Hospital Location Selection with Grey System Theory

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Abstract

The facility location selection is one of the most important decisions for investors and entrepreneurs. It is a strategic issue besides often decides the fate of such a facility. In this kind of strategic decisions, decision makers should take into account various objectives and criteria and the process of location selection is inherently complicated. This paper considers the hospital location selection for a new public hospital by using Gray Relational Analysis (GRA) and Analytic Hierarchy Process (AHP). Gray Relational Analysis have been developed based on Grey System Theory. Grey System Theory is an interdisciplinary approach which first quantified by Deng in the early 1980's as an alternative method in creating the uncertainty have been proposed. The basic idea of emergence is to estimate the behavior of the systems which cannot be overcome by the stochastic or fuzzy methods with limited number of data. In this paper, the weights of criteria have been determined by using Analytic Hierarchic Process, then the grey relational degrees have been calculated for each alternative location.

Keywords: Gray Relational Analysis, Analytic Hierarchy Process, Location Selection.

Introduction

Location of an establishment is the most geographically convenient place for a business in terms of raw material supply, manufacture, storage, and distribution activities as well as execution of economic objectives throughout its organizational life span (Burdurlu, 1993). For an industrial business, the location of establishment is the most convenient place for supply, manufacture, storage, and distribution functions and as well as execution of economic objectives. Although economic geographer Thunen's study in 1826 is accepted as the beginning of central place theory, operational researchers trace the roots back to Alfred Weber's book "Theory of the Location of Industries" published in 1929. (Terouhid et al., 2012). Industrial location problem gains more and more importance on the basis of advancing technology, means of transportation, and increase in population resulting in a shortage of convenient locations. Although the initial studies discuss quantitative measures like cost and distance into account, today the problem involves qualitative measures which make it much more complicated.
Finding the optimal industrial location is a strategic decision and a misjudgment creates problems in the process and directly effects cost and profitability. Therefore, in industrial location, the core principals outlined below should be considered (Kobu, 2006):

- The needs of the business should be objectively studied and the decisions should be unbiased.
- The studies should be carried out systematically, employ miscellaneous and trusted resources.
- Location studies should be conducted step by step without mixing certain stages.
- In each stage, required expert people and institutions should be identified and the ways to utilize them should be explored.

In industrial locationing issues, different objectives can be determined based on the characteristics of the problem. The objectives that are usually considered in location problems can be different. Some of them can be as follows:

- Minimizing the total setup cost.
- Minimizing the longest distance from the existing facilities.
- Minimizing fixed cost.
- Minimizing total annual operating cost.
- Maximizing service.
- Minimizing average time/ distance traveled.
- Minimizing maximum time/ distance traveled.
- Minimizing the number of located facilities.
- Maximizing responsiveness.

Recently, environmental and social objectives based on energy cost, land use and construction cost, congestion, noise, quality of life, pollution, fossil fuel crisis and tourism are becoming customary. Consequently, one of the most important difficulties to tackle these problems is to find a way to measure these criteria (Farahani et al., 2010).

As industrial locationing is a strategical decision, it is one of the most important issues in achieving long term success. Choosing a wrong location would be costly and hard to correct. Human resources, costs, proximity to customer and suppliers criteria make the industrial locationing decisions harder. These criteria fall into two categories, subjective and objective (Liang and Mao-jiun, 1991):

- Objective criteria: Financial criteria such as investment costs.
- Subjective criteria: Qualitative criteria such as finding work force and climate conditions.

Most of the time, the optimum solution of industrial locationing problems requires more than one criteria or objective function. Therefore, multi-criteria decision mechanisms are applied in industrial locationing problems. AHP was used by Viswanadham and Kameshwaran (2007) in R&D facility locationing and by Fernandes and Ruiz (2009) in industrial locationing. ANP was used by Partovi (2006) in company locationing, by Tuzkaya et al. (2008) in waste storage locationing, and Aragones-Beltran et al. (2010) in urban solid waste facility locationing. TOPSIS method was used by Ertuğrul and Karakaşoğlu (2008) in textile manufacture facility locationing, by Awasthi (2011) in urban distribution center locationing, and by Mokhtarian and Hadi-Venchen (2012) in dairy plant locationing. ELECTRE method was used by Barda (1990) in thermal plant locationing problem, by Norese (2006) in waste incineration and disposal facility locationing, and by Ka (2011) in dry cargo harbor locationing. Keleş and Tunca (2015) used hierarchical ELECTRE method in Teknokent locationing. SMAA (stochastic multi-criteria acceptability analysis) method was used by Hokkanen et al. (1999) in harbor locationing, by Menou et al. (2010) in main distribution center for air cargo locationing. There are also hybrid applications. For instance, there are studies offering use of AHP and TOPSIS together for locationing (Yang et al, 1997; Kuo, 2002; Yong, 2006; Chou et al, 2007).

Fuzzy multi-criteria methods are also employed in locationing (Liang and Mao-jiun, 1991, Chou et al., 2008, Chou, 2010, Kahraman et al., 2003, Kaya and Çınar, 2008). Kaboli et al., (2007) used fuzzy AHP approach in plant locationing. Demirel et al. (2010) applied Choquet integral in storage locationing. Özdağoğlu (2011) used fuzzy ANP method. Momeni et al. (2011) used fuzzy VIKOR method for a plant locationing problem.

Hospital Location Selection

The general public's demand for health is rising promptly with the improvement of the living standard. Hospitals are one of the most important infrastructural objects. The increasing population, especially in developing countries, amplifies the demand for new hospitals. Hospitals are usually funded by the public sectors, by profit or nonprofit health organizations, charities, insurance companies or even religious orders. No matter who provides the answer, where to locate a new hospital is an important question to ask. Hospital site selection plays a vital role in the hospital construction and management. From aspect of the government, appropriate hospital site selection will help optimize the allocation of medical resources, matching the provision of health care with the social and economic demands, coordinating the urban and rural health service development, and easing social contradictions. From aspect of the citizen, proper hospital site selection will improve access to the health care, reduce the time of rescue, satisfy people's medical needs as well as enhance the quality of life. From the aspect of the investors and operators of the hospital, optimum hospital site selection will definitely be cost saving on capital strategy. It is an inevitable trend for hospitals to adopt cost accounting in order to adapt to the development of the market economy. Besides, better hospital site selection will promote the strategy of brand, marketing, differentiation and human resource, and enhance the competitiveness (Zhou et al., 2012). Hospital site selection is related to various aspects of the society. Mixed views and debates on which criteria are most important would confuse even health care experts. Previous studies were mainly classified into three categories based on the hospital type and scale as shown below:

- General hospital : Capture rate of population, current and projected population density, travel time, proximity to major commuter and public transit routes, distance from arterials, distance from other hospitals, anticipated impact on existed hospitals, land cost, contamination, socio-demographics of service area.
- Children hospital : Conformity to surrounding region, incremental operating costs, site purchase cost, travel time, proximity to public transport, traffic routes, site ownership, site shape, site gradient, ground conditions (soils/rock), access, ease of patient flow and staff movement, existing infrastructure and availability of services, perimeter buffer zone, environmental considerations, future population and prominence.
- Professional medicine and cure hospital: proximity to future expansion space, consistency with city zoning/policies, compatibility with surrounding uses, character and scale, cost of site control, helicopter access, local community preferences, accessibility, centrality, environment, land ownership, size and future population and prominence (Ali et al., 2011).

Schuurman et al. (2006) tried to define rational hospital catchments for non-urban areas based on travel-time and considered general travel time; population density; socio-demographics of service area. Wu et al. (2007) used the Delphi method, the AHP and the sensitivity analysis to develop an evaluation method for selecting the optimal location of a regional hospital in Taiwan and determining its effectiveness and considered population number, density and age profile; firm strategy, structure and rivalry; related and supporting industries; governmental policy; capital, labor and land. Vahidnia et al. (2008) used Fuzzy AHP, tried to select the optimum site for a hospital in Tehran using a GIS, while at the same time considering the uncertainty issue and considered population density; travel time; distance from arterials; land cost; contamination. Fuzzy AHP was used in similar research conducted to solve the problem of a new hospital location determination in Ankara by Aydin (2009). Soltani et al. (2011) tried to select hospital site by using two stage fuzzy multi-criteria decision making process and considered distance to arterials and major roads; distance to other medical service centers; population density; parcel size for site screening and for site selection three main criteria; traffic, parcel characteristics, land use considerations.

Selecting a location for a potential hospital often decides the success or the failure of such a facility. It is thus important to assess the locations from multiple dimensions before selecting the site. This paper focuses on the multi factor evaluation of hospital sites using AHP and GRA.

Theoretical Background

1. **Analytic Hierarchy Process**

The Analytic Hierarchy Process (AHP) is a mathematical technique for multi-criteria decision making and is a structured technique for dealing with complex decisions. Rather than prescribing a "correct" decision. The AHP helps the decision makers find the one that best suits their needs and their understanding of the problem. Based on mathematics and psychology, it was developed by Thomas L. Saaty in the 1970s and has been extensively studied and refined since then. The AHP provides a comprehensive and rational framework for structuring a decision problem, representing and quantifying its elements, relating those elements to overall goals, and evaluating alternative solutions. It is used around the world in a wide variety of decision situations, in fields such as government, business, industry, healthcare, and education (El-abbadi et al.).

According to Saaty (1995), the AHP process is based on three principles of methodical process: constructing hierarchies, establishing priorities and reasonable consistency. The first step in AHP is to work on the decision problem in order to decompose it and then try to build a hierarchical structure from the criteria or sub criteria. According to Saaty (1990), decision maker should be careful with the structuring hierarchy. In order to do this, the structure should present the problem in a best way, all sides of the factors that affect the problem should be considered, all the information sources that might help the solution should be considered and all the participators who will be in the problem process should be defined (Tanyas et al., 2010).

The second step in using AHP is to set the priorities and weights for each element. The elements of each level of the hierarchy are rated using the pair wise comparison approach. The relative importance between two comparative factors is reflected by the element values of judgment matrix. Table 1 shows general form of the measurement scale. It has relative importance in scale of 1-9 (Saaty, 1980; Güngör et.al., 2014)

Table 1. Scale for pairwise comparison in AHP

Importance degree	Descriptions	Explanation
1	Equally important	Criteria i and j are of equal importance
3	Weakly important	Criteria i is weakly more important than objective j
5	Strongly important	Criteria i is strongly more important than objective j
7	Very strongly important	Criteria i is very strongly more important than objective j
9	Extremely important	Criteria i is extremely more important than objective j
2, 4, 6, 8	Intermediate values	For example, a value of 8 means that Criteria i is midway between strongly and more important than objective j

The actors' comparative decisions between the paired goals build the basic pair wise comparison according to the relative importance of one goal to another. Paired comparisons are asked to the respondents in order to define which goal or criteria in the pair are more important to him/her. Saaty's scale of measurement for the paired comparisons uses the verbal comparisons into numerical value of the scale as in Table 1.

After defining and decomposing the problem into a hierarchical structure with decision elements, the pairwise comparison matrix (A) is formed (1).

$$A = (a_{ij})_{nxn} = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

Where a_{ij} represents the judgment degree of ith factor compared to jth factor.

The weights vector (W_A) is formed (2).

$$W_A = \begin{bmatrix} \left(\prod_{j=1}^{n} a_{1j}\right)^{1/n} \\ \left(\prod_{j=1}^{n} a_{2j}\right)^{1/n} \\ \vdots \\ \left(\prod_{j=1}^{n} a_{nj}\right)^{1/n} \end{bmatrix} \quad (2)$$

The normalized weights vector (W'_A) is then obtained as follows:

$$W'_A = \begin{bmatrix} \left(\prod_{j=1}^{n} a_{1j}\right)^{1/n} \Big/ \sum_{i=1}^{n}\left(\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}\right) \\ \left(\prod_{j=1}^{n} a_{2j}\right)^{1/n} \Big/ \sum_{i=1}^{n}\left(\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}\right) \\ \vdots \\ \left(\prod_{j=1}^{n} a_{nj}\right)^{1/n} \Big/ \sum_{i=1}^{n}\left(\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}\right) \end{bmatrix} = \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{bmatrix} \quad (3)$$

The last step, is checking consistency. According to Saaty (1990), consistency is not guaranteed in any measurement type. Errors in judgment are common; therefore, the consistency ratio (CR) is used to measure the consistency in pair wise comparisons. He proved that for common matrix, the largest eigen value is equal to the size of comparison matrix. The inconsistency of comparison matrix is computed as follows:

$$CI = \left(\frac{\lambda_{max} - n}{n-1}\right) \quad (4)$$

Consistency check is applied by computing the consistency ratio (CR):

$$CR = \frac{CI}{RI} \qquad (5)$$

Where RI is the random index. The values of RI are shown in Table 2.

Table 2: RI values

n	2	3	4	5	6	7	8
RI	0	0,58	0,9	1,12	1,24	1,32	1,41

Where CR≤0.10, it means that the inconsistency of the pairwise comparison matrix is in desired interval and matrix is acceptable.

2. Grey Relational Analysis

Many systems, such as those that are social, economic, agricultural, industrial, ecological, or biological in nature, are named based on the fields and ranges to which the research subjects belong. In contrast, the name grey systems was chosen based on the colors of the subjects under investigation. For example, in control theory, the darkness of colors has been commonly used to indicate the degree of clarity of information. One of the most well accepted representations is the so-called “black box.” It stands for an object with its internal relations or structure totally unknown to the investigator. Here, we use the word “black” to represent unknown information, “white” for completely known information, and “grey” for that information which is partially known and partially unknown. Accordingly, we name systems with completely known information as white systems, systems with completely unknown information as black systems, and systems with partially known and partially unknown information as grey systems, respectively.

In our daily social, economic, and scientific research activities, we often face situations involving incomplete information. For example, in some studies of agriculture, even though all the information related to the area which is planted, the quality of seeds, fertilizers, irrigation, etc., is completely known, it is still difficult to estimate the production quantity and the consequent annual income due to various unknown or vague information related to labor quality, level of technology employed, natural environment, weather conditions, etc. (Liu et. Al., 2006).

There are four possibilities for incomplete information of systems.

1. The information of elements (or parameters) is incomplete.
2. The information on structure is incomplete.
3. The information on boundary is incomplete.
4. The behavior information of movement is incomplete

Having “incomplete information” is the fundamental meaning of being “grey”. In different circumstances and from different angles, the meaning of being “grey” can still be extended. For more details, see Table 3 (Liu et. Al., 2006).

Table 3. Comparison between black, grey and white systems

	Black	Grey	White
Information	Unknown	Incomplete	Known
Appearance	Dark	Grey	Bright
Process	New	Replace old with new	Old
Property	Chaos	Complexity	Order
Methodology	Negative	Transition	Positive
Attitude	Indulgence	Tolerance	Serenity
Conclusion	No result	Multiple solution	Unique solution

Probability and statistics, fuzzy mathematics, and grey systems theory have been the three most-often applied theories and methods employed in studies of non-deterministic systems. Even though they study objects with different uncertainties, the commonality of these theories is their ability to make meaningful sense out of incompleteness and uncertainties. The comparison of these three theories is in the following Table 4 (Liu et. Al., 2006).

Table 4. Comparison between grey systems theory, probability, statistics and fuzzy mathematics

	Grey systems theory	Probability, statistics	Fuzzy mathematics

Objects of study	Poor information Uncertainty	Stochastic Uncertainty	Cognitive Uncertainty
Basic sets	Grey hazy sets	Cantor sets	Fuzzy sets
Methods	Information coverage	Probability distribution	Function of affiliation
Procedure	Grey series generation	Frequency distribution	Marginal sampling
Requirement	Any distribution	Typical distribution	Experience
Emphasis	Intention	Intention	Extension
Objective	Laws of reality	Laws of statistics	Cognitive expression
Characteristics	Small samples	Large samples	Experience

Grey number represents that the information of the number is insufficient and incomplete, and it belongs to a range instead of crisp value. A grey number g denotes by ⊗g.

$$\otimes g = [g^-, g^+] \quad (6)$$

Where g^-, g^+ represent the lower and upper bound of the interval. Let $\otimes g_1$ and $\otimes g_2$ be two grey numbers, and be a crisp number, then the grey number arithmetic operations can be shown as follows:

$$\otimes g_1 = [{g_1}^-, {g_1}^+] \quad (7)$$

$$\otimes g_2 = [{g_2}^-, {g_2}^+] \quad (8)$$

Grey number addition

$$\otimes g_1 + \otimes g_2 = [{g_1}^-, {g_1}^+] + [{g_2}^-, {g_2}^+] = [{g_1}^- + {g_2}^-, {g_1}^+ + {g_2}^+] \quad (9)$$

Grey number subtraction

$$\otimes g_1 - \otimes g_2 = [{g_1}^-, {g_1}^+] - [{g_2}^-, {g_2}^+] = [{g_1}^- - {g_2}^+, {g_1}^+ - {g_2}^-] \quad (10)$$

Grey number multiplication

$$\otimes g_1 . \otimes g_2 = [{g_1}^-, {g_1}^+][{g_2}^-, {g_2}^+] = [\min\{{g_1}^-{g_2}^-, {g_1}^-{g_2}^+, {g_1}^+{g_2}^-, {g_1}^+{g_2}^+\}, \max\{{g_1}^-{g_2}^-, {g_1}^-{g_2}^+, {g_1}^+{g_2}^-, {g_1}^+{g_2}^+\}] \quad (11)$$

Grey number division

$$\frac{\otimes g_1}{a} = \left[\frac{{g_1}^-}{a}, \frac{{g_1}^+}{a}\right] \quad (12)$$

$$\frac{a}{\otimes g_1} = \left[\frac{a}{{g_1}^+}, \frac{a}{{g_1}^-}\right] \quad (13)$$

Where ${g_1}^- > 0,\ {g_1}^+ > 0,\ {g_2}^- > 0,\ {g_2}^+ > 0,\ a > 0.$

The grey relational analysis with grey numbers and group decision making procedure has been developed, as shown in step 1 to step 8.

Step 1: Assume that L experts have been invited to participate in the evaluation of the alternative. Establish the grey decision-making matrix (G^k).

Assuming that there are m alternative characterized by n criteria, and the decision-making matrix given by the (k)th expert has been shown in Eq. (14)

$$\otimes G^k = \begin{bmatrix} \otimes g_{11}^k & \cdots & \otimes g_{1n}^k \\ \vdots & \ddots & \vdots \\ \otimes g_{m1}^k & \cdots & \otimes g_{mn}^k \end{bmatrix} \quad (14)$$

$\otimes g_{ij}^k = [{g_{ij}}^-, {g_{ij}}^+]$, i=1,2,3,….,m; j=1,2,……,n (15)

Where $\otimes g_{ij}^k$ represents the value of the (j)th criterion of the (i)th alternative evaluated by the (k)th expert.

Step 2: Normalize the data in the decision-making matrix, the methods for data processing should be chosen according to the types of the criteria. If the larger the criteria, the better the alternative, the criteria can be called benefit-criteria, on the contrary, the larger the criteria, the worse the alternative, the criteria can be called cost-criteria.

Benefit-criteria:

$\otimes y_{ij}^{k} = \frac{\otimes g_{ij}^{k}}{\max_{i=1}^{m}\{\otimes g_{ij}^{k,+}\}}$, i=1,2,3,….,m; j=1,2,……,n

(16)

Cost criteria:

$\otimes y_{ij}^{k} = \frac{\min_{i=1}^{m}\{\otimes g_{ij}^{k,-}\}}{\otimes g_{ij}^{k}}$, i=1,2,3,….,m; j=1,2,……,n

(17)

Step 3: Generate the reference alternative, the normalized matrix has been shown in Eq. (18), and the reference alternative can be determined by Eqs. (19) and (20). Reference alternative is the ideal best one.

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

(18)

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

(19)

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

(20)

Where $y_j^{k,0}$ is the reference value in relation to the (j)th criterion.

Step 4: Calculate the difference between the alternatives and the reference alternative, and construct the difference matrix by Eqs. (21) and (22).

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

(21)

$$\otimes \Delta_{11}^{k} = \left[y_j^{k,0} - y_{ij}^{k,+}, y_j^{k,0} - y_{ij}^{k,-}\right], i = 1,2, \ldots\ldots, m; j = 1,2,3, \ldots\ldots, n \qquad (22)$$

Step 5: Calculate the grey relational coefficient for each alternative by Eqs. (23), (24) and (25).

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

(23)

$$\otimes \varepsilon_{ij}^{k,-} = \frac{\min_{i=1}^{m}\min_{j=1}^{m}\Delta_{11}^{k,-} + \rho\max_{i=1}^{m}\max_{j=1}^{m}\otimes\Delta_{11}^{k,+}}{\Delta_{11}^{k,+} + \rho\max_{i=1}^{m}\max_{j=1}^{m}\otimes\Delta_{11}^{k,+}}$$

(24)

$$\otimes \varepsilon_{ij}^{k,+} = \frac{\min_{i=1}^{m}\min_{j=1}^{m}\Delta_{11}^{k,-} + \rho\max_{i=1}^{m}\max_{j=1}^{m}\otimes\Delta_{11}^{k,+}}{\Delta_{11}^{k,-} + \rho\max_{i=1}^{m}\max_{j=1}^{m}\otimes\Delta_{11}^{k,+}}$$

(25)

Where $\otimes \varepsilon_{ij}^{k}$ is the grey relational coefficient, ρ represents the distinguishing coefficient, it takes the value of 0.5 in this paper.

Step 6: Calculate the grey relational degree. A grey relational degree is a weighted sum of the grey relational coefficients, as shown in Eq. (26).

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

(26)

Where $\otimes \omega_j$ represents the grey weight (weighting coefficient) of the (j)th criterion.

Step 7: Whiten the grey relational degree and rank the alternatives. The whitening relational degree can be calculated by Eqs. (27) and (27). Rank the alternative according to the rule that the bigger the whitening relational degree, the better the corresponding alternative.

$$\otimes \gamma_i^{k} = [\gamma_i^{k,-}, \gamma_i^{k,+}]$$

(27)

$$\gamma_i^{k} = \frac{\gamma_i^{k,-} + \gamma_i^{k,+}}{2}$$

(28)

Where $\otimes\gamma_i^k$ represents the grey relational degree and γ_i^krepresents whitening relational degree of the (i)th alternative respectively.

Step 8: Carry out group decision-making. Calculate the integrated relational degrees according to Eq. (29), and rank the prior order of the alternative according to the rule that the bigger the integrated relational degree, the better the corresponding alternative.

$$\gamma_i = (\prod_{k=1}^{L} \gamma_i^k)^{1/L} \tag{29}$$

Where γ_i represents the integrated relational degree of the i(th) alternative (Manzardo et. Al., 2012).

Under many situations, the values of the quantitative and qualitative criteria are often imprecise or vague, therefore GRA, one of the sub-branches of Deng's Grey Theory (Deng, 1989). Yang et al. (2006) used a combined AHP and GRA for supplier selection problem. AHP was used to calculate relative importance weightings of qualitative criteria. Then, the qualitative and quantitative data were utilized together and obtained the grey relational grade values. The best supplier had the highest grey relational value among others. Li et al. (2007) proposed a grey-based decision-making approach to the supplier selection problem. Congjun et al. (2009) presented a study on group decision making model based on grey relational analysis. Chiang-Ku et al (2009) used ANP and GRA to evaluate the employability of graduates from department of risk management and insurance. The paper proposed a curriculum performance evaluation method combining the Analytical Network Process (ANP) and the Grey Relational Analysis (GRA). Feng et al. (2011) presented a Study on Grey Relation Analysis Based on Entropy Method in Evaluation of Logistics Center Location grey relational analysis. The weights of the evaluation indexes were defined by the entropy method. The quantitative process and comparison of the qualitative information were made by GRA. Manzardo et al. (2012) developed a grey-based group decision-making methodology for the selection of hydrogen technologies in life cycle sustainability perspective. Kose et al. (2013) suggested an integrated approach based on grey system theory for personnel selection. Birgun et al. (2014) presented a study on a multi-criteria call center site selection by hierarchy grey relational analysis and the paper dealed with an approach based on AHP and GRA for choosing the best call center site. Hashemi et al. (2015) proposed an integrated green supplier selection approach with analytic network process and improved grey relational analysis.

Execution

In this case hospital location selection problem for a public hospital. Public benefit should be maximized whereas possible regret should be minimized in this process. In this case, GRA is recommended. The decision-makers consisted by three academics and three experts from the ministry of health. Three locations have been proposed by the governorship and the municipality for hospital site selection evaluation. These location sites are shown as a_1, a_2, and a_3.

Many different criteria are considered for hospital site selection in many different researches and based on the considered situations for each research case. These criteria are integrated in the current research and classified into six criteria. These criteria are listed as:

- **C_1: Site conditions and surrounding** (Site size, Site preparation time, Parking: Surrounding street network to accommodate adequate parking, Proximity to banking facility, Proximity to community services, and Attractive outlook)
- **C_2: Accessibility and traffic** (Public transport link, Bicycle, Pedestrian, and Commute time for hospital staff)
- **C_3: Patient/emergency access consideration** (Helicopter access and Access to road network)
- **C_4: Cost** (Site preparation cost, Operational cost, and Maintenance cost).
- **C_5: Future considerations** (Expansion ability and Represent different geographic regions).
- **C_6: Nuisance** (Atmosphere conditions and Noise).

The weights of these criteria calculated by using AHP. The group leader determined the weights of the criteria which is calculated by using AHP. Where CR=0.04, it means that the inconsistency of the pairwise comparison matrix is in desired interval and matrix is acceptable. The weights of the criteria are as shown in Table:5.

Table: 5 The pair-wise comparison matrix for criteria

	C1	C2	C3	C4	C5	C6	W_i
C1	1	3	5	1	7	9	0.34
C2	1/3	1	3	1/3	5	7	0,17
C3	1/5	1/3	1	1/5	3	5	0,09
C4	1	3	5	1	7	9	0,34

C5	1/7	1/5	1/3	1/7	1	3	0,05
C6	1/9	1/7	1/5	1/9	1/3	1	0,03

After determining the weights of criteria, the next step is establish the grey decision-making matrix (G^k). The grey decision-making matrix (G^k) was established by the using decision making references as shown in Table 6. The next step, we normalized the data in the decision-making matrix and we generated the reference alternative as shown in Table 7. After normalized the data, we calculated the difference between the alternatives and the reference alternative, and construct the difference matrix as shown in Table 8. The next step we calculated the grey relational coefficient for each alternative as shown in Table 9.

Table 6: The grey decision-making matrix (G^k).

		Accessibility and traffic	Patient/ emergency access consideration	Site conditions and surrounding	Future considerations	Nuisance	Cost
DM#1	a_1	0.8 , 1.0	0.4 , 0.6	0.4 , 0.6	0.6 , 0.8	0.4 , 0.6	0.4 , 0.6
	a_2	0.6 , 0.8	0.6 , 0.8	0.6 , 0.8	0.4 , 0.6	0.6 , 0.8	0.6 , 0.8
	a_3	0.8 , 1.0	0.4 , 0.6	0.6 , 0.8	0.8 , 1.0	0.6 , 0.8	0.4 , 0.6
DM#2	a_1	0.6 , 0.8	0.8 , 1.0	0.4 , 0.6	0.6 , 0.8	0.4 , 0.6	0.4 , 0.6
	a_2	0.6 , 0.8	0.6 , 0.8	0.6 , 0.8	0.4 , 0.6	0.4 , 0.6	0.8 , 1.0
	a_3	0.4 , 0.6	0.6 , 0.8	0.8 , 1.0	0.6 , 0.8	0.6 , 0.8	0.6 , 0.8
DM#3	a_1	0.6 , 0.8	0.6 , 0.8	0.2 , 0.4	0.6 , 0.8	0.6 , 0.8	0.2 , 0.4
	a_2	0.4 , 0.6	0.6 , 0.8	0.6 , 0.8	0.8 , 1.0	0.6 , 0.8	0.6 , 0.8
	a_3	0.6 , 0.8	0.4 , 0.6	0.4 , 0.6	0.6 , 0.8	0.4 , 0.6	0.6 , 0.8
DM#4	a_1	0.4 , 0.6	0.8 , 1.0	0.4 , 0.6	0.4 , 0.6	0.6 , 0.8	0.4 , 0.6
	a_2	0.8 , 1.0	0.6 , 0.8	0.4 , 0.6	0.4 , 0.6	0.4 , 0.6	0.8 , 1.0
	a_3	0.8 , 1.0	0.4 , 0.6	0.6 , 0.8	0.6 , 0.8	0.6 , 0.8	0.6 , 0.8
DM#5	a_1	0.8 , 1.0	0.6 , 0.8	0.2 , 0.4	0.4 , 0.6	0.4 , 0.6	0.4 , 0.6
	a_2	0.4 , 0.6	0.4 , 0.6	0.6 , 0.8	0.6 , 0.8	0.6 , 0.8	0.4 , 0.6
	a_3	0.6 , 0.8	0.6 , 0.8	0.4 , 0.6	0.6 , 0.8	0.8 , 1.0	0.4 , 0.6
DM#6	a_1	0.4 , 0.6	0.6 , 0.8	0.6 , 0.8	0.4 , 0.6	0.4 , 0.6	0.4 , 0.6
	a_2	0.6 , 0.8	0.6 , 0.8	0.4 , 0.6	0.4 , 0.6	0.2 , 0.4	0.8 , 1.0
	a_3	0.8 , 1.0	0.4 , 0.6	0.4 , 0.6	0.4 , 0.6	0.6 , 0.8	0.6 , 0.8

Table 7: Normalized decision-making matrix

		Accessibility and traffic (Benefit)		Patient/ emergency access consideration (Benefit)		Site conditions and surrounding (Benefit)		Future considerations (Benefit)		Nuisance (Benefit)		Cost (Cost)	
y^{k0}		1.0		1.0		1.0		1.0		1.0		1.0	
DM#1	a_1	0.8	1.0	0.5	0.75	0.5	0.75	0.6	0.8	0.5	0.75	0.66	1.0
	a_2	0.6	0.8	0.75	1.0	0.75	1.0	0.4	0.6	0.75	1.0	0.5	0.66
	a_3	0.8	1.0	0.5	0.75	0.75	1.0	0.8	1.0	0.75	1.0	0.66	1.0
DM#2	a_1	0.75	1.0	0.8	1.0	0.4	0.6	0.75	1.0	0.5	0.75	0.66	1.0
	a_2	0.75	1.0	0.6	0.8	0.6	0.8	0.5	0.75	0.5	0.75	0.4	0.5
	a_3	0.5	0.75	0.6	0.8	0.8	1.0	0.75	1.0	0.75	1.0	0.5	0.66
DM#3	a_1	0.75	1.0	0.75	1.0	0.25	0.5	0.6	0.8	0.75	1.0	0.5	1.0
	a_2	0.5	0.75	0.75	1.0	0.75	1.0	0.8	1.0	0.75	1.0	0.25	0.66
	a_3	0.75	1.0	0.5	0.75	0.5	0.75	0.6	0.8	0.5	0.75	0.25	0.66
DM#4	a_1	0.4	0.6	0.8	1.0	0.5	0.75	0.5	0.75	0.75	1.0	0.66	1.0
	a_2	0.8	1.0	0.6	0.8	0.5	0.75	0.5	0.75	0.5	0.75	0.4	0.5
	a_3	0.8	1.0	0.4	0.6	0.75	1.0	0.75	1.0	0.75	1.0	0.5	0.66
DM#5	a_1	0.8	1.0	0.75	1.0	0.25	0.5	0.5	0.75	0.4	0.6	0.66	1.0
	a_2	0.4	0.6	0.5	0.75	0.75	1.0	0.75	1.0	0.6	0.8	0.66	1.0
	a_3	0.6	0.8	0.75	1.0	0.5	0.75	0.75	1.0	0.8	1.0	0.66	1.0
DM#6	a_1	0.4	0.6	0.75	1.0	0.75	1.0	0.66	1.0	0.5	0.75	0.66	1.0
	a_2	0.6	0.8	0.75	1.0	0.5	0.75	0.66	1.0	0.25	0.5	0.4	0.5
	a_3	0.8	1.0	0.5	0.75	0.5	0.75	0.66	1.0	0.75	1.0	0.5	0.66

Table 8: The difference matrix

Δ^k		Accessibility and traffic		Patient/ emergency access consideration		Site conditions and surrounding		Future considerations		Nuisance		Cost	
y^{k0}		1.0		1.0		1.0		1.0		1.0		1.0	
DM#1	a_1	0	0.2	0.25	0.5	0.25	0.5	0.2	0.4	0.25	0.5	0	0.34
	a_2	0.2	0.4	0	0.25	0	0.25	0.4	0.6	0	0.25	0.34	0.5
	a_3	0	0.2	0.25	0.5	0	0.25	0	0.2	0	0.25	0	0.34
DM#2	a_1	0	0.25	0	0.2	0.4	0.6	0	0.25	0.25	0.5	0	0.34
	a_2	0	0.25	0.2	0.4	0.2	0.4	0.25	0.5	0.25	0.5	0.5	0.6
	a_3	0.25	0.5	0.2	0.4	0	0.2	0	0.25	0	0.25	0.34	0.5
DM#3	a_1	0	0.25	0	0.25	0.5	0.75	0.2	0.4	0	0.25	0	0.5
	a_2	0.25	0.5	0	0.25	0	0.25	0	0.2	0	0.25	0.34	0.75
	a_3	0	0.25	0.25	0	0.25	0.5	0.2	0.4	0.25	0.5	0.34	0.75
DM#4	a_1	0.4	0.6	0	0.2	0.25	0.5	0.25	0.5	0	0.25	0	0.34
	a_2	0	0.2	0.2	0.4	0.25	0.5	0.25	0.5	0.25	0.5	0.5	0.6
	a_3	0	0.2	0.4	0.6	0	0.25	0	0.25	0	0.25	0.34	0.5
DM#5	a_1	0	0.2	0	0.25	0.5	0.75	0.25	0.5	0.4	0.6	0	0.34
	a_2	0.4	0.6	0.25	0.5	0	0.25	0	0.25	0.2	0.4	0	0.34
	a_3	0.2	0.4	0	0.25	0.25	0.5	0	0.25	0	0.2	0	0.34
DM#6	a_1	0.4	0.6	0	0.25	0	0.25	0	0.34	0.25	0.5	0	0.34
	a_2	0.2	0.4	0	0.25	0.25	0.5	0	0.34	0.5	0.75	0.5	0.6
	a_3	0	0.2	0.25	0.5	0.25	0.5	0	0.34	0	0.25	0.34	0.5

Table 9: The grey relational coefficient

$\otimes\varepsilon_{ij}^{k}$		Accessibility and traffic	Patient/ emergency access consideration	Site conditions and surrounding	Future considerations	Nuisance	Cost
Wi		0.166	0.089	0.336	0.047	0.026	0.336
DM#1	a_1	0.56 , 1	0.33 , 0.5	0.33 , 0.5	0.38 , 0.56	0.33 , 0.5	0.42 , 1
	a_2	0.38 , 0.56	0.5 , 1	0.5 , 1	0.29 , 0.38	0.5 , 1	0.33 , 0.42
	a_3	0.56 , 1	0.33 , 0.5	0.5 , 1	0.56 , 1	0.5 , 1	0.42 , 1
DM#2	a_1	0.55 , 1	0.6 , 1	0.33 , 0.43	0.55 , 1	0.38 , 0.55	0.47 , 1
	a_2	0.55 , 1	0.43 , 0.6	0.43 , 0.6	0.38 , 0.55	0.38 , 0.55	0.33 , 0.38
	a_3	0.38 , 0.55	0.43 , 0.6	0.6 , 1	0.55 , 1	0.55 , 1	0.38 , 0.47
DM#3	a_1	0.75 , 1	0.75 , 1	0.38 , 0.43	0.58 , 0.65	0.75 , 1	0.5 , 1
	a_2	0.5 , 0.6	0.75 , 1	0.75 , 1	0.83 , 1	0.75 , 1	0.38 , 0.52
	a_3	0.75 , 1	1.5 , 0.6	0.5 , 0.6	0.58 , 0.65	0.5 , 0.6	0.38 , 0.52
DM#4	a_1	0.33 , 0.43	0.6 , 1	0.38 , 0.55	0.38 , 0.55	0.55 , 1	0.47 , 1
	a_2	0.6 , 1	0.43 , 0.6	0.38 , 0.55	0.38 , 0.55	0.38 , 0.55	0.33 , 0.38
	a_3	0.6 , 1	0.33 , 0.43	0.55 , 1	0.55 , 1	0.55 , 1	0.38 , 0.47
DM#5	a_1	0.65 , 1	0.6 , 1	0.33 , 0.43	0.43 , 0.6	0.38 , 0.48	0.52 , 1
	a_2	0.38 , 0.48	0.43 , 0.6	0.6 , 1	0.6 , 1	0.48 , 0.65	0.52 , 1
	a_3	0.48 , 0.65	0.6 , 1	0.43 , 0.6	0.6 , 1	0.65 , 1	0.52 , 1
DM#6	a_1	0.38 , 0.48	0.6 , 1	0.6 , 1	0.52 , 1	0.43 , 0.6	0.52 , 1
	a_2	0.48 , 0.65	0.6 , 1	0.43 , 0.6	0.52 , 1	0.33 , 0.43	0.38 , 0.43
	a_3	0.65 , 1	0.43 , 0.6	0.43 , 0.6	0.52 , 1	0.6 , 1	0.43 , 0.52

Then we calculated the grey relational degree. A grey relational degree is a weighted sum of the grey relational coefficients. Where $\otimes\gamma_i^k$ represents the grey relational degree and γ_i^krepresents whitening relational degree of the i(th) alternative respectively as shown in Table 10. The last step is calculating the integrated relational degrees according to Eq. (29), and rank the prior order of the alternative according to the rule that the bigger the integrated relational degree, the better the corresponding alternative as shown in Table 11.

Table 10: The grey relational degree

		$\gamma_i^{k,-}$	$\gamma_i^{k,+}$	γ_i^{k}
DM#1	a_1	0.403005	0.753611	0.578308
	a_2	0.41517	0.703672	0.559421
	a_3	0.471373	0.9555	0.713436
DM#2	a_1	0.448832	0.796182	0.622507
	a_2	0.412063	0.586818	0.499441
	a_3	0.467811	0.710445	0.589128
DM#3	a_1	0.531865	0.791652	0.661759
	a_2	0.586417	0.773824	0.68012
	a_3	0.592115	0.643476	0.617796
DM#4	a_1	0.42404	0.731052	0.577546
	a_2	0.403118	0.568491	0.485804
	a_3	0.478358	0.770643	0.6245
DM#5	a_1	0.480028	0.775781	0.627904
	a_2	0.520593	0.869679	0.695136
	a_3	0.499103	0.807861	0.653482
DM#6	a_1	0.530863	0.903923	0.717393
	a_2	0.44027	0.601004	0.520637
	a_3	0.474654	0.670224	0.572439

Table 11: Integrated relational degree

a_1	0.629081183
a_2	0.567517327
a_3	0.626831599

Conclusion

Hospital location site selection problem turns into a complicated problem that one decision-maker cannot handle as amount of the investment increases. In this case, personal expertise is not enough and the subject should be examined from different angles. Therefore, the problem was handled by group decision making method as the information and experience provided by the persons would be more than one person's information and experience and this would increase the effectiveness of the decision. Location site selection is a strategical decision and a mistake would be very hard to correct. As a result of the study alternative 1 (a_1) was selected by the group. As you see a1 and a3 had very close value. a_1 and a_3 are very close places and nearly same size, so the result did not surprise us too much.

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