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Hospital Location Selection with Utility Range Based Interactive Group Decision Method

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Abstract

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 Utility Range Based Interactive Group Decision Method. The process of site selection is inherently complicated. A careless site imposes exorbitant costs on city budget and damages the environment inevitably. Nowadays, multi-attributes decision making approaches are suggested to use to improve precision of decision making and reduce surplus side effects. Utility range based interactive group decision method is proposed for solving this complex problem and selection of the location which has the highest utility. Main theme underlying the method is every group member wants to compare their partial utility information with other group members. This procedure reflects the incomplete information as linear range because it can count easily from partial utility information. Range type makes the incomplete information effective and efficient to demonstrate the group members. In addition to this, range type utility information makes easy to compare every group members' utility information with group's information and collecting the each group member's utility information within group's utility information. To obtain group utility, preference aggregation method is used. Interactive procedure helps to make consensus of the group. Utility information calculated by using optimism coefficient which is determined by the group. A numerical example for hospital location selection is given to illustrate the proposed method finally.

Keywords: Group Decision Making and Negotiation, Multi-Criteria Decision Making, Location Selection

INTRODUCTION

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 [1]. 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 [2].

Schuurman et al. [3] 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. [4] 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. [5] 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 [6]. Soltani et al. [7] 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 by using Utility Range Based Interactive Group Decision Method.

UTILITY RANGE BASED INTERACTIVE GROUP DECISION METHOD

A group decision making process is generally defined as reducing the different choices among objects and reaching a common preference or group preference from the options given [8]. Additionally, when the group members only give incomplete information, the selection is generally not finalized in a single step. For example, a decision maker may not be able to state or want the definite idea or detailed preference of the weight of properties. The reasons why a decision maker can only provide incomplete information are:

1. It may be necessary to make the decision in limited time or with inadequate data.
2. Many properties are abstract because they reflect the social and environmental effects or do not have a financial value.
3. The decision maker does not have sufficient interest or knowledge [9,10].

In order to find the most appropriate solution in a group decision making problem, there are many methods to be applied in decision analysis area [11]. A few studies among them have used uncertain preference models in group decision making [12,13]

In this study, the multi-criteria group decision making method will be applied based on the utility information of each group member. The utility information will be considered as incomplete information because the utility is not stated clearly. Since the utility information of each group member is different and it is very difficult to find a common or agreed information range, even though a method to add them is used, the selection of an alternative directly from information not agreed will not reflect the utility of the group. It is preferred for each group member to change their incomplete utility information by agreement interactively instead of this total information of the group.

The multi-criteria group decision making models are characterized with the following components:

- $A=\{a_i\}_{i=1,M}$: Alternative cluster with M element
- $I=\{i\}_{i=1,N}$: Criteria cluster with N element
- $K=\{k\}_{k=1,K}$: The cluster of K number of group elements in group decision making.
- w_i : The weighed importance of the group related to criteria i.
- w_i^k: The weighed importance of k. decision maker related to i.criteria.
- w^k: The weighed importance related to k. group member.
- $u_i^k(a)$: The individual incomplete utility information of k. group member related to a. alternative for the i. criteria given.
- $u_i^G(a)$: The incomplete utility value of the group regarding a. alternative for the i. criteria given.
- $W=\{\Phi_w, \Sigma_i w_i=1, w_i>=0\}$: The cluster of limitations or all possible values of the weighs of criteria.
- U_i^k : The utility limitations cluster seen with the individual incomplete information of k group member regarding the a. alternative of the given i. property. $\{ u_i^k(a^ı), u_i^k(a) \} \in U_i^k$
- $\Psi (a^ı,a) = \{W,U\}$, two alternatives to be evaluated.
- Ω : The priority relations cluster among alternatives.

In multi-criteria group decision making situations; the alternative cluster evaluated in terms of a criteria family is considered. In the classical evaluation of alternatives, adding all properties creates the utility function. Here the properties are assumed as independent in terms of contribution. For am alternative, the total value of k or the expected utility:

$$V^k(a_m) = f(u_1^k(a),..,u_n^k(a_m)) = \sum_{i=1}^{N} w_i^k u_i^k(a_m) \qquad (1)$$

Equality (1) is the expected utility under certainty however it can be extended to cases that is not quite certain [10]. The main purpose of the approaches to make a single decision under multi-criteria:

- Calculating the expected value or expected utility for each alternative.
- Comparing each expected utility value among alternatives.
- Determining the priority relations among alternatives.

The main problem in group decision making is to combine individual preferences to achieve a common preference. Various procedures have been set forth to overcome this problem and these are different from each other in many terms but there are difficulties in taking the incomplete information regarding the utility of the alternatives and the weights of the properties. For example, obtaining the utility information is a problem in itself alone. The procedure here uses the utility expressed as individual incomplete information in order to overcome these challenges [14]. This procedure reflects the incomplete information as the linear range because it can be easily calculated from the incomplete utility information. The type of range makes the incomplete information effective in order to show the incomplete information to group members. Additionally, the range type utility information makes it easy to compare the utility information of each group member and the group and to collect the utility information of each group member within the group utility information. White [15] has suggested a structure for multi-criteria group decision making. It is as follows with a slight change:

STEP 1: (Calculating the individual utility ranges) In transforming the incomplete utility information of the group members regarding the options for each criteria to range form can be solved with the following equation (2) linear programming. This procedure reflects the incomplete information as linear range. The range type makes the incomplete information effective in order to show the incomplete information to group members. Additionally, the range type utility information makes it easy to compare the utility information of each group member with the group and to add the utility information of each group member within the group utility information.

$$\min/\max u_i^k(a), U_i^k \subset \psi(a\ ,a) \qquad (2)$$

STEP 2: (Combining the preferences) It is finding the group utility range of each alternative on each property through combination range and agreement range of individual utility functions.

The group utility function of am alternative is achieved by combining the utility functions of group members and shown as below:

$$V_G(a_m) = f(V^1(a_m),.....,V^K(a_m)) = \sum_{k=1}^{K} w^k \sum_{i=1}^{N} w_i^k u_i^k(a_m) \quad (3a)$$

Assuming that the agreement weights of the group are used and the decision makers are interested in the common criteria, the equation of group utility is given in 3b.

$$V_G(a_m) = \sum_{k=1}^{K} w^k \sum_{i=1}^{N} w_i u_i^k(a_m) = \sum_{i=1}^{N} w_i \sum_{k=1}^{K} w^k u_i^k(a_m) \quad (3b)$$

While combining the individual utility ranges to a common range of the group's preferences, the group members may tend to agree on their opinion differences while searching for a common decision [13]. We use two types of group utility range. These are consensus utility range and combination utility range. The consensus utility range is obtained by finding the intersection of the individual utility ranges of all members. It is found by using the following formula:

The agreement (intersection) range of the group

$$= (\max_k \min w_i^k, \min_k \max w_i^k) \quad (4)$$

The combination utility range defines the range of the lowest and highest utility range among the utility ranges of all members. It is found by using the following formula [14]:

The combination range of the group

$$= (\min_k \min w_i^k, \max_k \max w_i^k) \quad (5)$$

STEP 3: (Degradation procedure of the difference between the agreed range and the combination range) After determining the total and consensus utility ranges, the difference is checked. For this $V(a_i)$ is used that represents the ratio of combination range to consensus range. $V(a_i)$: states the consensus degree of a option for criteria i. This also shows whether there is a consensus. Looking at the $V(a_i)$ value, there are three situations for the group members to achieve consensus.

$V(a_i)$=(Group Consensus Range)/(Group Combination Range) (6)

Situation 1: $V(a_i) \leq 0$: In this case, there is no consensus. There is a conflict. It shows that the group did not reach an agreement. If a solution is to be found, the group members are expected to compare the individual utility ranges regarding the incomplete information of the group members to the utility of the other members and change them.

Situation 2: $0 \leq V(a_i) \leq$ δi: There is consensus. However it is not within an acceptable range such as δi. Here, δi represents the threshold value set for criteria i. In order to reach consensus, either this limit is reduced or the decision makers change their utility range.

Situation 3: $V(a_i) \geq$ δi: This situation shows that there is consensus and this consensus is within acceptable limit.

STEP 4: The options are put in an order or chosen by finding weakness or full priority relations based on comparisons in two.

STEP 5: If at least one of the group members is not satisfied with the result and wants to change previous opinion, step 1 is repeated, if there is no such situation, it ends at the result in step 4 [11].

The weakest point of the above procedure is that the options are based on comparisons in two but the priorities of these options are not placed on any scale. This situation causes problem about this method in cases where scaling is necessary such as performance evaluation. There are differences between the options but there is no answer regarding the amount. Instead, the following steps can be followed after step 3.

STEP 4: The utility range of the group regarding the options is determined in criteria level. This utility range is based on the group consensus utility range that was agreed on step 3.

STEP 5: The utility range of the group will be weighed and min and max utility values are reached for the options. While calculating this, the following equations are solved. The weight of the criteria should serve the purpose of the decision and their totals should be one [16].

$$U_{\min}{}^G(a_j) = \min \sum_i W_i \min U_i^G(a_j) \quad (7)$$

$$U_{\max}{}^G(a_j) = \max \sum_i W_i \max U_i^G(a_j) \quad (8)$$

STEP 6: The values obtained are evaluated according to Hurwicz decision model. This decision model is a consensus of optimist and pessimist approaches. That means it will help us for a consensus decision with an Optimist Coefficient (α) ranging between 0 and 1 which is the group decision between the minimum and maximum values. Maximum values set by the group for each option and are multiplied by Optimist Coefficient (α) and minimum values are multiplied by pessimist coefficient (1- α) and the values are added. The following procedure is used in finding the Alfa value.

STEP 6.1: Calculating α value

1. The incomplete information type decision makers are asked to state their optimist level in range form. The vagueness and risks in the future are the most important obstacles in reaching the maximum utility value that decision makers state. Within this context, we try to set the optimist coefficient of the group from the individual optimism of the decision makers. The reason we take the optimist coefficient as incomplete information is the existence of the vagueness and risk that lead us to use the optimist coefficient and this vagueness causes the information to be incomplete. While clear results are obtained under sufficient information, in cases where there is vagueness and risk, clear results are unfortunately not obtained.

2. The consensus and combination range of the group are calculated. It is checked whether the consensus ratio is sufficient. If it is not, the consensus procedure used in utility information is applied.

3. The minimum value within the consensus range of the group is taken as α value to minimize regret.

STEP 7: If at least one member of the group is not satisfied with the result and wants to change his/her previous opinion, step one is repeated. If not, the result in step 6 is accepted.

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, Utility Range Based Interactive Group Decision

Method. The decision-makers consisted by three academics and three experts from the ministry of health. Four 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, a_3 and a_4.

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 importance of the criteria was determined by the group leader based on the priorities of the the ministry of health. Since the decision makers did not know the method, the meeting was planned as four whole day sessions. The target was to explain the method in the first session, presenting the problem and obtaining the incomplete utility information from the decision makers in the second session, converting the information turned into utility range to group utility range and to obtain the alpha weight information (optimist coefficient) and evaluating the options in the fourth session. The sessions were carried out by one session in the morning and three sessions in the afternoon. In the first session, it was targeted to transfer the method. In the last session, after the decision was announced, a questionnaire was made to learn the opinions of the group members regarding the method. A satisfactory choice for the group members was made among the options.

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 a_1 and a_3 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.

This method utilizes the decision-makers' tendency to provide partial information. Partial information causes uncertainty and risk. Therefore, users with partial information would like to increase their level of information. The method is important because it targets obtaining the group's common benefit information. It was seen that the use of this method provides an opportunity to mutually and continually correct the misunderstanding in the group members' communication, increase the decision-makers' ability to handle the situation multi-dimensionally, and ensure that the more experienced and informed group members would benefit from their mastery. The comments about the method are that made it easier to reach the group's objections rather than the persons', increase cooperation and coordination between the group members, and made the evaluation process more objective. However, the time to reach a decision took longer than the personal decision making processes, but the quality of the decision increased due to the increase in the amount of information used.

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