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Employment of multi criteria decision making techniques and mathematical formulation for Construction of the sustainable hospital

Zahra Mohammadnazari[1]; Seyed Farid Ghannadpour[1,]*

[1] *Department of industrial engineering, Iran University of science and technology, 16846-13114.*

Abstract

Background and objective: One of the most prominent factors in the success of medical systems is finding a proper location to build hospitals and other medical care centers. On the other hand, sustainable development is illustrated an important concept for both private and public sectors which focuses on three aspects of development: social, environmental and economical. Hence in order to find the best location, taking in to account sustainable criteria, can pave the path of meeting triple bottom line requirements in the field of hospitals construction.

Methods: Focus in this paper is on identifying the best location for the hospital construction with the help of best-worst method to find weights of each criteria and then The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to rank the possible locations. After applying TOPSIS method, with the use of additive utility function we analyze the initial ranking. In the next step Mathematical formulation has been applied in order to find the proper locations to open hospital. The objective functions consist of two equations; the first one is minimizing the opening cost and penalty cost (because of the fact that the proximity of hospitals to patients are of high importance); the second one is related to maximizing the utilities obtained from las step.

Results and conclusion: according to the case study which was implemented in Tehran, the best locations for hospital construction considering penalty cost, construction cost and utilities of each hospital to offer better service, have been identified.

Keywords: Sustainable Supplier selection, Multiple Criteria Decision Making, Data Envelopment Analysis, Multi-Attributed Utility Theory

1. Background and objectives

Hospitals are one of the critical medical centers due to the fact that their services needs to be efficient while meeting environmental and social targets. Not only are these factors significant for hospitals, but also limited space and large construction investment and operating cost can influence hospitals construction(1).one of the most important issues which must be taken in to account is finding the best and most desirable location for hospital construction. The importance of this issue is supported by the fact that hospitals must be shared among different types of patients with different access time. As their relief and comfort is the ultimate goal of hospitals and other medical centers, so selecting the best place for hospitals' locations is a momentous task (2). Strategic planning of hospitals is long term decisions like facility location and Capacity relocation for which decision makers need to consider various policy objectives such as improving accessibility and minimizing costs. Location-finding and Location-allocation models help decision makers to analyze the opening, closing or resizing of facilities in order to achieve some specific objectives (3).

Sustainable development is one of the most fundamental scientific and practical fields of development and excellence in modern human societies. This issue is particularly important for under developed countries, and so far, many actions have been taken in to account to determine its policies. They have become widespread since the end of the 1980s and remained a challenge for policy makers and the scientific community(4). In the concept of Sustainable development the 'triple bottom line', coined by John Elkington, requires the balancing of financial, social and environmental objectives. Considering 'triple bottom line' in the health sector is crucial (1), because "sustainable development is not arbitrary"(5) .In fact, to advance into sustainability, sustainability oriented companies

* Corresponding author (✉). Permanent Address: Department of Industrial Engineering, Iran University of Science and Technology, Tehran, Iran, 16846-13114.
Tel.: +98 21 73225015;
Email: ghannadpour@iust.ac.ir

needs to amalgamate the TBL(Triple bottom line) perceptions in their decision making, and this behavior culminates in effectively implementing sustainability initiatives in strategic planning processes. Thus, sustainability within a business model requires a company to adapt a pervasive sustainability orientation and organize this approach in sustainability plans (6). The need for integrating 'triple bottom line' in the health sector has been sensed, but less systematic attempts have been made to model the competing objectives (1).

Multi-criteria decision-making (MCDM) is an important branch of decision-making theory. MCDM problems fall into two classes with respect to the solution space of the problem: continuous and discrete. To handle continuous problems, multi-objective decision-making (MODM) techniques will be applied. Discrete problems will be solved with multi-attribute decision- making (MADM) techniques (7).in the field of Multi-criteria decision-making several MCDM methods have been proposed; the most popular one is AHP(Analytic Hierarchy Process) (8, 9), ANP (Analytic Network Process) (10), TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) (11, 12) , ELECTRE (Elimination Et Choix Traduisantla REalité) (Elimination and Choice Expressing REality) (13, 14) ,VIKOR (VlseKriterijumska Optimizacija I Kompromisno Resenje) (15) , and PROMETHEE (Preference Ranking Organization method for Enrichment Evaluations) (14, 16, 17) . Additive utility method is one of the decision making tools which tries to infer or evaluate the decision-making models using preference data or previous decisions as a list of ranking choices. The Additive utility method is a way for extracting the Additive utility functions among a set of past data. These methods receive the scores (reference set) or an input to help detecting set of choices by decision makers and also ranking of the choices from best to worst. After receiving the inputs, this method uses the linear programming techniques to get a private decision making model in form of a utility function for decision maker to recreate completely and precisely the presented ranking for choices, as much as possible. The utility function can also evaluate the utility of the options which are not in reference set according to given scores. So it can be said that the utility functions diminishes biased point of views of decision makers (18). UTASTAR method suggested by Siskos and Yannacopoulos (19) is an advanced version of primary UTA. In original UTA (20), there is an independent error for each alternative $a \in A_R$,and is called σ(a) which should be minimized.

Popovic and his colleagues proposed an efficient model for the selection of an optimal location for the construction of a tourist hotel. The application of the multiple-criteria decision-making (MCDM) methods is proposed because the examined problem is related to a set of alternatives that should be estimated against a set of conflicting criteria. The model apply the adapted step-wise weight assessment ratio analysis (SWARA) for the finding of the weights of criteria and the Weighted Sum method, based on the decision-maker's preferred levels of performances for the final prioritization and ranking of alternative locations. At last a case study has been delineated which includes the consideration of six Serbian mountains as the potential locations where a tourist hotel could be constructed (21). Sedady, Beheshtinia proposed a MCDM technique in order to find the priority of renewable power plants construction with the help of technical, political aspects and sustainable triple bottom line (22).

In the path of utilizing MCDM techniques for finding the solutions in different field, Beheshtinia, Omidi applied BSC and CSR to find the criteria regarding the performance evaluation of banks; furthermore, an integrated form of AHP-FTOPSIS, AHP-FVIKOR, MDL-FTOPSIS and MDL-FVIKOR using the Copeland method To rank the options (23). For evaluation of criteria that affect hospital service quality Torkzad, Beheshtinia modified digital logic–technique analytical hierarchy process to evaluate hospital service quality. The Copeland method has been used to aggregate the results(24). For ranking the suppliers in advertising industry Beheshtinia, Nemati-Abozar considered a novel approach. Modified Digital Logic (MDL) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) using fuzzy theory has been used to help researchers to find the solution (25). In order to present a solution for finding suitable technology transfer strategy for roller concrete road pavement, Beheshtinia, Ahangareian Abhari applied Modified Digital Logic (MDL) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). In this research, criteria have been identified using Delphi method. In the next step MDL is used for obtaining the attribute relative importance. TOPSIS method has been utilized in the last step in order to rank the alternatives(26).Because of variability in emergency department in hospitals, M. Gul et al. applied interval type-2 fuzzy analytic hierarchy process (IT2FAHP) in their study in order to evaluate the performance of hospitals specifically in the emergency ward. (IT2FAHP) has been used to extract criteria and obtain their weights. In the next step ELECTRE method has been implemented to evaluate the ED performance and select the best scenario. M. Gul et al tried to incorporate and consider manager's preferences in their modeling(27). Ghatreh Samani, Hosseini-Motlagh presented a policy in order to lessen the disruption risk using hybrid technique of the fuzzy analytic hierarchy process and grey rational analysis. To control and manage the network a p-robust formulation is presented. They tried to design a network for blood supply chain for disruptions and uncertainties (28). Ghatreh Samani et al. designed an integrated blood supply chain network with the help of multi-objective mixed integer linear programming model. Uncertainty in demand of blood products and their irregular supply while considering perishability of blood products are the major issues of this research. a trade-off analysis between the cost efficiency (via minimizing the total costs) and the responsiveness level of the designed network has been takin in to consideration in their study(29). Goh et al. studied how a logistics service provider managing the suppliers for several hospitals can amend the supplier selection process. The paper attempts to the take in to account set for healthcare supplier selection such as response time, reliability, stock quantity, in order to realize optimal cube utilization, cost, and customer satisfaction (30). Lupo proposed a framework to evaluate service quality in the public healthcare sector. ServQual disconfirmation paradigm and the Analytic Hierarchy Process (AHP) method have been applied to help decision makers estimate the service quality expectations. Linguistic evaluation scales parameterized by triangular fuzzy numbers has helped the author to cover subjectivity and vagueness on the part of stake holders (31).

Cheraghi et al. presented model for blood platelets production planning using a mixed-integer linear programming considering the processes of blood collection as well as production/testing, inventory control and distribution. While integrating the processes of blood collection as well as production/testing, inventory control and distribution. a robust programming approach is implemented to capture the uncertainty(32).

In the study of Duane and his colleagues Probabilistic modelling using secondary data analysis has been implemented. They tried to Estimates carbon emitted by a health service using human resource information and applying decision-support model to measure the carbon footprint.so they tried to use triple bottom line optimization in the case of planning for hospitals considering patient choice and carbon mitigation and cost reduction. the results of this study shows that Clinic utilization rates improved by proper planning from 50% to 78% and Human resource savings were identified that could be redirected towards improving patient care(1). Dos Santos used AHP to assess criteria for sustainability models in various fields, so he identified fourteen application areas of AHP to support sustainable development. He used MCDM approaches in the field of Manufacturing and urban-related sustainability decisions, hence he used Fuzzy AHP as a support tool (33). Mestre and her colleagues aim to inform how the hospital networking system may be organized when the decision maker wants to improve geographical access considering costs (3).In the paper of Moscelli, the authors investigated (a) how patient choice of hospital is influenced by distance, quality and waiting times, (b) differences in choices between patients in urban and rural locations, (c) the relationship between hospitals' elasticities of demand to quality and the number of local rivals, and how these changed after relaxation of constraints on hospital choice in England in 2006. Using a data set on over 500,000 elective hip replacement patients over the period 2002 to 2013 we find that patients became more likely to travel to a provider with higher quality or lower waiting times. According to this paper the rate of patients who refer to the hospital increased from 25% to almost 50% as hospital quality increased. They stated that distance is the major predictor of hospital choice. Before 2006, demand was sometimes higher for providers with worse quality or longer waiting times, but after 2006 these patterns changed and we find that patients preferred providers with lower waiting times(34). Moore, ReVelle tried to maximize coverage of population on either the number of each type of facility using relaxed linear programming is used to solve the resulting integer programming problem. An application is described that uses distance and population data developed for a region of Honduras (35). Ruth RJ Used a quantitative model to aid in planning an efficient hospital service among hospitals in a region. The planning is to be done by a regional health systems planning agency, which sets or enforces standards of accessibility and acceptability to be achieved through a modification of the current system. Constraints of theirs model focus on accessibility and acceptability by patients and also meeting the required quality standards and handling the target population needs(36). Güneş ,Yaman presented an integer programming formulation for the hospital re-planning problem. The model finds the best re-allocation of resources among hospitals to minimize the system costs subject to quality and capacity constraints. A case study in the Turkish hospital is illustrated to show the implications of consolidation of health insurance funds on resource allocations and flow of patients in the system (37). Pérez-Pineda,E. Privetera took Guadalupano Hospital as case study for understanding the factors shaping the sustainable growth of hospital administration and operations to focus on the need for a professional management team(38). Some researches like the proposed model of Otay. et al focused on the performance evaluation of Healthcare industry. a new multi-expert fuzzy approach integrating intuitionistic fuzzy Data Envelopment Analysis (DEA) and intuitionistic fuzzy Analytic Hierarchy Process (IF-AHP) with a real life case study was presented by him.(39). A frame work based on the concept of fuzzy sets theory and the VIKOR method for evaluating the hospital service quality under a fuzzy environment was proposed by Chang, T.-H (40). In table 1 the following a summary of researches which have been conducted in the field of hospital planning and location allocation is shown .

Table 1. Summary of researches

Ref.	MCDM Methods						Programming Model	Sustainable Criteria			Constraints			Performance Evaluation
	AHP	TOPSIS	DEA	VIKOR	PROMTHE	DEMATEL		Social	Environmental	Economical	Accessibility	acceptability	quality	
[33]	✓	-	-	-	-	-	-	✓	✓	✓	-	-	-	-
[35]	-	-	-	-	-	-	✓	-	-	-	✓	✓	-	-
[36]	-	-	-	-	-	-	✓	-	-	-	-	-	✓	-
[39]	-	✓	✓	-	-	-	-	-	-	✓	-	-	-	-
[41]	-	-	-	-	✓	✓	-	-	-	-	-	-	-	-
[3]	-	-	-	-	-	-	✓	-	✓	✓	-	-	-	-
[42]	✓	-	-	-	-	-	-	-	✓	-	-	-	-	✓
[37]	-	-	-	-	-	-	✓	-	-	-	✓	-	-	-
[43]	✓	-	-	-	-	-	-	-	✓	-	-	-	-	-
[44]	-	-	-	-	-	-	✓	-	-	-	✓	-	-	-
[45]	-	✓	-	-	-	-	-	-	✓	✓	-	-	-	-
[46]	-	-	-	-	✓	-	-	-	-	-	-	-	-	✓
[47]	✓	-	-	-	-	-	-	-	✓	✓	-	-	-	-

Statistics show that for every 1000 people, 3 beds have been assigned in order to meet the needs of target population, but this number is far from the average all around the world. Hence, in this study we seek to present a methodology for finding the best location in order to construct hospital owing to the fact that meeting the demand of population is momentous. Hospital construction is not our only solution, we tried to find the best location according to the demand zones and also utility of each hospitals to assign the demands to the hospitals. The proposed methodology consists of 2 parts; MCDM approach to obtain the utilities of each hospital and mathematical formulation to help us decide about allocation of demand zones to hospitals. To start using MCDM approaches, the first thing that needs to be done is obtaining each one of criteria's weights. Gaining the mentioned weights, some methods have been utilized. Best-worst method is among them which introduced by Jafar Rezaei (7). In order to use experts' ideas we need to be sure that those ideas are not biased and eventually can express the strength of criterion I to criterion j appropriately. Obtaining weights of each criterion, decision makers (DM) compare criterion with the best one and also with the worst, so with applying this method DM can express his preferences more easily that will culminate in facilitating the comparing process. In the next step, by obtaining criteria's weights, The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) has been chosen to rank the possible locations for building the hospital. Through using TOPSIS the alternatives' ranking has been found. Some of the multi-criteria decision-making (MCDM) techniques use the utility function to appraise value (utility) of alternatives. With the use of UTASTAR Method we can analyze the initial ranking and the evaluation of criteria's weight in the decision management perspective. Other advantages of this method are the following:

- Estimation of the utility function and the selection of options with the least information.

- Solve the issue even if the indices are not independent of each other.

- Obtaining the weight of evaluation of criteria from previous decision-making data (41) (42).

Hence after applying TOPSIS method, with the help of UTASTAR Method the evaluation of criteria's weight will be obtained. In the last step, mathematical formulation has been applied in order to find the proper locations to open hospital. The objective functions consist of two equations; the first one is minimizing the opening cost and penalty cost (because of the fact that the proximity of hospitals to patients are of high importance); the second one is related to maximizing the utilities obtained from las step. Considering the literature review and the table of articles, the followings have been found research gap:

Sustainable development triple bottom line has not been found in the articles related to the location finding. There have not been any researches in order to find the location for hospitals using TOPSIS method while considering a hybrid approach using multi objective programming. Applying mathematical formulation in order to find the best hospitals to be built and assigning the patients to the hospitals are considered the novel idea behind the scenario of this research. Some articles utilized hybrid approaches in the field of hospital performance evaluation but not in hospital construction. No article has been found in which additive utility function has been implemented for extracting the utility functions among a set of past data in order to pave the path of decision making regarding the hospital construction. This method receives the scores (reference set) or an input to help detecting set of choices by decision makers and also ranking of the choices from best to worst. After receiving the inputs, this method uses the linear programming techniques to get a private decision making model in form of a utility function for decision maker to recreate completely and precisely the presented ranking for choices, as much as possible.

2- Method

As it was mentioned before, finding the best possible place for hospital construction is momentous. . Based on the studies which has been conducted, healthcare infrastructure provides the basic support for healthcare operations and services, and they are essential for effective operations of healthcare systems. Accessibility to health care services is a central policy goal in most health care systems. Regarding the accessibility of healthcare facilities, it has been proved that distance to hospitals is an important factor when patients choose the healthcare service. The proposed methodology consists of 2 parts; MCDM approach to obtain the utilities of each hospital and mathematical formulation to help us decide about allocation of demand zones to hospitals. Furthermore, identifying proper criteria to be applied in the first stage needs vigilance.in this paper according to the importance of sustainability concept and its effect on the prosperity of the society, the criteria have been determined using sustainable factors. In the first step, 6 criteria have been found which will be explained in the further paragraphs. By determining the appropriate criteria, in order to rank the possible options, TOPSIS method has been implemented, but to start the process of ranking, criteria's weights need to be obtained. Best-worst method is used to obtain desired weights.at last by gaining the ranking from TOPSIS method Additive utility method is used to infer or evaluate the decision-making models using preference data or previous decisions as a list of ranking choices. The Additive utility method is a way for extracting the Additive utility functions among a set of past data. This method receives the scores (reference set) or an input to help detecting set of choices by decision makers and also ranking of the choices from best to worst.in the last step, mathematical formulation has been applied in order to find the proper locations to open hospital. The objective functions consist of two equations; the first one is minimizing the opening cost and penalty cost (because of the fact that the proximity of hospitals to patients are of high importance); the second one is related to maximizing the utilities obtained from las step. Figure1 shows the Steps of this research in brief.

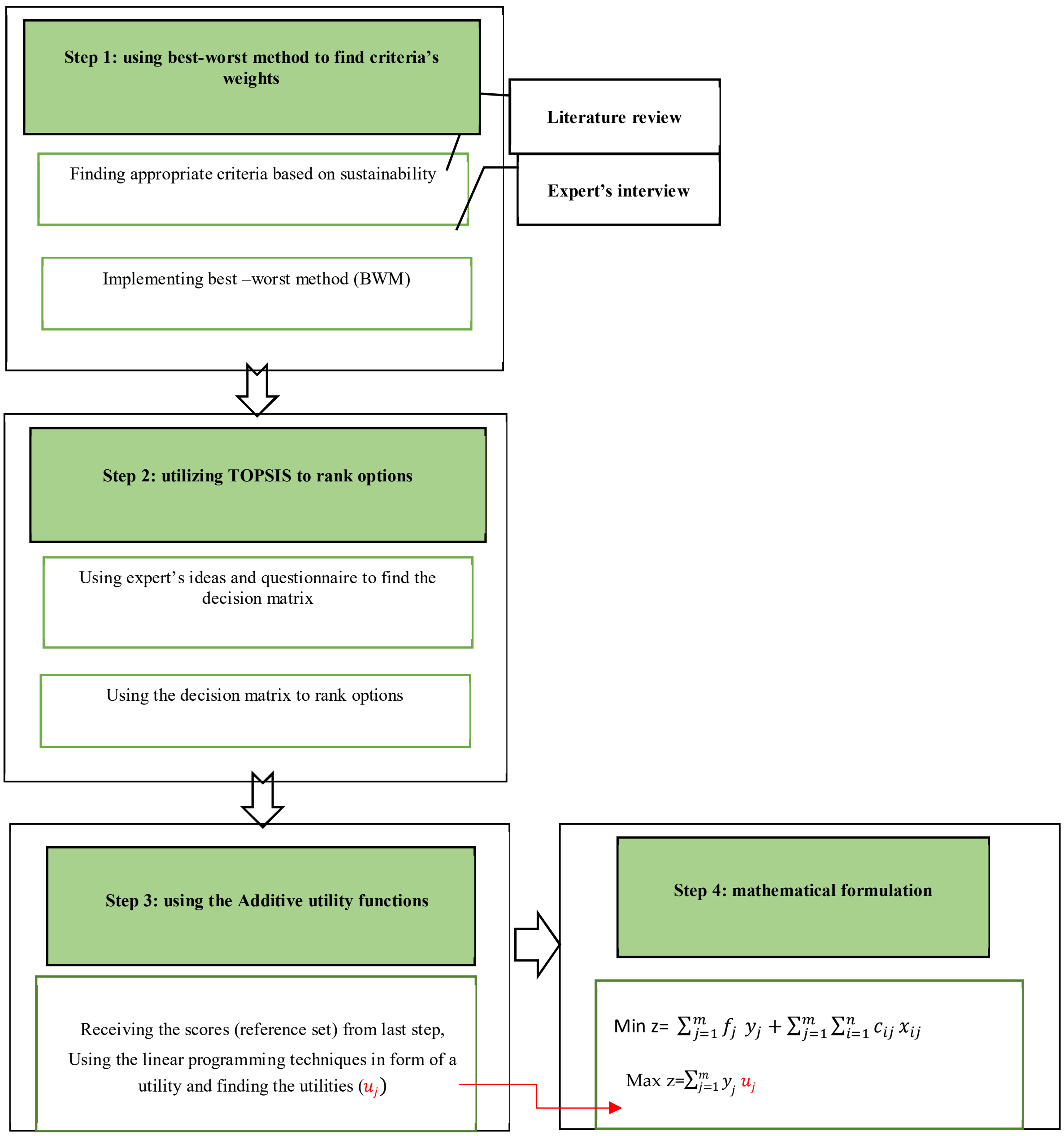

Figure 1. Research methodology

2.1 finding criteria

There has been 6 criteria used in the questionnaire which will be discussed below:

The first factor is related to accessibility of the location. Nowadays, with the growing population in cities and villages, two factors of availability and time of movement from a specific place to destination, play a decisive role in choosing the method of transportation to the destination. Therefore, subjects such as timely emergency services, allocation of a parking lot with the demanded capacity, the number of available subways and bus stations at a distance of about two kilometers and ... are the critical factors for evaluating and finalizing the value and scoring of each of the options, so for avoiding the complexity and considering the mentioned subjects we have assigned a number to each alternative based on the three questions below:

1-What is the number of subways within a radius of two kilometers of the site being investigated (for each subway, the alternative is scored for 2)

2. What is the infrastructure or the possibility of developing welfare factors related to health centers? How many of them are found in for each alternative in the case (0 = none .1 = some facilities are available but there are deficiencies, 2: Existing welfare factors is desirable)

3- How many bus stations are located at a radius of two kilometers from the site (for each station, the alternative is scored by 0.5)

The second factor is related to the tangible negative effect on the traffic in the surrounding area. One of the consecutive factors for finding the best location is the impact of the construction on traffic congestion. Owing to the fact that one way of accessing to the hospitals are by private cars for which the traffic jam are so important.

The third factor is environmental factors which can be summarized as below question:

-What are the options for managing the range of infectious hospital waste?

The forth factor is financial matters. The construction of a service center, as a project, has a financial dimension. The establishment of a service center requires capital to begin with, which is essentially an investment. The interpretations of any available options should be based on indicators such as the price of the ground in which we want to build a hospital, the forecast and calculation of the return on investment, taking into account the estimated uncertainty of the estimated demand and the economic conditions of the inhabitants of the area, to ultimately measure the attractiveness of each of the schemes for the investors.

The fifth factor is target population. In fact, the most basic and most important criterion to be considered in each service facility is the target community that is intended to get the service. Whenever the target community is larger, there will be a need to establish a service center such as a hospital. Most of the criteria described above, such as financial issues, accessibility, etc., are, to a significant extent, influenced by the population referred to the health center.

The sixth factor is potential for future development. In the strategic review, one of the decisive factors in decision making is the potential for future development. In order to examine this factor, there are sub-factors such as land prices, elasticity, predictability, demand, and so on. This factor in the hospital's Perhaps is not a decisive factor, but there are examples in country that a clinic or a small clinic has become a major medical center, such as seyyed al shohada infirmary and Noor Clinic, which were originally a small health center, but over time have been expanded to become larger centers.

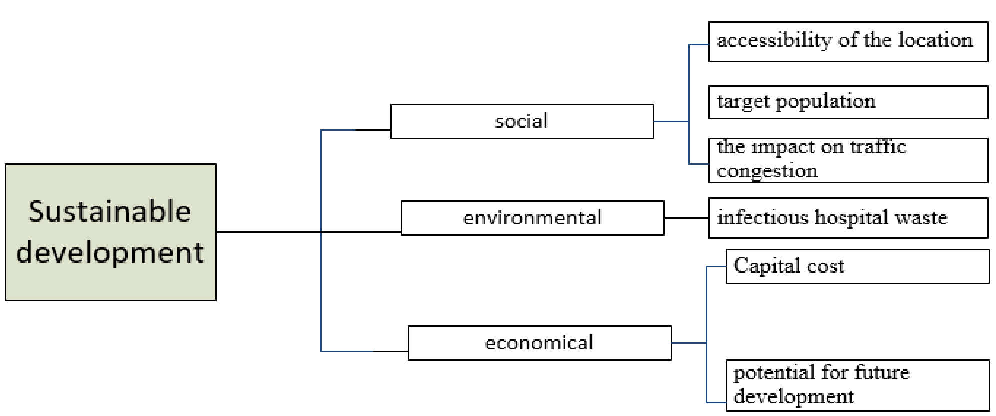

Figure 2. Criteria found based on sustainable development for location finding analysis

2.2 best-worst method (BWM)

BWM is a pairwise comparison-based multi-criteria decision-making method which has been utilized in different field such as green innovation (43), technology evaluation and selection (44), logistics performance evaluation (45) , research and development performance evaluation (46) and supply chain management.

To discuss the steps of this method, at first it is necessary to look over the concept and the purpose behind using this methodology.

Suppose we have n criteria and we want to make a pairwise comparison matrix, so as to begin the process of obtaining weights of each of the criteria.as it is shown below, in this matrix every of the elements is indicating the relative preference of criteria to each other; moreover, the pairwise comparison matrix will be filled by decision maker (DM) using 1 to 9 scale. For instance, a_{ij} is the relative preference of criterion I to the criterion j. if$a_{ij} = 1$, it shows that criterion I and criterion j have the same importance and if$a_{ij} > 1$, it shows that i is regarded as much more important one. If $a_{ij} = 9$, it is an indication of extreme importance of i to j (7).

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & & a_{2n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix} \quad [1]$$

Considering the reciprocal property of matrix, to complete the above mentioned matrix, (n-1)/2 pairwise comparisons will be done. There is a point regarding this matrix that needs our heed; it is related to its consistency .according to what is mentioned in literature a pairwise comparison matrix is consistent if:

$$a_{ik} \times a_{kj} = a_{ij} \ , \quad \forall i,j \quad [2]$$

The subject that was delineated above was the basics of pairwise comparison matrix, but still a question will be left and that one is the assurance and reliability of this matrix. In order to use experts' ideas we need to be sure that those ideas are not biased and eventually can express the strength of criterion I to criterion j appropriately. Best-worst method is introduced by Jafar Rezaei (7) in order to obtain weights of each criterion through comparing others criterion with the best one and also comparing them with the worst, so with applying this method DM can express his preferences more easily and eventually the comparing process will be facilitated.

In this section, we describe the steps of BWM that can be used to derive the weights of the criteria(7).

Step1. Determining asset of decision criteria

In this step, we consider criteria $\{ c_1, c_2, c_3, \ldots c_n\}$ that should be used for decision making.

Step2. Finding the best and the worst criteria.

In this step DM needs to identify the most important and also the least important criteria

Step3. Determining the preference of the best one over other criteria using a number between 1 to 9, which at last will make best-to- others vector.

$$A_{\boldsymbol{B}} = (a_{B1}, a_{B2}, \ldots, a_{B2}) \quad [3]$$

Step4. Determining the preference of other criteria over the worst one using a number between 1 to 9, which at last will make others- to-worst vector.

$$A_{\boldsymbol{w}} = (a_{w1}, a_{w2}, \ldots, a_{wn})^T \quad [4]$$

Step5. Finding the optimal weights $(w_1, w_2, w_3, \ldots w_n)$.The optimal weight for each criteria is the one for which $\frac{w_B}{W_J}$=a_{ij} and also $\frac{w_j}{W_W}$=a_{jW}.

To meet the requirements mentioned for obtaining criteria's weights, the maximum absolute differences | $\frac{w_B}{W_J}$-a_{ij}| , | $\frac{w_j}{W_W}$-a_{jW}| for all j needs to be minimized. Hence the model is shown in equation 5:

$$min \max_j \left\{ \left| \frac{W_B}{W_j} - a_{Bj} \right|, \left| \frac{W_j}{W_w} - a_{jw} \right| \right\}$$

s.t.

$$\sum_j W_j = 1$$

$$W_j \geq 0, far\ all\ j \quad [5]$$

In order to make the model in the linear form equation6is obtained:

$$min\ \xi$$

s.t.

$$\left| \frac{W_B}{W_j} - a_{Bj} \right| \leq \xi\ for\ all\ j$$

$$\left| \frac{W_j}{W_w} - a_{jW} \right| \leq \xi\ for\ all\ j \quad [6]$$

$$W_j \geq 0, far\ all\ j$$

2.3 TOPSIS method

The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was first put forward by Hwang and Yoon in 1981 .TOPSIS is an effective method for solving problems existing in multi-attribute decision-making with finite alternatives. The principle of this method is to rank the alternatives by calculating the distance of each alternative from the ideal solution and the negative ideal solution for problems in decision-making, thus to determine the optimum alternative.

Here are steps of TOPSIS method (47):

1) determining the decision matrix R = { r_{ij}}, in which r_{ij} is the value of the j th attribute in the i th alternative; i = 1, 2, …, m ; j = 1, 2, …, n .

(2) Taking in to account the difference of attributes in dimension and order of magnitude, normalize the decision matrix R and transform it to the normalized matrix $\acute{R}$= { $\acute{r_{ij}}$} .

(3) Finding the weighted normalized decision matrix V = {v_{ij} } by the following equation:

v_{ij}= W_j $\acute{r_{ij}}$

(5) Calculating the $D_{IS}$and $D_{NIS}$by the following equations:

$$\boldsymbol{S}_i^+ = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^+\right)^2}$$
$$\boldsymbol{S}_i^- = \sqrt{\sum_{j=1}^{n}\left(v_{ij} - v_j^-\right)^2} \quad [7]$$

6) Calculating the relative closeness of each alternative by the following equation:

$$RC_i = \frac{S_i^-}{S_i^+ + S_i^-} \quad [8]$$

The value of relative closeness reflects the relative superiority of the alternatives. Larger $RC_{\ i}$ indicates that the alternative i is relatively better, whereas smaller $RC_{\ i}$ indicates this alternative is relatively poorer.

2.4 UTASTAR method

In UTA literature, the Concepts, assumptions, definitions are presented as followings(41):

- The set of criteria is as {g_1, g_2, …, g_{N}} where N is the number of criteria.
- The reference set is denoted as A_{R} And a∈ A_{R} Is a single option in A_{R}.
- The evaluation scale of the criterion is $[g_{i^*}, g_i^*]$ where g_{i^*} Is defined as the worst score and g_i^*, is the best score in the scale.
- The score or performance of option α on ith criterion is denoted as $g_i(\alpha)$, and $g(a)$ is the vector of performances (or scores) of the option α on all N criteria. If it is assumed that criteria value or preference increases as the score increases, it holds:

$$\begin{cases} g_i(\alpha) > g_i(\beta) \Leftrightarrow \\ \alpha \succ \beta(\alpha\ is\ preferred\ to\ \beta) \\ g_i(\alpha) = g_i(\beta) \Leftrightarrow \\ \alpha \sim \beta(\alpha\ is\ preferred\ to\ \beta) \end{cases} \quad [9]$$

The utility function for criterion is defined as u_i And the global utility function as u. In literature the criteria utility functions are usually regarded marginal utility functions. Global and marginal utility functions are positive, non-decreasing, monotonous, real number functions. The global utility function ranges in [0,1] interval, but the marginal range to a fraction of it. Utility functions are formally defined as:

$$u_i: [g_{i^*}, g_i^*] \rightarrow [0,1] \quad [10]$$

The utility of option α on criterion is denoted as $u_{\mathrm{I}}[g_{\mathrm{I}}(\alpha)]$ and the global utility of option as $u[g(\alpha)]$. While criteria utility functions are considered as non-decreasing functions it holds that:

$$\begin{cases} u[g(\alpha)] > u[g(\beta)] \Leftrightarrow \\ \alpha \succ \beta(\alpha\ is\ preferred\ to\ \beta) \\ u[g(\alpha)] = u[g(\beta)] \Leftrightarrow \\ \alpha \sim \beta(\alpha\ is\ preferred\ to\ \beta) \end{cases} \quad [11]$$

The global utility function is assumed to be an additive function like following: (Equation 12)

$$u[\bar{g}(\alpha)] = \sum_{i=1}^{N} u_i[g_i(\alpha)] \quad [12]$$

Subject to the following constraints:

$$\begin{cases} \sum_{i=1}^{N} u_i[g_i^*] = 1 \\ u_i[g_{i^*}] = 0 \qquad ;\forall i = 1,2,\dots,N \end{cases} \quad [13]$$

Each marginal utility function is assumed to be continuous and piecewise linear, meaning that it contains linear parts linked each to the next one. Moreover, the evaluation scale $[g_{i^*}, g_i^*]$ of criterion is assumed to be divided into (α_i −1) equal intervals. The end points of intervals are denoted as g_i^j For criterion and interval, and are given from the following formula: (Equation 14)

$$g_i^j = g_{i^*} + \frac{j-1}{a_i - 1}[g_i^* - g_{i^*}] \ ; \quad \forall i = 1,2,\dots,N \quad [14]$$

The marginal value of an option α on criterion is approximated using linear interpolation: (Equation 15)

$$u_i[g_i(\alpha)] = u_i[g_i^j] + \frac{g_i(\alpha) - g_i^j}{g_i^{j+1} - g_i^j}\{u_i[g_i^{j+1}] - u_i[g_i^j]\} \ ; \quad \forall i = 1,2,\dots,N \quad [15]$$

In UTASTAR the global utility of an option a is: (Equation 16)

$$u'[g(\alpha)] = \sum_{i=1}^{N} u_i[g_i(\alpha)] - \sigma^+(\alpha) + \sigma^-(\alpha) \quad [16]$$

$\sigma^+(\alpha)$ and $\sigma^-(\alpha)$ are the overestimation and underestimation errors.

Supposing that reference set options are ordered from the most preferred to the least preferred, i.e. α_1 Is the best option and α_M Is the worst one, the utility differences of two consecutive options are: (Equation 17)

$$\Delta(\alpha_k, \alpha_{k+1}) = u'[g(a_k)] - u'[g(a_{k+1})] \quad [17]$$

Also, it is required that (Equation 18)

$$\begin{cases} \Delta(\alpha_k, \alpha_{k+1}) > \delta, & if\ \alpha_k \succ \alpha_{k+1} \\ \Delta(\alpha_k, \alpha_{k+1}) = 0, & if\ \alpha_k \sim \alpha_{k+1} \end{cases} \quad [18]$$

Where δ is a small positive number.

Eventually the utility differences of successive interval endpoints are: (Equation 19)

$$w_{ij} = u[g_i^{j+1}] - u[g_i^j] \geq 0 \quad ;\forall i = 1, 2, \ldots, N \quad ;\forall j = 1, 2, \ldots, a_i - 1 \quad [19]$$

It can be extrapolated that: (Equation 20)

$$\begin{cases} u_i(g_i^1) = 0 \quad ; \forall i = 1.2. \ldots . n \\ u_i(g_i^j) = \sum_{t=1}^{j-1} W_{it} \quad ; \forall i = 1,2, \ldots, n \quad ; \forall j = 2, 3, \ldots, \alpha_i - 1 \end{cases} \quad [20]$$

Having the preference order of the reference set options, the problem is to estimate the utility functions (their coefficients) on all criteria such that the order resulting when sorting with utilities calculated with the estimated utility functions, is as similar as possible with the given one. Considering the previous concepts and assumptions, the following linear program (LP) is used to estimate marginal and global utility functions. (Equations 21)

$$Min\ Z = \sum_{k-1}^{m} \left(\sigma_{(a_k)}^{+} + \sigma_{(a_k)}^{-}\right)$$

S.t:

$$\begin{aligned} &\begin{cases} \Delta(a_k, a_{k+1}) \geq \delta\ if\ a_k \succ a_{k+1} \\ \Delta(a_k, a_{k+1}) \geq 0\ if\ \ a_k \sim a_{k+1} \end{cases} \\ &u_i[g_i^{j+1}] - u_i[g_i^j] \geq 0 \quad ;\forall i, j \\ &\sum_{i-1}^{N} \sum_{j-1}^{a_i-1} w_{ij} = 1 \quad w_{ij} \geq 0 \quad ;\forall i, j \\ &w_{ij} \geq 0 \ \ , \sigma_{(a_k)}^{+} \geq 0 \ \ , \sigma_{(a_k)}^{-} \geq 0 \ \ ;\forall i, j\ and\ k \end{aligned} \quad [21]$$

2.4 mathematical formulation

The mathematical model of hospital location problem with constraints regarding the number of opened hospitals will be discussed in this section. This problem is considered as a binary integer-programming. The following notations are used to formulate the mathematical model.

Table2. Indexes, parameters and variables

Indexes	description
I	set of patients I=$\{\mathbf{1}, \mathbf{2}, \ldots \boldsymbol{n}\}$
J	set of potential hospital sites J=$\{\mathbf{1}, \mathbf{2}, \ldots \boldsymbol{m}\}$
parameters	**description**
$\mathbf{f_j}$	facility setup cost (j∈ J)
$\mathbf{s_j}$	Capacity of hospital j (j∈ J)
$\mathbf{c_{ij}}$	the transportation cost from client i to facility j.
$\mathbf{u_j}$	utility of constructing hospital j
p	Number of opened hospitals
Variables	**description**
$\mathbf{x_{ij}}$	Binary variable; if patients i is assigned to hospital j ,it will be 1
$\mathbf{y_j}$	Binary variable ;if hospital j is opened , it will be 1

F1 : Min z= $\sum_{j=1}^{m} f_j \; y_j + \sum_{j=1}^{m} \sum_{i=1}^{n} c_{ij} \, x_{ij}$ [22]

F2 : Max z=$\sum_{j=1}^{m} y_j \, u_j$

Subject to:

$\sum_{j=1}^{m} x_{ij} = 1 \qquad \forall i \in I$ [23]

$\sum_{i=1}^{m} x_{ij} \le s_j y_j \qquad \forall j \in J$ [24]

$x_{ij} \le y_j$ [25]

$\sum_{j=1}^{m} y_j \le p \qquad \forall j \in J \, , i \in I$ [26]

$x_{ij} = \{0,1\} \qquad \forall j \in J \, , i \in I$ [27]

$y_j = \{0,1\} \qquad \forall j \in J \, , i \in I$ [28]

The objective function (22) is to minimize the total cost which consist of construction cost and penalty cost and also maximizing the utility of hospital construction. Penalty cost is cost related to borne by the patients because of the distance which he needs to travel to get to the hospital. Constraints (23) ensures that each patient is assigned to a hospital. Constraints (24) guarantees that the total demands of patients assigned to a hospital does not exceed the hospital capacity. Constraints (26) guarantees that the number of opened hospitals needs to be maximum up to p. Constraints (5) and (6) provides the binary condition.

As the proposed model is multi objective programming, in order to solve, Pareto optimality is implemented. Trade-off between the objectives has been examined and different solutions suggested.

3. Results

In this section a case study is delineated regarding the problem of finding the best location to construct hospital considering sustainable criteria in Tehran capital of Iran. In Iran for every 1000 people, there is only1.7 beds available in hospitals. Statistics shows that this number is about 3 beds per 1000 people all around the world. There is also another point that needs our heed, roughly about 40-50% of available hospitals are in specific regions and districts. The available capacity of hospitals are much less than demands of patients (approximately in some districts 110% of capacity will be filled). Based on some specified factors such as the population of the district, proximity to the nearest hospital, traffic jam, land cost five locations have been determined as potentials for hospital construction. Five alternatives have been taken in to account to be examined according to multi criteria decision making (MCDM) techniques. The proposed locations are in district 2, district 1, district20, district21, district22.according to the government target for providing 43700 beds, about 24000 beds needs to be dedicated to TEHRAN. Some part of the planned beds have been provided, hence in this research Contractors are to build maximum two hospitals among the alternatives to meet demands. In the first step according to the three aspects of sustainable development, 6 criteria have been found which have been explained in the last section. The above mentioned criteria is summarized in table2 .After determining the appropriate criteria, in order to rank the possible options, TOPSIS method has been implemented, but to start the process of ranking, criteria's weights need to be obtained. Best-worst method is used to obtain desired weights. At last with the use of UTASTAR Method the weight of evaluation of criteria will be obtained. The selection phase is the next step after obtaining the utility of each hospital. With the help of mathematical formulation which has been discussed in the last section, construction cost and penalty cost have been minimized while maximizing the utilities of hospital construction. In this case study, 110 patients will be assigned to the hospitals, this based on the conducted survey for finding the average patients referred to emergency ward in hospitals all over the city. There will be a tradeoff between objectives in order to find the optimum solution. The results will be shown in the last part of this section.

Table 3 Sustainable criteria

Criteria	description
C1	accessibility of the location
C2	Traffic congestion
C3	infectious hospital waste handling
C4	Capital cost
C5	target population
C6	potential for future development

Figure 3 shows the available locations for hospital construction in Tehran.

3.1 best-worst method

By considering above mentioned factors and by using the experts' ideas, we have found that the target population is the most important criterion, besides, the potential for future development is the worst one.by using the BEST –WORST method, the weights have been obtained.

As it is obvious the most important one, criterion 5, has got higher weight.

Figure 3. Potentials for hospital construction

Table 2 the obtained weights for each criterion

	C1	C2	C3	C4	C5	C6
Weights	0.11408816	0.09507347	0.1426102	0.19014693	0.42350908	0.03457217

Table 3 the decision matrix

	C1	C2	C3	C4	C5	C6
District 2	3	5	4	9	5	2
District 21	6	5	2	9	2	1
Distrcict20	5	3	5	1	9	2
District 18	5	3	3	9	1	1
District 22	1	1	5	6	8	4

3.2 TOPSIS method

In the next step, the decision matrix has been used for finding the best location. The decision matrix is shown in table (5). In this matrix the target population is in the scale of 1/1000.other elements of this matrix derived from questionnaires and according to what was mentioned above in the section of criteria finding.

By using TOPSIS method the ranking have been obtained:

Table 4. The ranking of criterion

District 20	0.9063027014317055
District 22	0.730599570093584
District 2	0.4432692735843358
District 21	0.20889738319128623
District 1	0.16464311098858914

3.3 UTASTAR method

In the next step, additive utility function has been applied to evaluate criteria's weights. The next table is the evaluation weights which will at last be used as utility in mathematical formulation.

Table 5. The evaluation weights

District 20	0.872
District 22	0.608
District 2	0.579
District 21	0.518
District 1	0.238

3.4 multi objective programming application

By applying mathematical formulation, we will be able to select the best hospitals and assign the patients to the hospitals. i is the number of patients, which has been assumed to be 110, while j is the number of candidate hospitals which is 5. The capacity of each hospital and the construction cost is introduced in table 8.

Table 6. Construction cost and hospitals capacity

	Construction cost (billion Toman)	Capacity (number of beds)
District 20	150	112
District 22	80	130
District 2	100	142
District 21	42	150
District 1	120	100

Using GAMS software, we found that which hospitals need to be constructed according to the constraints related to the capacity of hospitals and the maximum number of hospitals that is available for contractors to be built.

4. Discussion

In this section we will discuss the solutions for the proposed mathematical formulation in order to find the best place for hospital construction and the best way of assigning the patients. Utilizing different methods of solving multi-objective programming, we will look forward to use Pareto optimality for obtaining the solution. Different possible solutions have been found. F1 is related to the costs of hospital construction and F2, the utility function. While contractors are willing to maximize the utility of constructing hospitals, they intend to lower their costs which eventually found to be in conflict. Among set of solutions, dominant ones have been chosen and Pareto frontier has been demonstrated in figure 4.

Frontier line has been shown in this figure. Among set of Pareto solutions, decision maker will make his choice to construct the recommended hospitals.

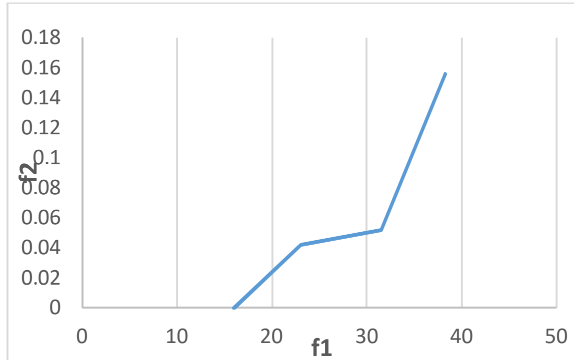

Figure 4. Pareto Frontier line

Among the set of Pareto solutions, decision maker can decide whether to build hospitals in district 20 and district 2 or only in district 21. Hospital construction in district 21 can bring the maximum utility but the costs are not optimum. On the other hand construction in district 20 and district 2 will minimize the cost objective but the utility objective will not be maximized. It can be demonstrated that as utility of hospital construction increases, costs will increase. There exist a straight relation between the utility of hospital construction and costs. Contractors and decision makers can choose the desirable location based on their priorities and budget. If the utility of construction is their first priority owing to social, environmental and economic concerns, then constructing a hospital in district 21 can meet their requirements. If hospitals in districts 2 and 20 construct, it can be estimated that the utilities won't be so much high, but in the medium amount. In this case costs become efficient and contractors gain is conspicuous.

In a brief overview of this methodology, there is a remarkable point that needs to be scrutinized. The number of hospitals in Iran cannot meet the demand, hence policy makers are looking forward to construct hospitals, so as to obliterate the obstacles. In this path, finding the appropriate locations for hospital construction is of high importance. Alternatives for hospital construction must be identified based on some factors in which the most important one is demand zones. Besides, expert ideas in various aspects of hospital construction must be taken in to consideration. Based on the studies which has been conducted healthcare infrastructure provides the basic support for healthcare operations and services, and they are essential for effective operations of healthcare systems. Accessibility to health care services is a central policy goal in most health care systems. Regarding the accessibility of healthcare facilities, it has been proved that distance to hospitals is an important factor when patients choose the healthcare service. There have been some researches in the field of location finding of hospitals using location allocation models but the novel approach in this study is related to the hybrid methodology and considering experts ideas.

5. Conclusions and future work

Sustainable development has been considered a subject that can help societies not only to achieve welfare but also mitigate the costs. As Sustainable development is an important concept for both private and public sectors which focuses on three aspects of development: social, environmental and economical, Focus in this paper is on identifying the best location for the hospital construction with the help of best-worst method using sustainable criteria to find weights of each criteria and then applying The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to rank the possible locations. In order to analyze the initial ranking and the evaluation of criteria's weight in the decision management perspective, additive utility function has been applied. Mathematical model has also been applied in order to assign the patients to the hospitals, considering that only a specific number of hospitals can be built. In the end, a numerical example has been discussed which was seeking for the appropriate location for hospital construction and the best assignment of patients to hospitals. In discussion, trade-off between the objectives has been delineated. Despite all the efforts which have been investigated in literature of this subject, proposing a novel methodology based on the integration of MCDM techniques and mathematical formulation of location allocation can pave the path of decision making for policy makers. Taking in to account the experts' idea in the first phase of this research, beside the multi objective mathematical formulation which seeks to minimize the construction cost and maximize the utility of hospital construction has a significant impact on fulfilling the goals of society to better deal with demands. Based on the reviewed literature performance evaluation of medical care centers is of high degree of prominence, so future studies can focus on different ways of performance evaluation besides considering hospital construction, which has not been identified in the literature. Emergency management and planning is one of the main topics because of high variability in its planning, Vehicle routing problems can play a part in performance evaluation and emergency planning, owing to the fact that emergent situations need to be supported in the best possible way, so meeting the demand of emergent patients while evaluating its performance can be of great help.

Abbreviations:

- The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)
- Multi-attribute decision- making (MADM)
- Analytic Network Process (ANP)
- Analytic Hierarchy Process (AHP)
- Elimination Et Choix Traduisantla REalité)(Elimination and Choice Expressing Reality (ELECTRE)
- VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR)
- Preference Ranking Organization method for Enrichment Evaluations (PROMETHEE)
- Decision maker (DM)
- Triple bottom line (TBL)
- Multi- objective decision-making (MODM)
- Adapted step-wise weight assessment ratio analysis (SWARA)
- Data Envelopment Analysis (DEA)
- Intuitionistic fuzzy Analytic Hierarchy Process (IF-AHP)

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