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Priority Strategy Development with Intuitionistic Fuzzy DEMATEL Method for Reducing Energy Costs in Hospitals

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ABSTRACT

Sustainable health service delivery plays a vital role for the development of countries. Sustainability of health services is associated with many factors. One of these factors is energy costs. Hospitals are buildings with high energy consumption. Accordingly, it is important to reduce energy costs in hospitals. For this purpose, it is necessary to determine the factors affecting the costs. In this way, improvements can be made without incurring very high costs. However, there are limited studies on determining the factors affecting energy costs in hospitals. Therefore, the aim of this study is to identify the important factors affecting energy costs in hospitals. In this context, the research question of the study is to determine which strategies will be implemented to reduce energy costs in hospitals. As a result of the literature review, the criteria affecting these costs are determined. The identified criteria are weighted by intuitionistic fuzzy DEMATEL method. The analysis results show that the most appropriate strategy is to reduce energy dependency with renewable energy alternatives (w=0,143). The criterion of reducing energy costs through government incentives also has an important place (w=0,136). The least influential factor is distributing informative documents on energy saving to patients/caregivers (w=0,9). Therefore, to manage energy costs in hospitals, it is appropriate to turn to renewable energy alternatives. Furthermore, government incentives such as tax exemptions are an important strategy. Establishing a good monitoring mechanism by the management would be appropriate to reduce costs.

1. Introduction

The literature review, the purpose of the study and the necessity for the study are given in this section.

1.1 General Information on Energy Consumption in Hospitals

The most crucial resource of a country is human beings. Qualified and productive human resources are directly related to the development of that country. The performance of individuals at the desired level is related to their health [1]. Therefore, it is very critical for individuals to stay

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healthy [2]. One of the most significant factors that ensure the state of being healthy is hospitals. Therefore, the service provided in hospitals must be uninterrupted. Many factors can be mentioned for an uninterrupted service delivery. One of these factors is effective cost management [3]. Many factors can be cost factors in hospitals. Apart from personnel expenses and technology investments, energy costs are one of the major factors that need to be managed [4]. According to a study, energy costs account for more than 10% of the total costs of hospitals [5]. Therefore, energy costs in hospitals need to be reduced. In this context, it would be appropriate to examine the factors affecting hospital energy costs.

It is possible to mention many factors affecting the energy consumption of hospitals. Incentive policies are one of them [6]. These policies can be in the form of tax reductions for hospitals. In addition, incentive practices for the use of renewable energy can be followed [7]. Apart from this, the level of awareness of consumers on energy use is an important factor [8]. Both healthcare staff and patients play an active role in energy consumption in these buildings. Awareness is essential in terms of cost management [9]. The use of efficient equipment in hospitals is one of the key factors affecting this process. With the developing technology, the use of efficient equipment reduces energy consumption [10]. Although the initial investment cost is high, the use of renewable energy provides a great advantage in the long run. Providing energy production by installing solar panels or wind turbines on the roofs of hospitals contributes to hospitals to produce their own energy [11]. Besides, the execution of an effective audit mechanism from the hospital also contributes to controlling energy consumption [12].

1.2 Literature Review on Energy Consumption in Hospitals

In hospitals, medical devices and equipment have a uniquely important role in the delivery of healthcare services. Therefore, it can be said that energy consumption is linked to medical devices and equipment [13]. Therefore, it is significant in terms of efficiency that the devices used are economical. The sustainability analysis conducted on electricity companies emphasizes the importance of using efficient equipment in terms of sustainability [14]. Another factor is increasing the use of renewable energy [15]. Renewable energy projects have high initial investment costs, but in the long run, they contribute to achieving energy independence. In addition, the type of renewable energy to be used is also important [16]. The results of the study examining the challenges of renewable energy use in healthcare argue that the adoption of renewable energy is reliable [17].

Another factor affecting energy consumption in hospitals is the insulation status of the building. Temperature and humidity monitoring, which is important for the sustainability and quality of health services, is carried out in many areas [18]. Apart from this, temperature monitoring is conducted in many activities such as storing medicines and storing sterile materials in appropriate conditions. In addition, large amounts of energy are consumed for heating buildings in winter and cooling them in summer [19]. Some studies argue that ventilation systems have an important role in terms of energy costs [20]. Incentive policies are among the factors affecting the energy costs of hospitals [21]. It is suggested that government incentives have an important place to increase the use of renewable energy [22].

1.3 The Need for a New Study

Hospitals need to provide sustainable healthcare. To this end, energy costs need to be well managed. However, many factors affect energy costs in hospitals. Therefore, the right strategies need to be implemented to these factors. In this context, the factors affecting hospital energy costs must be identified. However, decision-makers can't intervene in all of these factors at the same time.

Ranking these factors in order of importance is important for developing the right strategies. For this purpose, weighting is done with the intuitionistic fuzzy DEMATEL method. When the literature is examined, studies on the determination of these factors are limited. This issue reveals the need for this study.

1.4 The Details of This Study

This study aims to find the most important indicators that affect energy costs in hospitals. Accordingly, the research question is to identify which strategies should be prioritized to reduce energy costs in hospitals. Firstly, the set of criteria affecting this process is identified based on the literature. In the following process, the weights of the criteria are calculated with intuionistic fuzzy DEMATEL. According to the results obtained, the prioritized strategies to be implemented are determined.

2. Methodology

In this article, it is aimed to find the most important strategies for the energy solution of hospital. To achieve this aim, the most effective criteria are defined. In this scope, intuitionistic fuzzy DEMATEL methodology is used. The details of the methodology are below [23].

First of all, the problem of the article is determined. Next, some criteria are selected from literature analysis. After that, the opinions of decision makers are collected with five-point scale [24]. The fuzzy number equivalents of expert opinions in Table 1 are used.

Table 1
Scale

Score	Fuzzy Numbers
0	((0,0,0,0),(0,0,0,0))
1	((0, 0.1, 0.2, 0.3), (0, 0.1, 0.2, 0.3))
2	((0.3, 0.4, 0.5, 0.6), (0.2, 0.4, 0.5, 0.7))
3	((0.7, 0.8, 0.9, 1), (0.7, 0.8, 0.9, 1))
4	((1,1,1,1), (1,1,1,1))

After the collection of the opinions, direct relationship matrix is created by the average values. Then, the defuzzified values are calculated. After that, the normalized values are computed by dividing by the largest of the row totals [25].

Total relation matrix is found. In calculating this matrix, first, the normalized matrix is subtracted from the elements of the identity matrix and its inverse is taken. Then, this result is multiplied by the normalized matrix. Finally, weights of the criteria are obtained [26]. For this, the sums of rows and columns of total relation matrix are calculated. The sum of the two total values is obtained.

3. Results

Selected criteria are defined from literature analysis. Selected criteria are summarized in Table 2 with codes in analysis.

Table 2
Selected Criteria

Criteria	Codes
Covering energy costs by providing finance through external borrowing-partnering	K1
Reducing energy costs with government incentives	K2
Distributing informative documents on energy saving to patients/caregivers	K3
Providing energy saving trainings to personnel	K4
Reducing energy dependency with renewable energy alternatives	K5
Preventing excess energy consumption by insulating the building	K6
Use of energy-efficient equipment	K7
Preventing excessive energy consumption by establishing an effective audit mechanism	K8

The opinions of the 15 decision makers are collected and the average values of fuzzy opinions are computed. The results are shared in Table 3.

Table 3
Direct Relationship Matrix

	K1	K2	K3	K4	K5	K6	K7	K8
K1	(0,0,0,0),(0,0,0,0)	(0.09,0.17,0.26,0.35),(0.07,0.17,0.26,0.36)	(0.26,0.33,0.39,0.46),(0.23,0.33,0.39,0.49)	(0.25,0.33,0.41,0.49),(0.23,0.33,0.41,0.51)	(0.29,0.37,0.44,0.51),(0.29,0.37,0.44,0.52)	(0.17,0.26,0.35,0.43),(0.15,0.26,0.35,0.46)	(0.26,0.34,0.42,0.5),(0.23,0.34,0.42,0.53)	(0.33,0.4,0.47,0.55),(0.29,0.4,0.47,0.58)
K2	(0.38,0.45,0.53,0.6),(0.37,0.45,0.53,0.61)	(0,0,0,0),(0,0,0,0)	(0.27,0.36,0.45,0.53),(0.22,0.36,0.45,0.59)	(0.37,0.45,0.54,0.63),(0.31,0.45,0.54,0.68)	(0.57,0.64,0.71,0.79),(0.56,0.64,0.71,0.79)	(0.51,0.6,0.69,0.77),(0.48,0.6,0.69,0.81)	(0.49,0.57,0.66,0.75),(0.45,0.57,0.66,0.79)	(0.55,0.63,0.72,0.81),(0.53,0.63,0.72,0.83)
K3	(0.17,0.25,0.33,0.41),(0.15,0.25,0.33,0.44)	(0.22,0.31,0.39,0.48),(0.19,0.31,0.39,0.51)	(0,0,0,0),(0,0,0,0)	(0.15,0.24,0.33,0.43),(0.12,0.24,0.33,0.45)	(0.11,0.19,0.28,0.37),(0.09,0.19,0.28,0.38)	(0.07,0.15,0.23,0.31),(0.07,0.15,0.23,0.31)	(0.07,0.15,0.23,0.31),(0.07,0.15,0.23,0.31)	(0.13,0.21,0.3,0.39),(0.11,0.21,0.3,0.41)
K4	(0.41,0.49,0.58,0.67),(0.38,0.49,0.58,0.69)	(0.33,0.41,0.49,0.57),(0.3,0.41,0.49,0.61)	(0.47,0.57,0.66,0.75),(0.45,0.57,0.66,0.78)	(0,0,0,0),(0,0,0,0)	(0.41,0.5,0.59,0.69),(0.38,0.5,0.59,0.71)	(0.36,0.45,0.53,0.62),(0.33,0.45,0.53,0.65)	(0.38,0.45,0.51,0.58),(0.37,0.45,0.51,0.59)	(0.45,0.54,0.63,0.73),(0.41,0.54,0.63,0.77)
K5	(0.71,0.77,0.84,0.91),(0.7,0.77,0.84,0.91)	(0.84,0.89,0.95,1),(0.84,0.89,0.95,1)	(0.46,0.53,0.61,0.68),(0.42,0.53,0.61,0.72)	(0.59,0.68,0.77,0.85),(0.57,0.68,0.77,0.87)	(0,0,0,0),(0,0,0,0)	(0.59,0.67,0.75,0.83),(0.58,0.67,0.75,0.85)	(0.54,0.63,0.73,0.82),(0.51,0.63,0.73,0.85)	(0.61,0.69,0.77,0.85),(0.58,0.69,0.77,0.87)
K6	(0,0,0,0),(0,0,0,0)	(0.09,0.17,0.26,0.35),(0.07,0.17,0.26,0.36)	(0.26,0.33,0.39,0.46),(0.23,0.33,0.39,0.49)	(0.25,0.33,0.41,0.49),(0.23,0.33,0.41,0.51)	(0.29,0.37,0.44,0.51),(0.29,0.37,0.44,0.52)	(0.17,0.26,0.35,0.43),(0.15,0.26,0.35,0.46)	(0.26,0.34,0.42,0.5),(0.23,0.34,0.42,0.53)	(0.33,0.4,0.47,0.55),(0.29,0.4,0.47,0.58)
K7	(0.38,0.45,0.53,0.6),(0.37,0.45,0.53,0.61)	(0,0,0,0),(0,0,0,0)	(0.27,0.36,0.45,0.53),(0.22,0.36,0.45,0.59)	(0.37,0.45,0.54,0.63),(0.31,0.45,0.54,0.68)	(0.57,0.64,0.71,0.79),(0.56,0.64,0.71,0.79)	(0.51,0.6,0.69,0.77),(0.48,0.6,0.69,0.81)	(0.49,0.57,0.66,0.75),(0.45,0.57,0.66,0.79)	(0.55,0.63,0.72,0.81),(0.53,0.63,0.72,0.83)
K8	(0.17,0.25,0.33,0.41),(0.15,0.25,0.33,0.44)	(0.22,0.31,0.39,0.48),(0.19,0.31,0.39,0.51)	(0,0,0,0),(0,0,0,0)	(0.15,0.24,0.33,0.43),(0.12,0.24,0.33,0.45)	(0.11,0.19,0.28,0.37),(0.09,0.19,0.28,0.38)	(0.07,0.15,0.23,0.31),(0.07,0.15,0.23,0.31)	(0.07,0.15,0.23,0.31),(0.07,0.15,0.23,0.31)	(0.13,0.21,0.3,0.39),(0.11,0.21,0.3,0.41)

After that, these values are defuzzified and normalized. The details of results are displayed in Table 4.

Table 4
Normalized Relationship Matrix

	K1	K2	K3	K4	K5	K6	K7	K8
K1	0.000	0.042	0.070	0.071	0.078	0.059	0.074	0.085
K2	0.095	0.000	0.078	0.097	0.132	0.125	0.120	0.132
K3	0.057	0.068	0.000	0.056	0.046	0.036	0.036	0.050
K4	0.104	0.088	0.119	0.000	0.106	0.095	0.093	0.114
K5	0.157	0.179	0.111	0.141	0.000	0.139	0.132	0.141
K6	0.130	0.139	0.102	0.119	0.099	0.000	0.110	0.113
K7	0.123	0.153	0.085	0.114	0.121	0.111	0.000	0.119
K8	0.132	0.132	0.121	0.150	0.112	0.113	0.103	0.000

Next, the total relation matrix is computed. The matrix is shared in Table 5.

Table 5
Total Relation Matrix

	K1	K2	K3	K4	K5	K6	K7	K8
K1	0.187	0.228	0.229	0.243	0.237	0.217	0.228	0.255
K2	0.389	0.301	0.335	0.373	0.383	0.373	0.365	0.404
K3	0.190	0.198	0.119	0.181	0.165	0.154	0.152	0.178
K4	0.363	0.348	0.342	0.253	0.332	0.318	0.314	0.357
K5	0.503	0.517	0.418	0.468	0.325	0.440	0.431	0.474
K6	0.417	0.421	0.355	0.390	0.357	0.261	0.357	0.389
K7	0.422	0.444	0.349	0.396	0.385	0.371	0.268	0.405
K8	0.432	0.429	0.384	0.428	0.379	0.374	0.363	0.301

According to the values in Table 5, the weights of the criteria are obtained. The weights of the criteria are illustrated in Table 6.

Table 6
Weights of Criteria

Criteria	Weights
K1	0.110656846
K2	0.135960947
K3	0.090475705
K4	0.125411551
K5	0.143705764
K6	0.127641561
K7	0.129175115
K8	0.136972511

The results of the analysis show that the most important factor affecting energy costs in hospitals is “Reducing energy dependency with renewable energy alternatives”. The weight value of the criterion is 0.143. The second most influential factor is “Preventing excessive energy consumption by establishing an effective audit mechanism”. The weight value of the criterion is 0.136. The least influential criterion is "Distributing informative documents on energy saving to patients/caregivers" with a weight value of 0.90.

4. Conclusions

This study aims to identify the most important factors affecting energy costs in hospitals. To this end, the research question is to determine which prioritized strategies should be implemented to reduce costs in this process. Through a literature review, many factors affecting energy costs in hospitals are identified. Then, these factors are weighted by the intuionistic fuzzy DEMATEL method. The results of the analysis show that the most appropriate strategy is to reduce energy dependency with renewable energy alternatives (w=0.143). The criterion of preventing excessive energy consumption by establishing an effective audit mechanism also plays an important role in this process (w=0.136). Furthermore, the criterion of reducing energy costs through government incentives is also essential in terms of managing costs (w=0.135). However, the factor with the lowest weight is calculated as distributing informative documents on energy saving to patients/caregivers (w=0.9). To manage energy costs in hospitals, the focus should be primarily on renewable energy. Concerns about the high initial investment cost should also be addressed. In addition, the inclusion of audits in planning makes a significant contribution.

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Conflicts of Interest

The authors declare no conflicts of interest.

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