1,1)	(0.14,0.38,1)
C19	(1,2.81,6)	(2,3.89,6)	(1,2.62,7)	(1,1,1)

Source(s): Authors' own creation

Table A6. Aggregate fuzzy decision matrix and weights calculation of criteria (D5)

	C20	C21	C22	C23	C24
C20	(1,1,1)	(2, 3.10,5)	(2,3.24,7)	(3,5.62,7)	(4,5.81,8)
C21	(0.20,0.32,0.50)	(1,1,1)	(1,2.32,6)	(2,3.87,5)	(4,5.30,8)
C22	(0.14,0.31,0.50)	(0.17,0.43,1)	(1,1,1)	(2,3.43,7)	(0.33,2.82,8)
C23	(0.14,0.18,0.33)	(0.20,0.26,0.5)	(0.14,0.29,0.50)	(1,1,1)	(2,4.17,6)
C24	0.13,0.17,0.25	(0.13,0.19,0.2)	(0.13,0.35,3)	(0.17,0.24,0.50)	(1,1,1)

Source(s): Authors' own creation

Table A7. Aggregate fuzzy decision matrix and weights calculation of criteria (D6)

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