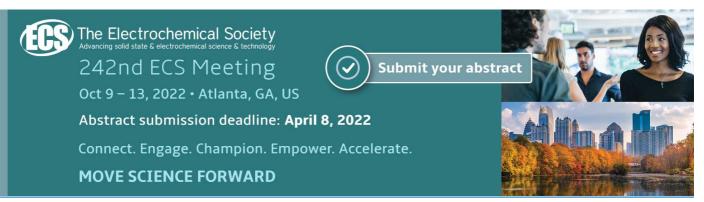**PAPER • OPEN ACCESS**

# Application of SWARA Technique to Find Criteria Weights for Selecting Landfill Site in Baghdad Governorate

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# Application of SWARA Technique to Find Criteria Weights for Selecting Landfill Site in Baghdad Governorate

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**Abstract.** In this study, Stepwise Weight Assessment Ratio Analysis (SWARA) is one of multi-criteria decision-making methods (MCDM). SWARA used to define the weights of main criteria and sub-criteria for selecting landfill sites in Baghdad governorate for municipality solid waste. To control of the environmental pollution and the spread of municipality solid waste in irregular sites, SWARA was used for this matter. The alternative Landfill site selection must be properly selected in terms of environmental, social and geological criteria. The obtained results of this study, the most important criteria for selecting municipality solid waste landfill sites were determined. Based on that, the ranking weights of main criteria and sub-criteria for selecting the landfill site for solid waste in Baghdad governorate were founds.

**Keywords:** SWARA, MCDM, Baghdad Governorate, landfill site.

## 1. Introduction

The diversification and increase of municipal solid waste generated by households as a result of population growth, social, economic and industrial activities, as well as the rise in the standard of living cost per capita and modern technological improvements. According to this increase in municipal solid waste in the governorate of Baghdad, this requires a regular landfill sites that follow the international, Arabic and local criteria. In this study, the environmental, social, and geological criteria will be the most prominent features. The influence of these criteria on air, water and soil causes damage to the environment and health and society. The aim of this study is to define the criteria for landfill site selection in Baghdad governorate. For this purpose, three parts were conducted. In the first part, studying landfill site selection criteria for municipality solid waste was examined. In the second part, information about the SWARA technique has been explained and finally, in the third part determining the weights of criteria landfill site by application the SWARA technique to solve the problem of this study was applied.

## 2. Literature Review

Some of the studies on landfill site selection for solid waste are given below. In this context, a study on the real application of the Elimination Et Choice Translating Reality ELECTRE III to be as a MCDM on the choice of landfill location in Oulu area of Finland. ELECTRE III technique was considered useful in selecting of landfill site for solid waste management systems where the outcomes of the numerous alternatives are somewhat uncertain [1]. In the Dakar city, different studies have carried out using the Preference ranking organization method for enrichment evaluation

PROMETHEE technique to find the worst and best areas to get the best alternative location for landfill site for solid waste for this city [2]. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) technique was used for selecting a regular landfill site using multi-criteria decision analysis and incomplete linear mixed programming methods [3]. Applying the Analytical Hierarchy Process AHP to be another MCDM, which pacts with set priorities of engineering design and operating aims in a number of modern and developed countries. It is also used to list and prioritize for social, economic, healthcare, safety, public perception goals and also used to find best alternative landfill site [4]. Restrictions used such as distance to the city centre, wells, irrigation canals, transportation ways, railways, distance from protected areas, population, land use, land value, and slope of land were considered to determine the most suitable sites in the Jomra zone. A final map of the work area is produced and the most suitable areas for selecting a landfill site were shown and the TOPSIS and ENTROPY methods were used [5]. A study provided an evaluation technique for choosing and ranking MSW disposal techniques suitable for DMs in non-governmental organization. Using the Analytical Network Process ANP, fourth key criteria, twenty-two sub-criteria, and four alternatives for landfill site selection were studied [6]. FUZZY TOPSIS is an ambiguous methodology for selecting a suitable method and landfill site of solid waste disposal. This technique is considered one of the best methods because it has the capability to represent un-confirmed qualitative data and give possible outcomes for membership in numerous grades. It is also considered an alternative to fuel derived from systematic landfill site, composting, burning and surplus. The weights of the landfill site selection criteria are determined via the impervious pair-matrices of the ANP technique. It was categorical that fuel derived from waste is the best alternative way in Istanbul city [7]. The substitute landfill sites of solid waste were determined via geographic information systems GIS giving to the criteria applied in landfill site selecting for municipality solid waste in two studying zones in Anatolian city [8]. An application that uses an analytical hierarchy process AHP technique to select the correct packing solid waste recycling center in Izmir city was performed [9]. In order to find the best scenario in choosing a landfill site for solid waste management in Bosnia and Herzegovina, the study presented very specific applications for decision making. Among the six alternatives site, geological, political, technological, economic, social and environmental objectives were taken in order to choose the best scenario for selecting a landfill site for municipal solid waste [10]. In addition, there were limited studies conducted to find the criteria weights of landfill site selection through SWARA approaches.

### 3. Methodology of Research
Methodology of research can be briefly illustrated by the following steps:
1. Gathering the required information (criteria), during theoretical study and field work about the study topic based on research plan that is used to find the main criteria and sub-criteria in landfill site select.
2. Field work, applied in Baghdad Mayoralty; Department of Solid Waste and Environmental (DSWE) and Department of Planning and Design (DPD) was performed in this study.
3. Using the open questionnaire from a group of engineering working in projects of solid waste management (field work) to gathering the data (criteria).
4. Using the SWARA technique to find the weights of main criteria and sub-criteria that should be considered during the process of selecting the locations of landfill sites in Baghdad Governorate.

### 4. Field work (Case study)
In this research, the field work in Baghdad Mayoralty of (DSWE) and (DPD) to meeting of a group of engineers that have the knowledge and experts in solid waste management and have the abilities to provide the accurate information about the criteria that is used to select the landfill site in Baghdad governorate.

### 5. Criteria for landfill site selection
The first most important phase in landfilling is the selection of a suitable site. the landfill site selection of solid waste requires a careful examination and evaluation of all of the criteria of landfill

construction and operation that could potentially result in adverse effects on the environment. There are a number of criteria here that capture by theoretical study and field work. For selecting a landfill site, which are environmental, social, and geology criteria are considered and every main criterion divided to sub-criteria as shown below.

### 5.1. Environmental main criteria (EMC)

The main objective of environment criteria is reducing pollution with desirable and lowest use of resources that its consequence is perfect output with extra production and a smaller amount of waste. EMC is divided into three sub-criteria as showed in table 1 below [11, 12].

**Table 1.**Environmental sub-criteria (ESC)

| No. | Environmental sub-criteria |
| --- | --- |
| 1 | Ecological value of scientific zones  (ESC1) |
| 2 | The distance to cemeteries locations (ESC2) |
| 3 | The distance to historical regions     (ESC3) |

### 5.2.Social main criteria (SMC).

The selection of landfills sites location depends on how much the citizen are trust the government authorities. Landfills may not be constructed on sites within a distance of less than 1000 m to settlements area because the location of the landfill, if it is chosen randomly, will greatly affect the surrounding population. SMC divided in to three sub-criteria. Showed in table 2 below [13, 14].

**Table 2.** Social sub-criteria(SSC)

| No. | Social sub-criteria |
| --- | --- |
| 1 | Distance from settlement area(SSC1) |
| 2 | Distance to health centres(SSC2) |
| 3 | Religion sites(SSC3) |

### 5.3. Geology main criteria (GMC).

Suitable geology is an important criterion for the siting of a landfill to ensure the containment of leachate in unlined dumps or when there is a failure of an engineered containment systems. The type rivers, irrigation network and groundwater depth are directly influenced by the geology of the area. GMC is divided into three sub-criteria as shown in table 3 below [15, 16].

**Table 3.**Geology sub-criteria(GSC)

| No. | Geology sub-criteria |
| --- | --- |
| 1 | Rivers (GSC1) |
| 2 | Irrigation network (GSC2) |
| 3 | Groundwater depth (GSC3) |

## 6. SWARA Technique

SWARA technique provides an opportunity to policy makers to choose the best decision based on dissimilar situations and imports criteria based on their wants and objectives. The other significant

point is the role of specialists. Specialists play a main role in the procedure of every significant project [17]. The SWARA technique is also valuable to be applied in the procedure of decision and policy-making at the highest level of decision-making in important subjects. In determining the weights of the criteria for the selection of landfill site for solid waste in Baghdad governorate, SWARA technique which consider the Multi Criteria Decision Making MCDM method was used. SWARA is one of the MCDM method that is used to derive the uncertainties involved in the procedure of assessing linguistic expressions of criteria and alternatives. The main benefit of SWARA technique based on decision-making problems is that it does not need some assessment to resolve decision problems and to arrange the criteria and it is a scale to find the priorities weights of criteria based on organizations' strategies or plans [18].

*6.1. Basic steps of SWARA technique*
The basic principles of SWARA and the procedure of the determination of the relative weights of criteria can be detail through the subsequent steps as below [19].

*6.1.1 Step One:*
Criteria requirement to be arranged according to their importance. In this phase, the specialists (experts) perform the ranking of the defined criteria according to the importance they have; for example, the most important criteria are in the first position, the least important are in the last position, while the criteria in between have ranked significance.

*6.1.2 Step Two:*
Determine scientific criteria $(S_j)$; evaluates the comparative significance of average value. Beginning from the second ranked criteria, it is necessary to find their importance, that is, how much criteria $(C_j)$ is more important than criterion $(C_j+1)$.

$$S_j \leftrightarrow j + 1 = \sum_{k=1}^{r} C_j \leftrightarrow j + 1 \ / \ r \qquad (1)$$

*6.1.3 Step Three:*
Calculate coefficient $(K_j)$ as follows:
$$K_j = \begin{cases} 1 & j=1 \\ S_j + 1 & j>1 \end{cases} \qquad (2)$$

*6.1.4 Step Four:*
Determine recalculated weight $q_j$ as follows:
$$q_j = \begin{cases} 1 & j=1 \\ q_j - 1/K_j & j>1 \end{cases} \qquad (3)$$

6.1.5 Step Five:
Calculate the weight values of the criteria with the sum that is equal to one:
$$W_j = q_j \ / \ \sum_{k=1}^{m} q_j \qquad (4)$$

Where $W_j$ represents the relative weight value of the criteria.

## 7. Results
Environmental, Social and Geological criteria are considered the most important criteria used in selecting landfill site in Baghdad governorate. Each main criterion was divided into sub-criteria, these criteria affect the process of finding the weights to selecting the landfill site. The opinion of experts was very importance and it was taken, and the experts have the experience and knowledge in the project of solid waste management. The height weights of main criteria were geology criteria by 44.6% and ranking in the first position, and the second position was environmental criteria by 34.1% and the third position was social criteria by 21.3%. The height weights of geology sub-criteria were the river by 48.3% and the height weight of environmental sub-criteria was ecological value of

scientific zones by 41.3% and the height weights of social sub-criteria was distance from settlement area by 46.7%. In this research, a MCDM form was formed to assess the main criteria and sub-criteria that will be used in the process of selecting a landfill site for a solid waste in Baghdad governorate. The main criteria and sub-criteria that were used in selecting landfill site were defined using a literature review and field work (case study) with expert opinions. These criteria were weighted because the criteria specified were not of equal importance. In this study, landfill site criteria are weighted by the SWARA technique.

*7.1 Information of experts*
To define the weight of the main criteria and sub-criteria for landfill site selection in Baghdad governorate, eight experts working at Baghdad Mayoralty from different department fields participated in this research. Their selection procedure was based on their practical experience in the relevant fields and also general knowledge of solid waste management. Information about the experts were cleared in table 4 below.

**Table 4.** Information on experts'

| Education Level | Specializations | Experience | Department |
|---|---|---|---|
| Ph.D. | Civil | 25 year | Water |
| Ph.D. | Civil | 22 year | Planning |
| Ph.D. | Environmental | 20 year | Sewage |
| MSc | Soil | 22 year | Solid Waste |
| MSc | Architect | 17 year | Planning |
| MSc | Mechanical | 25 year | Solid waste |
| BSc | Civil | 30 year | Water |
| BSc | Civil | 28 year | Transfer Station |

*7.2 Descending order the main criteria and sub-criteria by expert's opinion.*
By the eight experts, the main criteria and sub-criteria were ranking. Descending order and the obtained ranking order were further used in the SWARA technique. Tables 5, 6, 7 and 8 show the descending order in main criteria and sub-criteria. Table 5 shows the coding the main criteria descending order by eights experts. Every expert defines the favorite level of ratings for each single selected criterion by applying the ratings in the interval (1–7) [20].

**Table 5.** Main criteria descending order by eights experts

| Expert | (EMC) | (SMC) | (GMC) |
|---|---|---|---|
| Expert 1 | 5 | 5 | 6 |
| Expert 2 | 5 | 5 | 5 |
| Expert 3 | 5 | 4 | 5 |
| Expert 4 | 4 | 4 | 5 |
| Expert 5 | 5 | 4 | 6 |
| Expert 6 | 4 | 5 | 6 |
| Expert 7 | 4 | 4 | 5 |
| Expert 8 | 5 | 4 | 6 |
| Total= 8 | Sum= 37 | Sum= 35 | Sum= 44 |

After ranking the main criteria by eight experts. The main criteria descending order became in first position geology main criteria (GMC), second position environmental main criteria (EMC) and third position social main criteria (SMC).

Tables 6, 7 and 8 show the sub- criteria descending order by the eight experts. Every expert defines the favorite level of ratings for each single selected criterion by applying the ratings in the interval (1–7).

**Table 6.** Geology sub-criteria descending order by eights experts (GSC)

| Expert | GSC1 | GSC2 | GSC3 |
|---|---|---|---|
| Expert 1 | 4 | 4 | 3 |
| Expert 2 | 4 | 4 | 3 |
| Expert 3 | 4 | 3 | 4 |
| Expert 4 | 5 | 5 | 5 |
| Expert 5 | 4 | 5 | 5 |
| Expert 6 | 5 | 4 | 4 |
| Expert 7 | 5 | 4 | 3 |
| Expert 8 | 4 | 4 | 3 |
| Total= 8 | Sum= 35 | Sum= 33 | Sum= 30 |

After ranking the (GSC) by eight experts. The sub-criteria descending order become in the first position rivers (GSC1), second position irrigation network (GSC2) and third position groundwater depth (GSC3).

**Table 7.** Environmental sub-criteria descending order by eights experts (ESC)

| Expert | ESC1 | ESC2 | ESC3 |
|---|---|---|---|
| Expert 1 | 5 | 3 | 4 |
| Expert 2 | 6 | 4 | 5 |
| Expert 3 | 6 | 5 | 4 |
| Expert 4 | 5 | 4 | 6 |
| Expert 5 | 4 | 6 | 5 |
| Expert 6 | 5 | 4 | 5 |
| Expert 7 | 4 | 5 | 5 |
| Expert 8 | 6 | 5 | 5 |
| Total= 8 | Sum= 41 | Sum= 35 | Sum= 39 |

After ranking the (ESC) by eight experts. The sub-criteria descending order become in first position ecological value of scientific areas (ESC1), second position distance to historical areas (ESC3) and third position distance to cemeteries sites (ESC2).

**Table 8.** Social sub-criteria descending order by eights experts(SSC)

| Expert | SSC1 | SSC2 | SSC3 |
|---|---|---|---|
| Expert 1 | 5 | 4 | 3 |
| Expert 2 | 5 | 4 | 3 |
| Expert 3 | 4 | 3 | 4 |
| Expert 4 | 6 | 5 | 5 |
| Expert 5 | 5 | 6 | 6 |

| | | | |
|---|---|---|---|
| Expert 6 | 5 | 5 | 4 |
| Expert 7 | 5 | 4 | 3 |
| Expert 8 | 5 | 4 | 3 |
| Total= 8 | Sum= 40 | Sum= 35 | Sum= 31 |

After ranking the (SSC) by eight experts. The sub-criteria descending order become in first position distance from settlement area (SSC1), second position distance to health centers (SSC2) and third position religion sites (SSC3).

*7. 3 Determine (Sj) comparative significance of average value for main criteria*
Table 9 shows the result of application the equation (1) for main criteria to get the average value (Sj) from the eight experts' ideas.

**Table 9.** Relative importance assessment main criteria by experts' ideas

| Expert | GMC ↔ EMC | EMC ↔SMC |
|---|---|---|
| Expert 1 | 0.30 | 0.60 |
| Expert 2 | 1.00 | 0.80 |
| Expert 3 | 0.20 | 0.60 |
| Expert 4 | 0.40 | 0.30 |
| Expert 5 | 0.10 | 0.70 |
| Expert 6 | 0.10 | 0.80 |
| Expert 7 | 0.05 | 0.50 |
| Expert 8 | 0.30 | 0.60 |
| Average Value | 0.306 | 0.601 |

After the finishing from the (Sj) comparative between the main criteria by application step (2) in the equation (1). The next stage is the calculation the weights of main criteria by applications the step (3) in equation (2), step (4) in equation (3) and step (5) in equation (4).
Table 10 shows the weights of main criteria by application SWARA technique.

**Table 10.** Weights of main criteria by SWARA technique

| Main criteria | $(Sj \leftrightarrow j+1)$ | $K_j = Sj + 1$ | $qj = qj{-}1 / kj$ | $Wj = qj / \sum qj$ |
|---|---|---|---|---|
| GMC | ----- | 1.000 | 1.000 | 0.446 |
| EMC | 0.306 | 1.306 | 0.766 | 0.341 |
| SMC | 0.601 | 1.601 | 0.478 | 0.213 |
| | | | Sum= 2.245 | Sum= 1.000 |

*7. 4 Determine (Sj) comparative significance of average value sub-criteria.*
Comparative significance of average values of geology sub-criteria were obtained. Table 11 shows the result of application the equation (1) for geology sub- criteria to get the average value of (Sj) from eight experts' ideas.

**Table 11.** Relative importance assessment to geology sub- criteria by experts' ideas

| Expert | GSC1 ↔ GSC2 | GSC2 ↔ GSC3 |
|---|---|---|
| Expert 1 | 0.80 | 0.75 |
| Expert 2 | 0.30 | 0.45 |
| Expert 3 | 0.60 | 0.65 |
| Expert 4 | 0.55 | 0.45 |
| Expert 5 | 0.45 | 0.35 |
| Expert 6 | 0.75 | 0.65 |
| Expert 7 | 0.80 | 0.80 |
| Expert 8 | 0.10 | 0.15 |
| Average Value | 0.544 | 0.531 |

After finishing from (Sj) calculation of comparative between the geology sub-criteria by application step (2) in the equation (1), the next stage was the calculation the weights of geology sub-criteria by applications the step (3) in equation (2), step (4) in equation (3) and step (5) in equation (4).
Table 12 shows weights of the geology sub-criteria by application SWARA technique.

**Table 12.** Weights of the geology sub-criteria by SWARA technique

| Geology sub-criteria | (Sj↔ j+1) | K j=Sj + 1 | qj = qj−1/ kj | Wj = qj / ∑ qj |
|---|---|---|---|---|
| GSC1 | ----- | 1.000 | 1.000 | 0.483 |
| GSC2 | 0.544 | 1.544 | 0.647 | 0.313 |
| GSC3 | 0.531 | .1531 | 0.423 | 0.204 |
| | | | Sum= 2.070 | Sum= 1.000 |

Comparative significance (Sj) of average value for Environmental sub- criteria was determined. Table 13 shows the result of application the equation (1) for environmental sub- criteria to get the average value of (Sj) from eight experts ideas.

**Table 13.** Relative importance assessment to environmental sub- criteria by experts ideas

| Expert | ESC1 ↔ ESC3 | ESC3 ↔ ESC2 |
|---|---|---|
| Expert 1 | 0.25 | 0.30 |
| Expert 2 | 0.15 | 0.25 |
| Expert 3 | 0.30 | 0.40 |
| Expert 4 | 0.25 | 0.35 |
| Expert 5 | 0.15 | 0.20 |
| Expert 6 | 0.35 | 0.40 |
| Expert 7 | 0.20 | 0.30 |
| Expert 8 | 0.25 | 0.25 |
| Average Value | 0.240 | 0.306 |

After finding the (Sj) comparative between the environmental sub-criteria by application step (2) in the equation (1), the next stage was the calculation the weights of environmental sub-criteria by applications the step (3) in equation (2), step (4) in equation (3) and step (5) in equation (4).

Table 14 shows weights of the environmental sub-criteria by application SWARA technique.

**Table 14.** Weights of the environmental sub-criteria by SWARA technique

| Environmental sub-criteria | $(S_j \leftrightarrow j+1)$ | $K_j = S_j + 1$ | $q_j = q_{j-1}/k_j$ | $W_j = q_j / \sum q_j$ |
|---|---|---|---|---|
| ESC1 | ----- | 1.000 | 1.000 | 0.413 |
| ESC3 | 0.240 | 1.240 | 0.806 | 0.333 |
| ESC2 | 0.306 | .1306 | 0.617 | 0.254 |
|  |  |  | Sum= 2.423 | Sum= 1.000 |

Comparative significance (Sj) of average value for Social sub- criteria was calculated. Table 15 shows the results of application the equation (1) for social sub- criteria to find the average value of (Sj) from eight experts' ideas.

**Table 15.** Relative importance assessment to social sub- criteria by experts' ideas

| Expert | SSC1 $\leftrightarrow$ SSC3 | SSC3 $\leftrightarrow$ SSC2 |
|---|---|---|
| Expert 1 | 0.75 | 0.75 |
| Expert 2 | 0.35 | 0.45 |
| Expert 3 | 0.50 | 0.65 |
| Expert 4 | 0.55 | 0.35 |
| Expert 5 | 0.45 | 0.25 |
| Expert 6 | 0.70 | 0.55 |
| Expert 7 | 0.45 | 0.10 |
| Expert 8 | 0.25 | 0.15 |
| Average Value | 0.500 | 0.406 |

After finding the (Sj) comparative between the social sub-criteria by application step (2) in the equation (1), the next stage is the calculation the weights of social sub-criteria by applications the step (3) in equation (2), step (4) in equation (3) and step (5) in equation (4).
Table 16 shows weights of the social sub-criteria by application SWARA technique.

**Table 16.** Weights of the social sub-criteria by SWARA technique

| Social sub-criteria | $(S_j \leftrightarrow j+1)$ | $K_j = S_j + 1$ | $q_j = q_{j-1}/k_j$ | $W_j = q_j / \sum q_j$ |
|---|---|---|---|---|
| SSC1 | ----- | 1.000 | 1.000 | 0.467 |
| SSC3 | 0.500 | 1.500 | 0.667 | 0.312 |
| SSC2 | 0.406 | .1406 | 0.474 | 0.221 |
|  |  |  | Sum = 2.141 | Sum = 1.000 |

*7. 5 Final weights for main criteria by SWARA technique*
Table 17 shows the final weights for main criteria for selection landfill site in Baghdad governorate using SWARA technique.

**Table 17.** Final weights for main criteria for selection landfill site.

| Main criteria | Weight % |
|---|---|
| Geology | 44.6% |
| Environmental | 34.1% |
| Social | 21.3% |

*7. 6 Final weights for sub- criteria by SWARA technique*
Tables 18, 19 and 20 show the final weights for sub-criteria for selection landfill site in Baghdad governorate by used SWARA technique.

**Table 18.** Final weights for geology sub- criteria.

| Geology sub-criteria | Weight % |
|---|---|
| Rivers (GSC1) | 48.3% |
| Irrigation network (GSC2) | 31.3% |
| Groundwater depth (GSC3) | 20.4% |

**Table 19.** Final weights for environmental sub- criteria.

| Environmental sub-criteria | Weight % |
|---|---|
| Ecological value of scientific zones (ESC1) | 41.3% |
| The distance to historical regions (ESC3) | 33.3% |
| The distance to cemeteries locations (ESC2) | 25.4% |

**Table 20.** Final weights for social sub- criteria.

| Social sub-criteria | Weight % |
|---|---|
| Distance from settlement area (SSC1) | 46.7% |
| Distance to health centers (SSC2) | 31.2% |
| Religion sites (SSC3) | 22.1% |

**8. Conclusion**
This study aimed to find the weights of main criteria and sub-criteria that were used in selecting the landfill site in Baghdad governorate. Three main criteria and nine sub-criteria were used in this study. Also, the opinion of experts was taken to rank the main criteria and sub-criteria from higher to lower. This work has been discussed with experts who are considered to be as a part to this subject, but this number has not been increased due to time constraint. The SWARA technique was a new technique used as a powerful tool capable of determining the weights of main criteria and sub-criteria. On the other hand, the problem addressed in this study can be applied to other areas. In addition, the study can be developed in the future with the addition of fuzzy logic with other MCDM and other parametric or nonparametric methods, and the results can be compared and discussed.

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