



Towards Sustainable Healthcare: A Fuzzy Multi-Criteria Framework for Green Hospital Investments

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ARTICLE INFO

Article history:

Received 28 September 2024

Received in revised form 2 November 2024

Accepted 9 December 2024

Available online 24 January 2025

Keywords:

sustainable healthcare; green hospital;
fuzzy logic; decision-making

ABSTRACT

It is very necessary to develop optimal investment strategies for green hospitals. Optimal investment strategies are necessary for these hospitals to achieve maximum efficiency. Moreover, the right investment strategies ensure that green hospitals use resources such as energy and water efficiently. This contributes to the reduction of operational costs in the long term. For these reasons, the development of optimal investment strategies is of vital importance for the successful construction of green hospitals. On the other hand, a comprehensive need is needed to determine the most accurate investment strategies. This study also aims to develop the most appropriate investment strategies for green hospitals. To achieve this goal, a new model is established in which fuzzy logic and multi-criteria decision-making techniques are integrated. Effective waste management is the most important factor to be considered in this process. In addition, reducing the carbon footprint is another important issue in this context.

1. Introduction

It is very necessary to develop optimal investment strategies for green hospitals. This situation is very critical for environmental sustainability [1]. By determining these strategies, it is possible for these hospitals to create minimum environmental impact. In addition to this situation, this situation is also important for ensuring cost efficiency. These strategies contribute to green hospitals' efficient use of resources such as energy and water [2]. This situation also significantly supports the reduction of operational costs of businesses. Initial and operational costs are quite high in green hospital projects. Therefore, it is possible to reduce costs by determining optimal investment strategies. As a result, businesses gain a significant competitive advantage. Another benefit of this situation is the improvement of health service quality [3]. Green hospitals improve the health conditions of patients with better air quality and sustainable material use. Furthermore, this situation is also very critical for better compliance with legal regulations. For green hospitals to comply with legal regulations,

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<https://doi.org/10.59543/comdem.v2i.10969>

investment strategies must be planned correctly. To achieve this goal, it is very essential to develop optimal investment strategies.

There are a number of criteria that need to be taken into consideration in developing optimal investment strategies for green hospitals. Energy efficiency is the first important factor in this process [4]. To ensure financial sustainability of green hospitals, energy consumption must be minimized. As can be seen here, ensuring energy efficiency is of critical importance. In these hospitals, both the initial installation cost and the costs during the process are quite high [5]. One of the most important items in these high costs is energy consumption. Energy prices have been fluctuating a lot, especially due to the negativities experienced in global markets in recent times. To minimize this problem, hospitals need to use less energy. Therefore, applications that can provide energy efficiency are of key importance.

Water saving is also essential in developing optimal investment strategies for green hospitals [6]. Water consumption is also one of the important cost items for hospitals. As mentioned before, cost effectiveness must be ensured for the long-term sustainability of these hospitals. Otherwise, costs may become uncontrollable. This situation negatively affects the financial performance of hospitals. To minimize this problem, hospitals need to reduce their water consumption costs [7]. Water saving is also necessary for hospitals to achieve their sustainability goals. For these institutions to achieve green hospital status, they must not have negative environmental impacts. Water saving also allows for less consumption of natural resources [8]. In other words, it is a vital element for hospitals to be able to minimize water consumption to be sustainable.

Waste management is another factor that should be taken into consideration in developing optimal investment strategies for green hospitals [9]. There are serious medical wastes in hospitals. If these wastes are not disposed of effectively, they negatively affect people's health. Some diseases can be transmitted through these wastes [10]. Therefore, to be a sustainable hospital, waste management processes must be implemented effectively. In other words, these wastes must be disposed of with the most appropriate techniques. In this context, recycling of appropriate materials is very critical [11]. This contributes to the reduction of hospitals' waste. This issue is also very important for more successful waste management. On the other hand, recycling of materials also provides hospitals with a cost advantage [12]. As a result, hospitals can be stronger financially. This increases the long-term sustainability of these projects.

Reducing the carbon footprint is also very important in developing optimal investment strategies for green hospitals [13]. Hospitals consume a lot of energy. Today, this energy is generally provided by fossil fuels [14]. The main reason for this is that fossil fuel use has a price advantage. On the other hand, fossil fuel use causes significant carbon emissions [15]. This prevents hospitals from being sustainable. Therefore, hospitals need to focus on renewable energy use. The biggest problem here is that renewable energy projects are high cost. To achieve this goal, the costs of these projects need to be reduced. In this context, making the necessary technological investments significantly supports this issue [16]. On the other hand, another advantage of renewable energy projects is that interruptions occur due to climatic conditions. To minimize this problem, it is very necessary to develop effective energy storage systems.

Accordingly, the purpose of this study is to make evaluation to identify the most appropriate investment strategies for green hospitals. To achieve this goal, a new model is established in which fuzzy logic and multi-criteria decision-making techniques are integrated. The results of this study pave the way for the investors to give optimal investment decisions. With the help of this issue, it can be more possible to increase the effectiveness of the green hospitals.

This manuscript is organized as follows. The second part includes the details of the methodology. The third part states the results of the proposed model. The final part gives information about the main conclusion.

2. Methodology

The SIWEC method is a multi-criteria decision-making technique that determines the weights of criteria according to the rating values for the criteria by decision makers [17]. The main advantage of this method is that it allows decision makers to make wider range evaluations. In other words, the basis of the method is to give more importance to the decision maker with higher standard deviation. Thus, decision makers are encouraged to think more realistically [18].

The SIWEC method begins by asking decision makers to rate each criterion with a specific score [19]. Then, the scores are transformed into fuzzy numbers and the initial fuzzy decision matrix is constructed. In the next step, the normalized fuzzy decision matrix is created. For this, the elements of the matrix are divided by the maximum value. After the normalized fuzzy decision matrix is created, the standard deviation value is calculated for each decision maker. The elements of the normalized fuzzy decision matrix are multiplied by the standard deviation of the decision maker and summed. The total fuzzy values are defuzzified. Finally, the defuzzified values are normalized to obtain the criterion weights. The criterion with the largest value is considered the most important criterion.

3. Results

Five decision makers are selected for the SIWEC analysis on investment in sustainable healthcare. The criteria determined for the green hospital process are given in Table 1.

Table 1
Criteria Sets

	Definition	Code
	Water Saving [20]	WATSAV
	Energy Efficiency[21]	ENEFF
	Effective Waste Management[22]	EFFWSTMNG
	Reducing Carbon Footprint[23]	RECARFP
	Sustainable Material Use[24]	SUSMAT

The criteria in Table 1 are evaluated with a seven-point score by five decision makers. The evaluations are shared in Table 2.

Table 2
Evaluations

	WATSAV	ENEFF	EFFWSTMNG	RECARFP	SUSMAT
Decision Maker 1	4	7	7	7	5
Decision Maker 2	5	6	7	6	5
Decision Maker 3	3	4	6	5	6
Decision Maker 4	3	5	7	6	5
Decision Maker 5	5	4	6	5	5

The evaluations are transformed into trapezoidal fuzzy numbers and the initial fuzzy decision matrix is constructed. Then, the elements of the initial fuzzy decision matrix are normalized by dividing by the maximum value. The normalized fuzzy decision matrix is shown in Table 3.

Table 3
 The Normalized Fuzzy Decision Matrix

	WATSAV				ENEFF				EFFWSTMNG				RECARFP				SUSMAT			
DM 1	.4	.5	.5	.6	.8	.9	1.	1.	.8	.9	1.	1.	.8	.9	1.	1.	.5	.6	.7	.8
DM 2	.5	.6	.7	.8	.7	.8	.8	.9	.8	.9	1.	1.	.7	.8	.8	.9	.5	.6	.7	.8
DM 3	.2	.3	.4	.5	.4	.5	.5	.6	.7	.8	.8	.9	.5	.6	.7	.8	.7	.8	.8	.9
DM 4	.2	.3	.4	.5	.5	.6	.7	.8	.8	.9	1.	1.	.7	.8	.8	.9	.5	.6	.7	.8
DM 5	.5	.6	.7	.8	.4	.5	.5	.6	.7	.8	.8	.9	.5	.6	.7	.8	.5	.6	.7	.8

The standard deviation of the normalized fuzzy opinions of each decision maker is calculated. Afterwards, the normalized fuzzy decision matrix is multiplied with the standard deviation values and summed. The results are displayed in Table 4.

Table 3
 The Final Values

	WATSAV				ENEFF				EFFWSTMNG				RECARFP				SUSMAT			
	.31	.4	.47	.56	.51	.60	.64	.71	.69	.78	.84	.88	.59	.68	.73	.80	.5	.59	.66	.75

Finally, the values are defuzzified and the weights are normalized. The weights and rankings of the criteria are illustrated in Table 4.

Table 4
 The Defuzzified Values and Weights

Criteria	Defuzzified	Weights	Rank
WATSAV	0,433	0,137	5
ENEFF	0,617	0,195	4
EFFWSTMNG	0,798	0,252	1
RECARFP	0,701	0,221	2
SUSMAT	0,621	0,196	3

According to Table 4, the most important criteria are effective waste management and reducing carbon footprint.

4. Conclusions

Optimal investment strategies should be determined for green hospitals. This situation is very critical for environmental sustainability. Green hospitals improve the health conditions of patients with better air quality and sustainable material use. Furthermore, this situation is also very critical for better compliance with legal regulations. To achieve this goal, it is very essential to develop optimal investment strategies. There are a number of criteria that need to be taken into consideration in developing optimal investment strategies for green hospitals. Accordingly, this study tries to identify the most appropriate investment strategies for green hospitals. For this situation, a new model is established in which fuzzy logic and multi-criteria decision-making techniques are integrated. The results of this have a leading impact for the investors to give optimal investment decisions. Owing to this condition, it can be more possible to increase the effectiveness of the green hospitals. Effective waste management is the most important factor to be considered in this process. In addition, reducing the carbon footprint is another important issue in this context.

Author Contributions

Conceptualization, Y.G. and S.E.; methodology, S.Y.; software, H.D.; validation, Y.G., S.E. and S.Y.; formal analysis, H.D.; investigation, S.E.; resources, Y.G.; data curation, S.Y.; writing—original draft preparation, H.D.; writing—review and editing, Y.G.; visualization, S.E.; supervision, S.Y.; project

administration, H.D.; funding acquisition, Y.G. All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding.

Data Availability Statement

There is no data in this study.

Conflicts of 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.

Acknowledgement

This research was not funded by any grant.

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