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Integrated Best-Worst Method and Gray Relational Analysis for Hospital Location Selection: The Case of Burdur Province

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Abstract: The hospital location (site) selection problem involves determining the most suitable location for a healthcare facility. As a multi-criteria decision-making (MCDM) problem, it requires the evaluation of several factors, including strategic, economic, and social considerations, due to the direct impact hospital locations have on public health. To make an optimal decision, MCDM methods are typically employed to accurately assess the relevant criteria. These methods assist decision-makers in evaluating various factors and determining the best location for the hospital. This study focuses on selecting a site for a private hospital planned for Burdur Province, where no private hospital currently exists. In this context, three alternative locations were evaluated based on expert opinions from academicians, health managers, and urban planners. In the first phase of the study, the Best-Worst Method (BWM) was used to calculate the criteria weights, allowing for the subjective evaluation of multiple factors. Following this, the Gray Relational Analysis (GRA) method was applied to determine the most appropriate location by assessing the degree of similarity or dissimilarity between the alternatives. This combination of methods enabled the ranking of the alternatives, ultimately identifying the best site for the hospital.

Keywords: Hospital site selection, Multi-criteria decision-making, Best-worst method, Gray relational analysis

Introduction

Rapid changes in technology, the globalisation of the world and an increasingly competitive environment have made the decision-making processes of companies more crucial. In this context, the site selection is of vital importance for the success of a company. The basis of site selection studies is Weber's 'location theory'. Although location selection was initially based only on the purpose of reducing transport costs, subsequent studies have shown that site selection has an effect on service quality and thus its importance has increased (Aydın et al., 2009). Site selection for critical facilities such as hospitals is a complex process that requires consideration of many factors such as efficiency, accessibility, safety and cost. The consideration of natural, human and economic factors is of great importance for the efficiency, quality and equity of health services (Sahin et al., 2019). Therefore, hospital site selection is a strategic decision with long-term implications and requires an approach that has the potential for sustainability and prevention of future problems. Wrong site selection can lead to patient dissatisfaction and increased costs (Chatterjee, 2013). Hospital site selection is a critical decision process not only for health care managers, but also for government and health policy makers. This selection process involves evaluating criteria such as patient access to the hospital, environmental factors, proximity to other healthcare facilities and land costs. In this context, hospital site selection is usually analysed using MCDM techniques. MCDM techniques, which take more than one criterion into account, allow the advantages and disadvantages of each alternative to be systematically analysed and different factors to be effectively evaluated. In addition to MCDM, the carrying capacity model, Geographical Information Systems (GIS) or fuzzy models can also be used to solve this problem. One of the most preferred and widely used MCDM methods is Analytic Hierarchy Process (AHP). Other widely used methods include Analytic Network Process (ANP), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Vlsekriterijumska Optimizacija I Kompromisno Resenje (VIKOR), Elimination and Choice Expressing Reality (ELECTRE), Simple Additive Weighting (SAW), GRA, Evaluation Based on Distance from Average Solution (EDAS), Additive Ratio Assessment with Grey Relational Analysis (ARAS-G), Combined Distance-based Approach for Ranking Alternatives (CODAS), Criteria Importance Through Intercriteria Correlation (CRITIC), Entropy and fuzzy versions of these methods. Each stage of hospital site selection has its own specific MCDM method. This preference is due to the fact that the relevant stage of the problem is fully compatible with the method structure (Gul & Guneri, 2021).

This study presents a multi-criterion decision-making (MCDM) approach to determine the optimal site for a private hospital in Burdur, a province in Turkiye's Mediterranean region recognized for its agricultural, industrial, and tourism potential. Despite the fact that Burdur is a student hub and an important transport corridor, there is currently no private hospital in the city. To address this, a four-member decision-making team - comprising academics, health managers, health professionals and local government representatives – is assembled to evaluate three alternative sites. Based on a review of hospital site selection literature, seven criteria selected and a two-stage MCDM methodology is proposed. In the first stage, the selected criteria's are weighted using the linear BWM method; in the second stage, GRA is used to evaluate and rank the alternatives according to their scores. The remainder of the study is organised as follows: the second section is a literature review of hospital site selection methodologies. The third section describes in detail the MCDM methods used in this study, while the fourth section is dedicated to the application. The results are discussed in the conclusion and evaluation section.

Literature

Hospital site selection is a critical decision to improve the efficiency of health services and to meet the health needs of the community. This decision requires a MCDM process in which various factors are considered. The literature in this area shows that different methods and analyses have been used to optimise hospital site selection decisions. Lin et al. (2008) managed subjective judgements by using fuzzy AHP and sensitivity analysis for hospital site selection in Taiwan this approach was adapted by Aydın (2009) for Ankara, Türkiye, highlighting the flexibility of FAHP in dealing with uncertainty. Wu and Zhou (2012) obtained more reliable results by using GIS-based multi-criteria analysis method in Beijing et al. (2013) emphasised that the most important criteria are land cost and proximity to public transport with Fuzzy AHP in rural areas in India. Dehe and Bamford (2015) compared two different MCDM models for the NHS in the UK. Khaksefidi and Miri (2016) used MCDA methods considering multiple criteria in Iran. Kmail et al. (2017) combined GIS and AHP to identify the most suitable locations. Kumar et al. (2016) used ELECTRE approach in India. Celikbilek (2018) included the opinions of the board members in the decision-making process with the VIKOR method. Dell'Ovo et al. (2018) integrated MCDM and GIS for healthcare facilities in Milan. Mic and Antmen (2019) revealed the potential for improvement in site selection with fuzzy TOPSIS in Adana. Neisani Samani and Alesheikh (2019) increased citizen participation with Fuzzy-VIKOR. Rezayee (2020) used GIS-based multi ciriteria analysis to achieve balance by including environmental impacts and traffic flow. Nsaif et al. (2020) created a suitability map with GIS and remote sensing. Adalı and Tus (2021) determined market conditions with CRITIC method and ranked with TOPSIS, EDAS, and CODAS methods. Sutcuoglu and Yalcınkaya (2021) developed a decision support model including environmental and accessibility factors in Izmir.

Recently, Agac and Simsir (2022) evaluated risks and opportunities with AHP for pandemic hospitals. Hadi and Abdullah (2022) developed a web application with Cost-Effective-Impact Results Evaluation Model (MEREC) and modified TOPSIS for COVID-19 patients. Todorov and Todorova (2023) examined hospital site selection in terms of accessibility with GIS-based analysis in Bulgaria. Al Mohamed et al. (2023) integrated FAHP and Fuzzy TOPSIS methods for pandemic hospitals. Gazi et al. (2024) studied sustainable hospital site selection in Saudi Arabia using Spherical Entropy and Spherical VIKOR methods to meet the requirements of various diseases. Zandi et al. (2024) introduced a hybrid methodology combining GIS with MCDM methods for hospital site suitability in Tehran. The study used AHP, BWM, and Step-wise Weight Assessment Ratio Analysis (SWARA) to evaluate socio-environmental factors. For an in-depth literature review on the topic, the studies by Gul and Guneri (2021) and Ozkan et al. (2024) are recommended.

Method

In this study, a two-stage integrated integrated BWM and GRA method was applied for a private hospital selection problem. A review of the literature shows that these two methods are rarely used together, and the limited studies that do exist have not applied them to hospital site selection. Firstly, a decision-making team consisting of four experts working in Burdur province was formed. This decision-making team includes a doctor, a health manager, an engineer working in local government and an academician from the Industrial Engineering department. Afterwards, the main and sub-criteria to be used in the study are determined by reviewing the relevant literature, and the study is started.

In the first stage, the linear BWM method was used to determine the weights of the main criteria. While AHP is the most widely used method for this purpose, BWM, a newer approach, is less frequently applied. BWM's advantage is its reduced need for comparisons, as it only requires evaluating criteria against the best and worst options, enhancing consistency. In contrast, AHP uses pairwise comparisons for all criteria, offering more detail but requiring more effort. In the second stage, GRA was used for its strength in handling incomplete or uncertain data, making it effective even with limited information. This makes GRA suitable for real-world applications where data is restricted.

Best-Worst Method

The BWM method is one of the most recent methods developed by Rezaei (2015). As an MCDM method. In this method, the best (most important, most desirable) and worst (least important, least desirable) criteria are defined by the decision maker and a binary comparison vectors are used between best-others and worst-others to determine the weights of the criteria and the scores of the alternatives. By defining vector weight values for each alternative and criteria sets, final scores are determined and the best alternative is selected. The steps of the BWM as follows:

Step 1. Determination of decision criteria $(c_1, c_2, \dots, c_n)$ by experts.

Step 2. Determining the best and the worst criterion among the criteria. If the experts decide on two or more criteria as best or worst, the best and worst criteria are chosen arbitrarily. No comparison is made at this stage, where the decision maker determines the overall best and worst criteria.

Step 3. Determination of the preference for the best criterion over the other criteria using a number between 1 and 9. Here, 1 means that the criteria are equally important, while 9 means that the best criterion is much more important than the criterion in question. As a result, the best comparison vector $A_B = (a_{B1}, a_{B2}, \dots, a_{Bn})$ is obtained for the other criteria. Here, a_{Bj} denotes the preference of the best criterion (B) over criterion *j*. The value $a_{B_B} = 1$ signifies that the best criterion is compared to itself.

Step 4. Determination of the preference for the worst criterion relative to the other criteria using a number between 1 and 9. The worst comparison vector $A_W = (a_{1W}, a_{2W}, \dots, a_{nW})^T$ for other criteria is obtained: Here , a_{jW} denotes the preferability of criterion *j* with respect to the worst criterion (*W*). Also, since it is the same as the status of the best criterion, the value of the worst criterion compared to itself is equal to 1, $a_{W_W} = 1$. The benchmark comparison scale in Table 1 is used for the binary evaluations in Step 3 and 4.

Table 1. Benchmark comparision scale.

Scale	1	3	5	7	9	2,4,6,8
Definition of value	equal	medium	strong	very strong	absolute superiority	intermediate values

Step 5. Finding the optimal weights of the criteria $(w_1^*, w_2^*, \dots, w_n^*)$. The most suitable weights for the criteria are given by each value pair of $\frac{w_B}{w_j} = a_{Bj}$ and $\frac{w_j}{w_w} = a_{jW}$, which are determined based on comparisons. To satisfy the conditions for all *j*, a solution must be found by minimizing the maximum absolute differences $\left|\frac{w_B}{w_j} - a_{Bj}\right|$ and $\left|\frac{w_j}{w_w} - a_{jW}\right|$ as shown in Equation (1). Considering the condition that the sum of weights equals one and that weights are non-negative, the following optimization problem is formulated:

$$\min maxS_j \left\{\left|\frac{w_B}{w_j} - a_{Bj}\right|, \left|\frac{w_j}{w_w} - a_{jW}\right|\right\} \tag{1}$$

Under the following constraints

$$\sum_j w_j = 1, \quad w_j \geq \forall_j$$

The equation can be linearized as follows (Eq. (2)):

$$\text{Min } \mu \tag{2}$$

$$\left|\frac{w_B}{w_j} - a_{Bj}\right| \leq \mu, \qquad \left|\frac{w_j}{w_w} - a_{jW}\right| \leq \mu, \qquad \sum_j w_j = 1, \qquad w_j \geq \forall_j$$

Step 6. Determination of consistency ratios by using $\mu^*$and the consistency index value, as shown in Equation (3). To check the consistency of comparisons, the consistency index formula in Table 2 is applied. If the condition $a_{Bj}\ x\ a_{jW} = a_{BW}$ is met for all criteria *j*, the comparisons are fully consistent.

$$Consistency\ Ratio\ = \frac{\mu^*}{Consistency\ Index} \tag{3}$$

As the value approaches zero, consistency increases. Values below one are considered to have sufficient consistency (Arslanhan & Tosun, 2021).

Table 2. Consistency ındex values.

a_{BW}	1	2	3	4	5	6	7	8	9
Consistency index	0,00	0,44	1,00	1,63	2,30	3,00	3,73	4,47	5,23

Grey Relational Analysis

Deng Ju-Long introduced the Grey System Theory for the first time with his work ‘Control Problems of Grey System’ published in 1982. This theory aims to quantify uncertain information and detailed explanations of the structure of the theory were presented in the book ‘Introductions to Grey System’ published in 1989. In the Grey System, uncertain information is described as ‘black’, fully known information is described as ‘white’ and the data in between these two, which express partial information, is described as ‘grey’ (Lui & Lin, 2011). According to Lui and Lin (2011) grey systems are systems with uncertainty and these systems have two main characteristics:

Partial Information Status: Incomplete information, which is encountered in social, economic and scientific fields, includes incomplete information about parameters, structural elements, boundaries and behavioural characteristics of the system.

Data Inaccuracy: There are inherent errors in such uncertain systems and inaccuracies can be seen in conceptual, level and estimation types.

Grey numbers, which are the basic element of grey systems, are numbers whose exact value is unknown but are known to lie within a boundary range. In grey mathematics analyses, interval grey numbers with known upper and lower bounds are frequently used and are represented as ⊗a ∈ [a-,a+] (Aydemir et al., 2013). GRA is a method developed based on grey system theory and is used in relational rating, classification and decision making processes (Liu & Lin, 2006). Method aims to measure the relationship of each factor in a grey system with the reference factor and this relationship level is called ‘grey relational degree’. Used to determine the most appropriate option according to different criteria, GRA is a method that aims to select the best alternatives as a multi-criteria decision-making tool (Hinduja & Pandey, 2017; Fidan, 2018). The steps and formulation of the GRA method developed for group decision-making are as follows (Manzardo et al., 2012):

Step 1. Constructing the grey decision matrix in presence of *L* decision makers (Eq. (4)):

$$\otimes G^k = \begin{bmatrix} \otimes g_{11}^k & \cdots & \otimes g_{1n}^k \\ \vdots & \ddots & \vdots \\ \otimes g_{m1}^k & \cdots & \otimes g_{mn}^k \end{bmatrix} \tag{4}$$

$\otimes g_{ij}^k = [g_{ij}^-, g_{ij}^+]$, i= 1,2,3,….,m; j=1,2,……,n . $\otimes g_{ij}^k$ represents the evaluation of the *i^th^* alternative by the *k^th^* decision-maker in terms of the *j^th^* criterion.

Step 2. Normalisation of the decision-making matrix. In this process, different calculation method is applied according to the criterion. If the larger value is better in the criterion, it can be called as benefit criterion (Eq. (5)), if the smaller value is better, it can be called as cost criterion and it is calculated using the relevant formula in Equation (6).

$$\text{Benefit criteria:} \quad \otimes y_{ij}^{k} = \frac{\otimes g_{ij}^{k}}{\max_{i=1}^{m}\{\otimes g_{ij}^{k,+}\}},\ i=1,2,3,\ldots,m;\ j=1,2,\ldots\ldots,n \tag{5}$$

$$\text{Non-benefit criteria:} \quad \otimes y_{ij}^{k} = \frac{\min_{i=1}^{m}\{\otimes g_{ij}^{k,-}\}}{\otimes g_{ij}^{k}},\ i=1,2,3,\ldots,m;\ j=1,2,\ldots\ldots,n \tag{6}$$

Step 3. Creation of standardised decision matrix and reference series. At this stage, a standardised decision matrix (Eq. (7)) is created using the values obtained in the previous step and a reference series is created from the largest values in each column of the decision matrix (Eq. (8) - (9)).

$$\otimes Y^{k} = \begin{bmatrix} \otimes y_{11}^{k} & \cdots & \otimes y_{1n}^{k} \\ \vdots & \ddots & \vdots \\ \otimes y_{m1}^{k} & \cdots & \otimes y_{mn}^{k} \end{bmatrix} \tag{7}$$

$$y^{k,0} = \{y_1^{k,0}, y_2^{k,0}, y_3^{k,0}, \ldots, y_n^{k,0}\} \tag{8}$$

$$\otimes y_j^{k,0} = \max_{i=1}^{m} y_{ij}^{k,+}\ , j = 1,2,3, \ldots\ldots, n \tag{9}$$

where $y_j^{k,0}$ is the reference value in relation to the j^{th} criterion

Step 4. Calculation of the difference between the alternatives and the reference alternative (Eq. (10), and construction of the difference matrix (Eq. (11)).

$$\otimes \Delta_{11}^{k} = \left[y_j^{k,0} - y_{ij}^{k,+}, y_j^{k,0} - y_{ij}^{k,-}\right], i = 1,2, \ldots\ldots, m; j = 1,2,3, \ldots., n \tag{10}$$

$$\otimes \Delta^{k} = \begin{bmatrix} \otimes \Delta_{11}^{k} & \cdots & \otimes \Delta_{1n}^{k} \\ \vdots & \ddots & \vdots \\ \otimes \Delta_{m1}^{k} & \cdots & \otimes \Delta_{mn}^{k} \end{bmatrix} \tag{11}$$

Step 5. Creation of the grey relationship coefficient by Equation (12), (13), and (14). Here, $\otimes \varepsilon_{ij}^{k}$ represents the grey relational coefficient. ρ is the distinguishing coefficient, which takes values between 0 and 1, and in this study, it is set to 0.5.

$$\otimes \varepsilon_{ij}^{k} = [\otimes \varepsilon_{ij}^{k,-}, \otimes \varepsilon_{ij}^{k,+}] \tag{12}$$

$$\otimes \varepsilon_{ij}^{k,-} = \frac{\min_{i=1}^{m}\min_{j=1}^{m} \otimes \Delta_{ij}^{k,-} + \rho \max_{i=1}^{m}\max_{j=1}^{m} \otimes \Delta_{ij}^{k,+}}{\otimes \Delta_{ij}^{k,+} + \rho \max_{i=1}^{m}\max_{j=1}^{m} \otimes \Delta_{ij}^{k,+}} \tag{13}$$

$$\otimes \varepsilon_{ij}^{k,+} = \frac{\min_{i=1}^{m}\min_{j=1}^{m} \otimes \Delta_{ij}^{k,-} + \rho \max_{i=1}^{m}\max_{j=1}^{m} \otimes \Delta_{ij}^{k,+}}{\otimes \Delta_{ij}^{k,-} + \rho \max_{i=1}^{m}\max_{j=1}^{m} \otimes \Delta_{ij}^{k,+}} \tag{14}$$

Step 6. Calculation of the grey relational degree: The grey relational coefficients are multiplied by the weight of the corresponding criterion and then summed for each alternative to obtain the grey relational degree (Eq. (15).

$$\otimes \gamma_i^{k} = \sum_{j=1}^{n} \otimes \varepsilon_{ij}^{k} \otimes \omega_j \tag{15}$$

Step 7. Clarification of the grey relational degree (Eq. (16)).

$$\otimes \gamma_i^{k} = [\gamma_i^{k,-}, \gamma_i^{k,+}], \quad \gamma_i^{k} = \frac{\gamma_i^{k,-} + \gamma_i^{k,+}}{2} \tag{16}$$

Step 8. Group decision making and sorting by Equation (17).

$$\gamma_i = \left(\prod_{k=1}^{L} \gamma_i^k\right)^{1/L} \tag{17}$$

Results and Discussion

A review of studies shows that the most frequently used criteria for hospital site selection are access, cost factors, population density and demographics, environmental factors, proximity to existing health services, government and policy influence, adequacy of infrastructure, presence of competition, risk and safety considerations, and community and urban factors - community support, land use compatibility and environmental effects. These criteria are important in terms of access to health services, cost-effectiveness and social-environmental harmony by addressing operational and strategic issues in hospital site selection decisions. The study considered criteria proposed by Gun and Guneri (2021). Which are thought to provide valuable insights for research in this field. These criteria and sub-criteria are listed below.

- c_1: Cost criteria (capital cost, demand cost, land use cost)
- c_2: Demand criteria (population quantity, population density, population age distribution)
- c_3: Location criteria (distance to arteries&main roads, distance to medical suppliers, distance to residential & social life)
- c_4: Firm strategy, structure&competitors (management objective, competitor hospitals, policy maker's attitude)
- c_5: Related and supporting sectors (medicine and pharmacy sector, health sector, hospital management sector)
- c_6: Govermental criteria (qualifications & regulations & tax, promotion of medical network, promulgating tasks)
- c_7: Chance (sharp change in demand, unusual fluctuations in production cost, financial changes & exchange rate)

In the evaluation made by the decision-makers, the cost and chance criteria were considered non-benefit, while the other criteria were evaluated as benefit criteria. Also, the location criterion is based on proximity, and the chance criterion, which can be viewed in a positive sense, was assumed as unexpected and undesirable situations. After determination of criteria, firstly, the best/worst criteria selected for linear BWM according to the benchmark comparison scale, along with the pairwise comparisons made by the decision makers, are shown in Table 3 and Table 4.

Table 3. Binary comparison between best criteria and other criteria.

Decision makers	best	c_1	c_2	c_3	c_4	c_5	c_6	c_7
DM_1	c_2	3	1	4	8	7	6	9
DM_2	c_1	1	3	4	7	6	4	9
DM_3	c_3	2	4	1	6	5	3	9
DM_4	c_2	2	1	3	5	7	6	9

Table 4. Binary comparison between worst criteria and other criteria.

criteria	DM_1 worst c_7	DM_2 worst c_7	DM_3 worst c_7	DM_4 worst c_7
c_1	7	9	7	7
c_2	9	7	8	9
c_3	6	6	9	6
c_4	2	4	5	5
c_5	4	5	5	4
c_6	3	3	3	3
c_7	1	1	1	1

In the evaluation made by the decision-makers, the cost and chance criteria are considered non-benefit, while the other criteria are evaluated as benefit criteria. Also, the location criterion was assumed to be proximity, and the chance criterion, which can be viewed in a positive sense, is assumed to be unexpected and undesirable situations.

Subsequently, the criteria weights, associated threshold, and input-based consistency ratios, calculated using Eq. (1), (2), and (3), are presented in Table 5, thus concluding the first stage in which linear BWM is applied. The BWM assesses criteria importance ratios but has some limitations: lack of immediate consistency feedback, ordinal consistency consideration, and reliability thresholds. Liang et al. (2020) introduced an input-based cardinal consistency for immediate feedback, along with an ordinal measure to align pairwise comparison order with results, providing balanced thresholds. This method was adopted to the study.

Table 5. Calculated weight and consistency ratios.

Decision makers	Criteria Weights							Associated Threshold	Input-Based CR
	w_1^*	w_2^*	w_3^*	w_4^*	w_5^*	w_6^*	w_7^*		
DM_1	0.17	0.43	0.13	0.07	0.07	0.09	0.04	0.35	0.26
DM_2	0.40	0.16	0.12	0.07	0.08	0.12	0.03	0.35	0.29
DM_3	0.22	0.11	0.34	0.07	0.09	0.15	0.03	0.35	0.32
DM_4	0.22	0.37	0.15	0.09	0.06	0.07	0.03	0.35	0.26
w_j^*/n	0.25	0.27	0.19	0.07	0.08	0.11	0.03		

In the initial step of the second GRA evaluation stage, decision-makers' opinions on the options are gathered using grey numbers (Table 6) for each criterion, creating the decision matrix ($\otimes G^k$) presented in Table 7. The reference series values are italicized according to the nature of the criteria.

Table 6. The scale of grey number for the assessment of the alternative.

Criteria	Abbreviation	Scale of grey number
Very low	VL	(1.5,3.0)
Low	L	(3.0,4.5)
Medium	M	(4.5,6.0)
High	H	(6.0,7.5)
Very high	VH	(7.5,9.0)

Table 7. Decision matrix.

$\otimes G^k$		c_1 Non beneficial	c_2 Beneficial	c_3 Beneficial	c_4 Beneficial	c_5 Beneficial	c_6 Beneficial	c_7 Non beneficial
	a_1	(7.5 , 9.0)	(7.5 , *9.0*)	(7.5 , *9.0*)	(6.0 , *7.5*)	(7.5 , *9.0*)	(7.5 , *9.0*)	(4.5 , 6.0)
DM_1	a_2	(4.5 , 6.0)	(3.0 , 4.5)	(4.5 , 6.0)	(4.5 , 6.0)	(1.5 , 3.0)	(6.0 , 7.5)	(*3.0* , 4.5)
	a_3	(*3.0* , 4.5)	(3.0 , 4.5)	(4.5 , 6.0)	(4.5 , 6.0)	(3.0 , 4.5)	(6.0 , 7.5)	(3.0 , 4.5)
	a_1	(7.5 , 9.0)	(7.5 , *9.0*)	(7.5 , *9.0*)	(6.0 , *7.5*)	(7.5 , *9.0*)	(6.0 , *7.5*)	(7.5 , 9.0)
DM_2	a_2	(*3.0* , 4.5)	(4.5 , 6.0)	(3.0 , 4.5)	(4.5 , 6.0)	(6.0 , 7.5)	(4.5 , 6.0)	(*4.5* , 6.0)
	a_3	(3.0 , 4.5)	(4.5 , 6.0)	(4.5 , 6.0)	(4.5 , 6.0)	(4.5 , 6.0)	(4.5 , 6.0)	(4.5 , 6.0)
	a_1	(7.5 , 9.0)	(7.5 , *9.0)*	(7.5 , *9.0*)	(6.0 , *7.5*)	(6.0 , 7.5)	(4.5 , 6.0)	(7.5 , 9.0)
DM_3	a_2	(4.5 , 6.0)	(6.0 , 7.5)	(3.0 , 4.5)	(4.5 , 6.0)	(3.0 , 4.5)	(1.5 , 3.0)	(*4.5* , 6.0)
	a_3	(*1.5* , 3.0)	(4.5 , 6.0)	(3.0 , 4.5)	(3.0 , 4.5)	(7.5 , *9.0*)	(6.0 , *7.5*)	(4.5 , 6.0)
	a_1	(7.5 , 9.0)	(7.5 , *9.0*)	(7.5 , *9.0*)	(6.0 , *7.5*)	(7.5 , *9.0*)	(6.0 , *7.5*)	(6.0 , 7.5)
DM_4	a_2	(6.0 , 7.5)	(4.5 , 6.0)	(6.0 , 7.5)	(3.0 , 4.5)	(1.5 , 3.0)	(4.5 , 6.0)	(*4.5* , 6.0)
	a_3	(*3.0* , 4.5)	(4.5 , 6.0)	(4.5 , 6.0)	(4.5 , 6.0)	(6.0 , 7.5)	(4.5 , 6.0)	(4.5 , 6.0)

In Step 2, the decision matrix was normalized, and in Step 3, the standardized decision matrix $\otimes Y^k$ and the reference series were created (Table 8).

Table 8. Standardized decision matrix.

$\otimes y_{ij}^k$		c_1	c_2	c_3	c_4	c_5	c_6	c_7
$\mathbf{y^{k,0}}$		1.00	1.00	1.00	1.00	1.00	1.00	1.00
	a_1	(0.33 , 0.40)	(0.83 , 1.00)	(0.83 , 1.00)	(0.80 , 1.00)	(0.83 , 1.00)	(0.83 , 1.00)	(0.50 , 0.67)
DM_1	a_2	(0.50 , 0.67)	(0.33 , 0.50)	(0.50 , 0.67)	(0.60 , 0.80)	(0.17 , 0.33)	(0.67 , 0.83)	(0.67 , 1.00)
	a_3	(0.67 , 1.00)	(0.33 , 0.50)	(0.50 , 0.67)	(0.60 , 0.80)	(0.33 , 0.50)	(0.67 , 0.83)	(0.67 , 1.00)
DM_2	a_1	(0.33 , 0.40)	(0.83 , 1.00)	(0.83 , 1.00)	(0.80 , 1.00)	(0.83 , 1.00)	(0.80 , 1.00)	(0.50 , 0.60)

	a_2	(0.67 , 1.00)	(0.50 , 0.67)	(0.33 , 0.50)	(0.60 , 0.80)	(0.67 , 0.83)	(0.60 , 0.80)	(0.75 , 1.00)
	a_3	(0.67 , 1.00)	(0.50 , 0.67)	(0.50 , 0.67)	(0.60 , 0.80)	(0.50 , 0.67)	(0.60 , 0.80)	(0.75 , 1.00)
	a_1	(0.17 , 0.20)	(0.83 , 1.00)	(0.83 , 1.00)	(0.80 , 1.00)	(0.67 , 0.83)	(0.60 , 0.80)	(0.50 , 0.60)
DM_3	a_2	(0.25 , 0.33)	(0.67 , 0.83)	(0.33 , 0.50)	(0.60 , 0.80)	(0.33 , 0.50)	(0.20 , 0.40)	(0.75 , 1.00)
	a_3	(0.50 , 1.00)	(0.50 , 0.67)	(0.33 , 0.50)	(0.40 , 0.60)	(0.83 , 1.00)	(0.80 , 1.00)	(0.75 , 1.00)
	a_1	(0.33 , 0.40)	(0.83 , 1.00)	(0.83 , 1.00)	(0.80 , 1.00)	(0.83 , 1.00)	(0.80 , 1.00)	(0.50 , 0.67)
DM_4	a_2	(0.40 , 0.50)	(0.50 , 0.67)	(0.67 , 0.83)	(0.40 , 0.60)	(0.17 , 0.33)	(0.60 , 0.80)	(0.75 , 1.00)
	a_3	(0.67 , 1.00)	(0.50 , 0.67)	(0.50 , 0.67)	(0.60 , 0.80)	(0.67 , 0.83)	(0.60 , 0.80)	(0.75 , 1.00)

In Step 4, the difference matrix ($\otimes\Delta^k$) was created with the weights of criterias in Table 9.

Table 9. Difference matrix.

$\otimes\Delta^k$		c_1	c_2	c_3	c_4	c_5	c_6	c_7
	a_1	(0.60 , 0.67)	(0.00 , 0.17)	(0.00 , 0.17)	(0.00 , 0.20)	(0.00 , 0.17)	(0.00 , 0.17)	(0.33 , 0.50)
DM_1	a_2	(0.33 , 0.50)	(0.50 , 0.67)	(0.33 , 0.50)	(0.20 , 0.40)	(0.67 , 0.83)	(0.17 , 0.33)	(0.00 , 0.33)
	a_3	(0.00 , 0.33)	(0.50 , 0.67)	(0.33 , 0.50)	(0.20 , 0.40)	(0.50 , 0.67)	(0.17 , 0.33)	(0.00 , 0.33)
	a_1	(0.60 , 0.67)	(0.00 , 0.17)	(0.00 , 0.17)	(0.00 , 0.20)	(0.00 , 0.17)	(0.00 , 0.20)	(0.40 , 0.50)
DM_2	a_2	(0.00 , 0.33)	(0.33 , 0.50)	(0.50 , 0.67)	(0.20 , 0.40)	(0.17 , 0.33)	(0.20 , 0.40)	(0.00 , 0.25)
	a_3	(0.00 , 0.33)	(0.33 , 0.50)	(0.33 , 0.50)	(0.20 , 0.40)	(0.33 , 0.50)	(0.20 , 0.40)	(0.00 , 0.25)
	a_1	(0.80 , 0.83)	(0.00 , 0.17)	(0.00 , 0.17)	(0.00 , 0.20)	(0.17 , 0.33)	(0.20 , 0.40)	(0.40 , 0.50)
DM_3	a_2	(0.67 , 0.75)	(0.17 , 0.33)	(0.50 , 0.67)	(0.20 , 0.40)	(0.50 , 0.67)	(0.60 , 0.80)	(0.00 , 0.25)
	a_3	(0.00 , 0.50)	(0.33 , 0.50)	(0.50 , 0.67)	(0.40 , 0.60)	(0.00 , 0.17)	(0.00 , 0.20)	(0.00 , 0.25)
	a_1	(0.60 , 0.67)	(0.00 , 0.17)	(0.00 , 0.17)	(0.00 , 0.20)	(0.00 , 0.17)	(0.00 , 0.20)	(0.33 , 0.50)
DM_4	a_2	(0.50 , 0.60)	(0.33 , 0.50)	(0.17 , 0.33)	(0.40 , 0.60)	(0.67 , 0.83)	(0.20 , 0.40)	(0.00 , 0.25)
	a_3	(0.00 , 0.33)	(0.33 , 0.50)	(0.33 , 0.50)	(0.20 , 0.40)	(0.17 , 0.33)	(0.20 , 0.40)	(0.00 , 0.25)

In Step 5, the grey relational coefficients were calculated by multiplying and summing the grey relation coefficients and the criterion weights obtained by the decision-makers using the BWM method, presented in Table 10.

Table 10. Grey relational coefficients.

w		c_1 0.25	c_2 0.27	c_3 0.19	c_4 0.07	c_5 0.08	c_6 0.11	c_7 0.03
	a_1	(0.38 , 0.41)	(0.71 , 1.00)	(0.71 , 1.00)	(0.67 , 1.00)	(0.71 , 1.00)	(0.71 , 1.00)	(0.45 , 0.56)
DM_1	a_2	(0.45 , 0.56)	(0.38 , 0.45)	(0.45 , 0.56)	(0.51 , 0.67)	(0.33 , 0.38)	(0.56 , 0.71)	(0.56 , 1.00)
	a_3	(0.56 , 1.00)	(0.38 , 0.45)	(0.45 , 0.56)	(0.51 , 0.67)	(0.38 , 0.45)	(0.56 , 0.71)	(0.56 , 1.00)
	a_1	(0.33 , 0.36)	(0.66 , 1.00)	(0.66 , 1.00)	(0.63 , 1.00)	(0.66 , 1.00)	(0.63 , 1.00)	(0.40 , 0.46)
DM_2	a_2	(0.50 , 1.00)	(0.40 , 0.50)	(0.33 , 0.40)	(0.46 , 0.63)	(0.50 , 0.66)	(0.46 , 0.63)	(0.57 , 1.00)
	a_3	(0.50 , 1.00)	(0.40 , 0.50)	(0.33 , 0.40)	(0.46 , 0.63)	(0.40 , 0.50)	(0.46 , 0.63)	(0.57 , 1.00)
	a_1	(0.33 , 0.34)	(0.71 , 1.00)	(0.71 , 1.00)	(0.67 , 1.00)	(0.56 , 0.71)	(0.51 , 0.67)	(0.45 , 0.51)
DM_3	a_2	(0.36 , 0.38)	(0.56 , 0.71)	(0.38 , 0.45)	(0.51 , 0.67)	(0.38 , 0.45)	(0.34 , 0.41)	(0.62 , 1.00)
	a_3	(0.45 , 1.00)	(0.45 , 0.56)	(0.38 , 0.45)	(0.41 , 0.51)	(0.71 , 1.00)	(0.67 , 1.00)	(0.62 , 1.00)
	a_1	(0.38 , 0.41)	(0.71 , 1.00)	(0.71 , 1.00)	(0.67 , 1.00)	(0.71 , 1.00)	(0.67 , 1.00)	(0.45 , 0.56)
DM_4	a_2	(0.41 , 0.45)	(0.45 , 0.56)	(0.56 , 0.71)	(0.41 , 0.51)	(0.33 , 0.38)	(0.51 , 0.67)	(0.62 , 1.00)
	a_3	(0.56 , 1.00)	(0.45 , 0.56)	(0.45 , 0.56)	(0.51 , 0.67)	(0.56 , 0.71)	(0.51 , 0.67)	(0.62 , 1.00)

The γ_i^k values were obtained by clarification in Step 6 - 7, as shown in Table 11.

Table 11. Clarification of the grey relational degree

		$\gamma_i^{k,-}$	$\gamma_i^{k,+}$	γ_i^{k}			$\gamma_i^{k,-}$	$\gamma_i^{k,+}$	γ_i^{k}
	a_1	0.6176	0.8389	0.7283		a_1	0.5663	0.8232	0.6948
DM_1	a_2	0.4431	0.5534	0.4983	DM_2	a_2	0.4371	0.6580	0.5476
	a_3	0.4729	0.6699	0.5714		a_3	0.4289	0.6453	0.5371
	a_1	0.5711	0.7616	0.6664		a_1	0.6138	0.8389	0.7263
DM_3	a_2	0.4347	0.5318	0.4832	DM_4	a_2	0.4605	0.5690	0.5148
	a_3	0.4868	0.7422	0.6145		a_3	0.5028	0.7145	0.6086

In the final step, the alternatives were scored, identifying Alternative $_3$ as the highest-ranking option (Table 12).

Table 12. Scores obtained for the alternatives.

Alternative $_1$	0.7035
Alternative $_2$	0.5104
Alternative $_3$	0.5821

Conclusion

Hospital site selection is critical for efficient delivery of healthcare services and accessible service provision to the community. Appropriate site selection not only improves patient access and comfort, but also affects operating costs, resource allocation and long-term sustainability of the service. Effective hospital site selection improves public health, shortens response times and ensures that services reach a wide segment of the population.

In this study, BWM and GRA MCDM methods were used to determine the most appropriate site for a private hospital in Burdur province. BWM is a simple and fast method that allows decision makers to determine weights by comparing only the best and worst criteria, and it provides more reliable results by reducing comparison errors. In addition, its flexibility allows it to be used effectively in various fields. GRA, on the other hand, provides an objective approach to comparing alternatives and determining the most appropriate option by providing robust results even when data are uncertain or incomplete. Both methods provide decision makers with a flexible, reliable and practical solution, making them the preferred tools in complex decision-making processes.

The decision-making group consisting of four experts in the field evaluated the alternative three sites in the light of seven criteria. In the first stage, the criteria were weighted with the linear BWM method, and then grey numbers were used in the evaluation of three alternatives. The results revealed that the most suitable site for a privata hospital according to the determined criteria is Alternative$_1$. It is obvious that such analyses are an effective decision support tool for the development of health infrastructure and will help health institutions to make more informed, data-driven decisions.

The proposed method, which have been used together in only a limited number of studies in the literature, are considered a promising alternative when applied in a hierarchical structure or combined with other methods, especially given the complexity of real-world MCDM problems.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPSTEM Journal belongs to the author.

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