Selection of medical waste logistic firms by using AHP-TOPSIS methodology

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Abstract: - Hospitals create large amount of medical waste that endangers human health and sanitation if handled improperly. Hence, medical waste is to be handled by appropriate logistics firms that transport it to special disposal facilities to minimize the potential environmental hazards and decrease operational expenses. The selection of the most appropriate logistic service provider for medical waste management is an essential procedure to ensure hygiene. However, hospitals select their medical waste management firm inefficiently, where the service performance is often clouded by subjective judgment and past experience. This work presents a systematic and logical approach to evaluate hazardous medical waste management (HMWM) logistic firm selection process through AHP (Analytical Hierarchy Process) based TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) methodology. AHP process is used to obtain the criteria weights and then based on interviews with experts, TOPSIS method is used to objectively select the most suitable hazardous medical waste logistic firm to at the same time reduce overhead costs and enhance hazardous waste management in a hospital environment. The proposed method offers very efficient and precise means to select HMWM logistic firms than other subjective assessment methods do and so reduces the potential health and environmental risk for hospitals environment.

Key-Words: - Medical waste, hazardous medical waste management, logistic firm selection, AHP, TOPSIS

1 Introduction

Medical waste should be treated as special type of waste, defined as hazardous wastes. Many hospitals pay less attention to medical waste management, which can pose risks on their premises and thus translate into an increase in the amount of hazardous medical waste and related operating expenses [1].

The issue of medical waste management is becoming more of a concern for hospital managements as it can cause major impairments to health or environment if not handled properly. Ensuring suitable environments and minimizing the costs associated with medical waste management at the same time is a challenge for hospital management. Medical waste is usually transported by specialized firms to disposal facilities. The logistic firm selection for waste management process has therefore gained more importance in recent years. However, finding the right logistic firm is a cumbersome process for hospital managements to comply with regulations and be cost effective. Safe management of medical waste is of high priority as poor medical waste management can even lead to infections and contagious diseases, making the selection of the hazardous medical waste management (HMWM) logistics firm a crucial decision. There are a number of factors that affect the HMWM logistics firm selection process which involves different skilled people and vague and imprecise information about the problem.

Since selection of the HMWM logistic firms is based on the evaluation of several criteria of different alternatives, this is a multi-criteria decision-making (MCDM) problem. As more than one decision maker (DM) is involved, a group decision making (GDM) approach shall be employed. There are many methods (such as AHP, ANP, TOPSIS, ELECTRE, etc.) used in the literature in order to select the best available alternative among others. These methods either used precise information for the attributes or they are expressed in terms of membership functions of classical fuzzy approach. However, TOPSIS method is the most efficient and effective method among them for reaching a final conclusion about alternatives.

The rest of the paper is organized as follows: In section 2, a literature review about HMWM is detailed. Then the simple introduction to AHP and

TOPSIS is given. The detailed steps of the proposed method are explained in section 3. In the 4th section, a numerical experiment is illustrated to display the performance of the proposed method. Finally, the last section gives a conclusion to the study with a discussion of the obtained results and the limitation of the study. Then, the possible directions for future research opportunities is mentioned.

2 Literature Review

Hazardous medical waste (HMW) can be characterized as any unwanted material that are produced while undertaking medical treatment, health protection, and scientific research. The main sources for HMW are hospitals, clinics, health centers, diagnostic and research laboratories, autopsy centers, transfusion and hemodialysis centers, nursing homes and mortuaries [2].

Environmental regulations state that medical institutions can contract publicly or private owned firms to handle hazardous medical waste [3]. An Implementation of a Global Budget System which necessitates the hospitals and health care system to encounter the challenges of creating a fiscal balance in waste management operations is presented in [4].

HMWM may cause significant damage to human health and environment if not handled properly. Nowadays, there is an increasing popularity of choosing the right logistic firm for transporting medical waste. In a recent paper, the medical hazardous waste disposal firm is selected using the Analytical Hierarchy Process (AHP) and modified Delphi technique [5]. They suggest that their method reduced overhead costs and thus enhanced the management of hazardous waste. Another study suggested a fuzzy AHP method to medical and health care institutions for evaluating appropriate infectious medical waste disposal firms objectively and systematically [6]. This study developed a hazardous waste minimization procedure using MCDA approach with geographical information [7]. In this study, AHP is used to define the priorities of evaluation criteria since it was easier and useful.

A case study for waste management is carried out in the USA using DEA-TOPSIS techniques [8]. Another study proposed an assessment of hazardous waste management using AHP [9]. An AHP approach for sitting hazardous waste landfill in large areas based on site screening method is presented by Abessi and Saeedi [10]. Another study suggested a multi objective optimization model for the proper management of hazardous waste [11]. They have incorporated AHP with goal programming approach to prioritize the conflicting goals.

3 Methodology

MCDM methodologies are useful for comparing, ranking and selecting multiple alternatives with multiple criteria. When evaluating decision support systems, MCDM techniques are extensively used. When there are several alternatives available and a decision needs to be taken by favoring one over other alternatives, MCDM can be used. In real world situations, such problems frequently occur, where the decisions must be reached in the presence of several criteria to judge the available alternatives. In such circumstances compromise or tradeoffs should be made according to the outcome on the basis of one or more criteria. There are several MCDM methodologies in the literature. To summarize, a variety of different logistic firm selection approaches have been proposed in the literature based on different factors and techniques. This study proposes an AHP based TOPSIS approach for HMWM logistic firm selection in which the attributes are: Firm’s equipment, Firm’s Qualification, Firm’s Service Capability and Economic Factors.

3.1 AHP Process

As a decision-making method, AHP breaks down a multi-criteria decision problem into a hierarchical structure. It is first introduced by Saaty in 1977 in order to identify the weights of the criteria for decision-making purposes.

- Equipment is a criterion used to measure the container storage capacity, elimination of redundant use of machinery and management information systems.
- Qualification is to ensure companies vehicles are equipped with global positioning systems, efficiently deal with the amount of waste discarded and conform to environmental protection standards.
- Service Capability is to measure the speed up the appeal process, provide additional services promptly, clarify program alternatives and specialized skills.
- Economic Factors are to provide discounts for long term customers and establish a price for collecting fees.

3.2 TOPSIS Method

TOPSIS method is an MCDM methodology presented by Hwang and Yoon in 1981. This method exploits the hypothesis that the best preferred alternative is the one which is very far from the negative ideal solution and very near to positive ideal solution. The positive ideal solution takes the maximum of benefit criteria and minimum of the cost criteria, the negative ideal solution takes the minimum of benefit criteria and maximum of the cost criteria. Briefly, positive ideal solution takes the best value of the solution criteria while negative ideal solution takes the worst value of the solution criteria. This method ranks the alternatives by considering distances from positive ideal to negative ideal points. The procedure is as follows.

Step 1. Define the alternatives and criteria

Determination of the alternatives to be ranked and the criteria to evaluate these alternatives.

Step 2. Construct the decision matrix

Alternatives are placed on the rows of the decision matrix while criteria are placed on the columns of the matrix. The decision matrix is displayed as below.

$$A_{ij} = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{m1} & \cdots & a_{mn} \end{bmatrix},$$

Step 3. Normalization of the decision matrix

Use the equation 1 to normalize the decision matrix.

$$r_{ij} = \frac{w_{ij}}{\sqrt{\sum_{i=1}^{j} w_{ij}^2}}, j = 1, 2, 3, \ldots, j, \qquad i = 1, 2, 3, \ldots, n \qquad (1)$$

Step 4. Weighted normalized decision matrix

Use equation 2 to find weighted matrix. Weights are given as a result of AHP calculations.

$$v_{ij} = w_i * r_{ij}, j = 1, 2, 3, \ldots, j, \qquad i = 1, 2, 3, \ldots, n \qquad (2)$$

Step 5. Positive ideal solution and Negative ideal solution

Use equation 3 and 4 to find positive and negative ideal solutions, respectively.

$$A^* = \{v_1^*, v_2^*, \ldots, v_n^*\} \quad maxsimum\ values \qquad (3)$$

$$A^- = \{v_1^-, v_2^-, \ldots, v_n^-\} \quad minumum\ values \qquad (4)$$

Step 6. Calculate the separation measures

Use equation 5 and 6 to calculate separation measures of negative and positive ideal solutions.

$$d_i^* = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^*\right)^2}, j = 1, 2, \ldots, J \qquad (5)$$

$$d_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2}, j = 1, 2, \ldots, J \qquad (6)$$

Step 7. Calculate the closeness coefficient

Calculate the closeness coefficient for each alternative using the equation 7.

$$CC_i = \frac{d_i^-}{d_i^* + d_i^-}, i = 1, 2, \ldots, J \quad 0 \leq CC_i \leq 1 \qquad (7)$$

Step 8. Rank the alternatives.

4 Results

In this study, a hospital is to select a HMWM logistic firm for handling its hazardous waste. There are four logistics firm candidates; A1, A2, A3, and A4. In order to evaluate candidate logistic firms, Equipment, Qualification, Service Capability, and Economic Factors are considered as evaluation factors.

According to the hierarchical structure constructed, the weights for the criteria is displayed in Table 1. As shown, Equipment is the one that comes first with a value of 0.46. AHP is applied in order to calculate the weights for each criterion.

Table 1: Weights of the Criteria

Weight Vector	Equipment	Qualification	Service Capability	Economic Factors
Wj	0.46	0.23	0.17	0.14

Table 2 displays the decision matrix used in application.

Table 2: Decision Matrix

	Equipment	Qualification	Service Capability	Economic Factors
A1	6.9	3.1	9	7
A2	5.9	3.9	7	6
A3	6	3.6	8	8
A4	6.2	3.8	7	10

Normalized standard decision matrix is constructed in Table 3.

Table 3: Normalized Decision Matrix

	Equipment	Qualification	Service Capability	Economic Factors
A1	0.5509	0.4290	0.5774	0.4436

A2	0.4711	0.5397	0.4491	0.3802
A3	0.4791	0.4982	0.5132	0.5070
A4	0.4950	0.5259	0.4491	0.6337

By the help of criteria weights in Table 1, a weighted matrix is calculated by multiplying the weight with the standard matrix as shown in Table 4.

Table 4: Weighted Normalized Decision Matrix

	Equipment	Qualification	Service Capability	Economic Factors
A1	0.2541	0.0981	0.0956	0.0641
A2	0.2173	0.1234	0.0744	0.0549
A3	0.2210	0.1140	0.0850	0.0732
A4	0.2283	0.1203	0.0744	0.0915

In order to construct the negative and positive ideal solutions, the minimum and maximum values in the weighted standard decision matrix is taken, as shown in Table 5.

Table 5: Positive Ideal Solution and Negative Ideal Solution

A*	0.2541	0.1234	0.0956	0.0915
A-	0.2173	0.0981	0.0744	0.0549

Using the equation 5 and 6, values belong to each criterion in the column of decision matrix is subtracted from positive and negative ideal solution to construct the separation measures in Table 6.

Table 6: Separation Measures

	S*	S-
A1	0.0374	0.0435
A2	0.0561	0.0253
A3	0.0405	0.0267
A4	0.0336	0.0442

Table 7 displays the closeness coefficient calculated by using the equation 7 and ranking is done as shown.

Table 7: Closeness Coefficient and Ranking

	C*	Rank
A1	0.5379	2
A2	0.3110	4
A3	0.3975	3
A4	0.5685	1

A4 is the best alternative for HMWM logistic firms' selection.

5 Conclusion

HMWM logistic firm selection is a crucial decision for any hospital's overall strategic plan. This paper presents a TOPSIS MCDM model for evaluating alternatives in the HMWM problem. In order to compare, rank and select among multiple alternatives with multiple criteria, MCDM approaches are used. A number of different types of MCDM/fuzzy MCDM approaches have been proposed by researchers (such as AHP, ANP, TOPSIS, ELECTRE, etc.). This study proposes TOPSIS as an MCDM technique for the HMWM logistic firm selection problem in order to decide on the most proper firm. This approach is used to obtain the most efficient and effective ranking of the alternatives. It is a flexible and robust method to better understand a decision problem in case of uncertainty and vagueness in DMs perceptions.

Several future research directions could follow this study. The present approach considers the TOPSIS method. An interesting future work would be to consider other MCDM methods in order to resolve these problems effectively and satisfactorily.

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