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Municipal Solid Waste Landfill Site Selection: Integrating Multi-Criteria Decision-Making Methods and Mathematical Modelling - A Case Study

Onur DERSE[1], Elifcan GÖÇMEN POLAT[2]

Highlights:
- Landfilling of MSW has been addressed.
- Fuzzy-AHP is utilized to decide the weights.
- TOPSIS is conducted to rank the alternative landfill districts.

Keywords:
- Landfilling of municipal solid waste
- MCDM
- Fuzzy-AHP
- TOPSIS
- Location selection

ABSTRACT:

Increasing solid waste amount arisen from the urbanization and population growth is an inevitable outcome in many countries. Solid waste has become one of the serious environmental problems and peculiar solid waste pathways are required to prevent contamination of environment. The optimal planning of the waste management should comprise the operations such as minimization, collection, landfilling and recycling of the waste. Also, location selection for landfill of municipal solid waste (MSW) is an effective step even essential, due to growing area shortage for waste disposal. In this respect, landfilling of MSW has been addressed in Tunceli, Turkey using an integrated approach. The Fuzzy Analytical Hierarchy Process (Fuzzy-AHP), a multi-criteria decision-making (MCDM) method, is utilized to decide the weights of the environmental, technical, economic, and social criteria regarding uncertainty. Then, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is conducted to rank the alternative landfill districts. Finally, the sub locations of selected district are mathematical modelled regarding transport cost, investment cost and demand with an integer linear programming model. The computational results indicate the proposed method effectiveness with a systematic approach by integrating MCDM and mathematical modelling.

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INTRODUCTION

Urbanization, living standards, population expansion bring about the waste generation in the world (Minghua et al., 2009). Some researchers address that the cause of the generated waste is income and size of the family (Sujauddin et al., 2008). Waste management is one of the most critical issues due to the increasing waste generated each year (Ghiani et al., 2014). Waste management operations are mainly not conducted optimally due to improper collecting and routing decisions (Hazra and Goel, 2009). Although waste management comprises the minimization, collecting, transferring, and recycling of the waste, most municipalities organize the only waste collection using door to door and mixed techniques (Seyring et al., 2016) and unsanitary landfilling (Tınmaz & Demir, 2006). Increasing MSW generated by population growth is especially great problem not only this municipality but also all the world (Alfaia et al.,2017). Municipalities are not able to deal with this increasing waste stream on city centres (Rathi, 2006). To handle with large waste amount and ensuring a clean environment is required for the optimal management of MSW (Rabbani et al., 2018). Although MSW management is getting attraction in recent years, the installation of the waste facilities requires financial supports. This is associated with the expensive collection processes and recycling systems. Thus, uncontrolled MSW is the main source of most issues in developing countries (Joshi & Ahmed, 2016). The proper MSW management minimizes the waste amount and related problems and maximizes the energy production (Yousefloo & Babazadeh, 2020). MSW management includes collecting, transfer, treatment, recovery, and disposal activities (Bertanza et al., 2018). Although waste collection is an important part of MSW network to minimize emissions and energy utilization (Jaunich et al., 2016; Mora et al., 2014), landfilling is one of the most well-known treatment techniques (Ayvaz-Cadaroğlu et al., 2019). However, the lack of landfill can bring about undesired aspects for the environment, human health and thus, main challenge is to demonstrate the effectiveness of landfilling for a real case study.

The motivation of this study is to examine the generation and composition of MSW and improve the MSW system in Tunceli. According to Tunceli Province 2019 Environmental Report, there is no regular MSW landfilling facility in Tunceli. Solid waste storage area also brings about the different environmental pollution types and these pollutants cause the concern for human health. Leachates from this area mix with the city’s river and streams and hurt the quality of the water sources, causing great reactions from the public, especially in the village next to the storage area. Besides, a suggestion by the following paper is the other motivation of this paper: Zamorano et al. (2008) address that environmental, socio-cultural, and economical factors and engineering methods should be handled for selecting the landfill locations. This paper provides the interactions between quantitative and qualitative criteria for the location selection of landfilling facilities. First, with the Fuzzy AHP method, the importance of environmental, economic, social, and technical criteria is evaluated in terms of MSW. Then, using Fuzzy AHP-based TOPSIS, the most optimal area is decided for landfilling. In the last step, sub-locations are mathematically modelled based on the distances, cost, and demand. The main contributions of the paper, to the best of our knowledge, it is the first paper to provide a Municipal Solid Waste Management (MSWM) approach regarding various criteria in an integrated manner. Besides, providing a combined MCDM and mathematical modelling approach is handled for the first time to locate a waste landfilling facility. In addition, real data used in the study demonstrates the effectiveness of the study. Waste amount has increased especially during the coronavirus pandemic in Tunceli. This pandemic boosts the wastes and affects the living standards and environment (Göçmen, 2020). The next years can handle with the waste amount increases regarding the environmental issues. This increase also brings about medical and environmental risks (Singh et al., 2020). One of the critical aims in the context of waste management is where to establish the waste facility location for landfill. Most research studies examine the important metrics affecting waste management (Guerrero et al., 2013). In recent years, many researchers have been studied the location of the waste facilities. Higgs (2006), address the waste facility location using geographical information systems (GIS) and multi-criteria evaluation techniques. Darmian et al. (2020), address the optimization model to collect the MSW in Iran. A mathematical model of MSW transport system to minimize waste transportation time and cost is addressed (Monzambe et al., 2021). Polat (2021) investigates the medical waste treatment centre in Turkey using fuzzy modelling. Waste planning at the city level is examined regarding waste location and routing decisions. Most researchers address the waste collection using mathematical modelling (Valizadeh, 2020; Xue et al., 2015; Aliahmadi et al., 2020). In addition, a comprehensive MSW management is conducted utilizing the mathematical modelling approach by researchers (Lee et al., 2016; Ayvaz-Cavdaroglu et al., 2019; Asefi & Lim, 2017). Besides, mathematical modelling is also used for minimizing total cost (Salvia et al., 2002), maximizing the financial value (Münster & Meibom, 2011) and incorporating the optimal method in waste management (Rathi, 2007). MCDM is mainly used to solve MSWM problems (Singh, 2019). Selection of the optimal transportation firm is addressed using Fuzzy AHP-TOPSIS methodology in the waste management (Gumus, 2009) and decision making for solid waste management considering sustainable expansion is conducted using AHP based fuzzy TOPSIS (Pires et al., 2011). Ekmekçioğlu et al. (2010), use fuzzy AHP and TOPSIS to select site of MSW in Turkey. Demesouka et al. (2013) utilize the AHP and TOPSIS methods for MSW landfills. Bilgilioğlu et al. (2021) address the MSWM site using GIS and AHP. They evaluate the optimal sites using topographical, hydrological, geomorphological, infrastructural, and auxiliary criteria. Zarin et al. (2021) investigate the optimal solid waste landfill area using MCDM. Makonya & Msabi (2021) determine the optimal landfill sites using GIS based MCDM. The present work has some advantages comparing the preliminary papers in the literature (i) location selection for landfilling is handled considering the decision maker's assignments based on the experience and technical information (ii) the weights of environmental, economic, social, and technical criteria and ten sub criteria are obtained utilizing pairwise comparison via fuzzy-AHP method (iii) ranking of the candidate landfill locations are ensured via TOPSIS method.

MATERIALS AND METHODS

In this study, the model developed with the FAHP based TOPSIS technique and mathematical programming model. The proposed approach is recommended by incorporating the performance metrics to the mathematical modelling (Derse & Göçmen, 2019). To evaluate these determined alternatives, the criteria for the identified alternative areas are created after a detailed literature review and expert opinions. Waters criteria are obtained from the Tunceli Province 2019 Environmental Report. It is stated that Flora is concentrated in Tunceli Center, Ovacık, Pülümür, Hozat and Nazımiye districts. The forests are concentrated in Tunceli Center, Ovacık, Pülümür, Hozat and Nazimiye districts. The fauna is concentrated in Munzur Valley and its surroundings and Pülümür Stream. Therefore, the regions where the fauna is concentrated are assumed to be Tunceli Center, Ovacık and Pülümür. Based on this information, biodiversity scoring is obtained. Total agricultural field data is obtained from Republic of Turkey Ministry of Agriculture and Forestry, Tunceli Directorate of Provincial Agriculture and Forestry Population values are obtained from T. C. Tunceli Governorship. The amount of waste (taking into account the amount of collected medical waste) is obtained by the Tunceli Province 2019 Environmental Status Report Data and agro-ecological sub-regions of Tunceli province are obtained by Republic of Turkey Ministry of Agriculture and Forestry, Tunceli Directorate of Provincial Agriculture and Forestry. These values are entered into the system as soil and topography data. The determined criteria are categorized as environmental, economic, social, and technical:

Environmental consideration: Improper MSW management adversely affects the biodiversity. Landfill management has a critical role on biodiversity preservation (Weng et al., 2015). Biodiversity management efforts focus on the mitigate the MSW effects. Distance from water resources are the most sensitive criteria (Cheng & Thompson, 2016). The dominant field is agriculture in the region. Agricultural fields are degenerated with huge amount of MSW. As environmental criteria, water resources (Shariati et al., 2014), biodiversity (Kharat et al., 2016), and agricultural areas are determined.

Social consideration: Rapid growth of population bring about the increase of generated waste. The variability of MSW amount is highly affected with population (Gomez et al., 2008). Public acceptance is related with risk perceptions and trust (Liu et al., 2019). Thus, landfilling operations should ensure a proper benefit and risk rates. Public acceptance (Kharat et al., 2016) and population criteria were determined as social criteria.

Technical consideration: Soil and topography is important due to the spreading of wastes on soils cause the environmental risks. Waste-soil interactions should be balanced before the installation of the facility. Soil and topography (Kharat et al., 2016) and waste amount (Shariati et al., 2014) are determined as technical criteria.

Economic consideration: Critical economic sub criteria should be examined for a location selection problem. Waste landfill site is selected based on the lower land value and operation cost. Road network/access (Kharat et al., 2016), land value (Ali et al., 2021), operation &reclamation cost (Shariati et al., 2014) are determined as economic criteria.

Fuzzy AHP

The AHP (Analytical Hierarchy Process) method was developed by Saaty (1980). The AHP method is based on ranking the alternatives by comparing them according to different criteria. The lack of AHP is to be unable to handle the uncertainty for the comparison. Therefore, the fuzzy AHP approach was developed using Zadeh's (1965) Fuzzy Set Theory to reduce the negative effects of classical AHP. In this study, the extended Fuzzy AHP method developed by Chang (1996) is used.

TOPSIS

The TOPSIS, presented first by Hwang & Yoon (1981), ensures that the best alternative should be closest to the positive ideal solution and on the other hand the farthest from the negative ideal solution (Shukla et al., 2017). TOPSIS method consists of 6 steps. The steps of the TOPSIS method are discussed below (Ren et al., 2007).

<u>Step 1: Creating the decision matrix (A) (Equation 1)</u>

$$A' = [A'_{ij}]nxm ,i = 1, \ldots, n; j = 1, 2, \ldots, m \quad (1)$$

<u>Step 2: Calculate the normalized decision matrix (Equation 2)</u>

$$r_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \quad (2)$$

<u>Step 3: Creating a Weighted Decision Matrix</u>

In this step, the weights of evaluation factors are decided so that the total of the weights is 1. These determined weights are expressed as w_j. After the weights are determined, each element of the normalized decision matrix (r_{ij}) is multiplied by the weight of the relevant criterion (w_j) and the V_{ij} matrix is formed. V_{ij} matrix is as in Equation 3.

$$V_{ij} = [w_j . r_{ij}], i = 1, \ldots, n; j = 1, 2, \ldots, m \quad (3)$$

Step 4: Determine the negative ideal (Equation 4) and positive ideal (Equation 5) solution from the matrix A.

$$A^- = \{(\min_i v_{ij} \mid j \in J), (\max_i v_{ij} \mid j \in J')\} \quad (4)$$

$$A^+ = \{(\max_i v_{ij} \mid j \in J), (\min_i v_{ij} \mid j \in J')\} \quad (5)$$

Step 5: Calculate the separation measures

The separation of each alternative by positive ideal is presented as (Equation 6) and the separation of each alternative by negative ideal is presented as (Equation 7):

$$S_i^+ = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^+)^2} \quad (6)$$

$$S_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_j^-)^2} \quad (7)$$

Step 6: For each alternative, calculate the ratio C_i as Equation 8

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \quad (8)$$

Finally, the values obtained are organized and importance of the alternatives are determined.

Mathematical Programming Model

The sub locations of selected district are mathematically modelled regarding transport cost, investment cost and demand. The selected district is obtained via FAHP based TOPSIS. Decision Variables, x_{ij} is binary decision variable indicating whether there is a move from locations to districts, y_j is binary decision variable whether the location is established.

Sets and Parameters

i	set of districts	i= 1, …, I
j	set of locations	j= 1, …, J
a	location capacity for landfill	
ct	transportation cost	
ınv	investment cost	
s_i	waste amount of districts	
d_{ij}	distance between locations and districts	

Objective Function

In the mathematical programming model, the minimization of total of transportation cost and investment cost in Equation (1) are expressed in the objective function.

z is the value of the objective function.

Minimum z

$$\sum_i \sum_j d_{ij} * x_{ij} * ct + \sum_j y_j * \text{ınv} \quad (1)$$

Constraints

Equation (2) expresses that all wastes can be collected. Equation (3) ensures that it is possible travelling between locations and districts where the establishment decision is realized. Equation (4) shows that an assignment must be conducted for each district and represents the potential that can be established. The decision variables in equation (5) are binary decision variables.

$$\sum_j y_j * a \geq s_i \quad ,\forall i \quad (2)$$

$$x_{ij} \leq y_j \quad ,\forall i ,\forall j \quad (3)$$

$$\sum_{j} x_{ij} = 1 \qquad ,\forall i \tag{4}$$

$$x_{ij},\ y_i \in \{0,1\} \tag{5}$$

RESULTS AND DISCUSSIONS

In this section, the solution steps of the problem are discussed in detail. First, the weighting of the sub-criteria using the FAHP approach, then the evaluation of the alternatives with the FAHP-based TOPSIS method, and finally the optimization of a site selection for the most suitable area with the integrated mathematical programming model and FAHP-based TOPSIS method are provided. Table 1 shows the comparison matrix of sub- criteria.

Table 1. Comparison matrix of sub-criteria

	Waters	**Biodiversity**	**Agricultural Field**	**Population**	**Public Acceptance**
Waters	(1, 1, 1)	(2, 3, 4)	(3, 4, 5)	(4, 5, 6)	(3, 4, 5)
Biodiversity	(1/4, 1/3, 1/2)	(1, 1, 1)	(5, 6, 7)	(3, 4, 5)	(3, 4, 5)
Agricultural Field	(1/5, 1/4, 1/3)	(1/7, 1/6, 1/5)	(1, 1, 1)	(1/4, 1/3, 1/2)	(1/4, 1/3, 1/2)
Population	(1/6, 1/5, 1/4)	(1/5, 1/4, 1/3)	(2, 3, 4)	(1, 1, 1)	(1/3, 1/2, 1)
Public Acceptance	(1/5, 1/4, 1/3)	(1/5, 1/4, 1/3)	(2, 3, 4)	(1, 2, 3)	(1, 1, 1)
Waste Amount	(1/7, 1/6, 1/5)	(1/5, 1/4, 1/3)	(3, 4, 5)	(1/3, 1/2, 1)	(1, 2, 3)
Soil and Topography	(1/5, 1/4, 1/3)	(1/5, 1/4, 1/3)	(3, 4, 5)	(1/5, 1/4, 1/3)	(1/4, 1/3, 1/2)
Road Network/ Access	(1/8, 1/7, 1/6)	(1/8, 1/7, 1/6)	(2, 3, 4)	(1/6, 1/5, 1/4)	(1/5, 1/4, 1/3)
Land Value	(1/6, 1/5, 1/4)	(1/8, 1/7, 1/6)	(1, 2, 3)	(1/4, 1/3, 1/2)	(1/3, 1/2, 1)
Operation & Reclamation Cost	(1/6, 1/5, 1/4)	(1/8, 1/7, 1/6)	(1, 2, 3)	(1/4, 1/3, 1/2)	(1/6, 1/5, 1/4)

Table 1. Comparison matrix of sub-criteria (continued)

	Waste Amount	**Soil and Topography**	**Road Network/ Access**	**Land Value**	**Operation & Reclamation Cost**
Waters	(5, 6, 7)	(3, 4, 5)	(6, 7, 8)	(4, 5, 6)	(4, 5, 6)
Biodiversity	(3, 4, 5)	(3, 4, 5)	(6, 7, 8)	(6, 7, 8)	(6, 7, 8)
Agricultural Field	(1/5, 1/4, 1/3)	(1/5, 1/4, 1/3)	(1/4, 1/3, 1/2)	(1/3, 1/2, 1)	(1/3, 1/2, 1)
Population	(1, 2, 3)	(3, 4, 5)	(4, 5, 6)	(2, 3, 4)	(2, 3, 4)
Public Acceptance	(1/3, 1/2, 1)	(2, 3, 4)	(3, 4, 5)	(1, 2, 3)	(4, 5, 6)
Waste Amount	(1, 1, 1)	(1/4, 1/3, 1/2)	(2, 3, 4)	(1, 1, 1)	(2, 3, 4)
Soil and Topography	(2, 3, 4)	(1, 1, 1)	(2, 3, 4)	(2, 3, 4)	(2, 3, 4)
Road Network/ Access	(1/4, 1/3, 1/2)	(1/4, 1/3, 1/2)	(1, 1, 1)	(1, 2, 3)	(2, 3, 4)
Land Value	(1, 1, 1)	(1/4, 1/3, 1/2)	(1/3, 1/2, 1)	(1, 1, 1)	(2, 3, 4)
Operation & Reclamation Cost	(1/4, 1/3, 1/2)	(1/4, 1/3, 1/2)	(1/4, 1/3, 1/2)	(1/4, 1/3, 1/2)	(1, 1, 1)

The weights obtained by the FAHP are demonstrated in Table 2. The highest degree of importance is environmental criteria, social criteria, technical criteria, and economic criteria, respectively.

Table 2. Weighting of criteria and sub-criteria

Criteria	**Weight**	**Sub-criteria**	**Weight**
Environmental Consideration	0.5433	Waters	0.280052
		Biodiversity	0.236745
		Agricultural Field	0.026577
Social Consideration	0.2014	Population	0.101424
		Public Acceptance	0.099991
Technical Consideration	0.1446	Waste Amount	0.068132
		Soil and Topography	0.076424
Economic Consideration	0.1107	Road Network/Access	0.039265
		Land Value	0.043949
		Operation & Reclamation Cost	0.02744
Total	1	Total	1

Evaluation criteria and alternative locations are compiled to rank in the TOPSIS method and Table 3 demonstrates the comparison matrix of alternative regions' criteria.

Table 3. Comparison matrix of alternative regions' criteria

	Environmental Consideration			Social Consideration	
	Waters	**Biodiversity**	**Agricultural Field**	**Population**	**Public Acceptance**
Tunceli (province centre)	419.241	10	8700	49694	4
Çemişgezek	558.226	5	20200	8347	6
Hozat	34.27	8	7200	6891	7
Mazgirt	71.041	5	26400	8430	6
Nazımiye	9.234	8	4800	3599	8
Ovacık	6.146	10	8180	6998	7
Pertek	117.754	5	28600	11669	5
Pülümür	230.242	10	9100	3760	8

Table 3. Comparison matrix of alternative regions' criteria (continued)

	Technical Consideration		Economic Consideration		
	Waste Amount	**Soil and Topography**	**Road Network/ Access**	**Land Value**	**Operation & Reclamation Cost**
Tunceli (province centre)	53.976	361520	2	750	9000
Çemişgezek	1.635	361520	3	55	5500
Hozat	1.831	415920	5	290	7500
Mazgirt	0.834	361520	2	85	6000
Nazımiye	0.579	415920	2	400	8000
Ovacık	0.116	415920	3	190	7900
Pertek	1.275	361520	2	140	7000
Pülümür	0.754	415920	1	90	6100

With the application of the FAHP based TOPSIS method, the results of the alternatives. Tunceli (province center) is obtained as the most suitable regular MSW facility location (C* 0.770399). Development of a mathematical programming model is conducted using the results of the FAHP based TOPSIS technique. By the integrated mathematical programming model, the most suitable area (y_j) are Aktuluk location, İsmet İnönü location and Moğultay location for site selection (Table 4).

Table 4. Result of y_j decision variable and x_{ij} decision variable

j	y_j	**i**	**Aktuluk**	**İsmet İnönü**	**Moğultay**
Atatürk location	0	Tunceli (province center)			1
Cumhuriyet location	0	Çemişgezek	1		
Moğultay location	1	Hozat	1		
Alibaba location	0	Mazgirt	1		
Aktuluk location	1	Nazımiye		1	
İsmet İnönü location	1	Ovacık			1
Esentepe location	0	Pertek	1		
Yeni location	0	Pülümür		1	

Optimal location planning for the MSW ensure many advantages such as sustainability, clean environment, human health, and recycling. This study deals with the interactions between quantitative and qualitative criteria for the location selection of landfilling facilities regarding the importance of environmental, economic, social, and technical criteria, the distances, cost, and demand. In this study, because of the ranking, the highest degree of importance is environmental criteria, social criteria, technical criteria, and economic criteria, respectively. According to Karasan et al. (2019), the highest degree of importance is social factors, environmental impacts, and economic conditions, respectively for the landfill site selection. Shariati et al. (2014), the highest degree of importance is environmental factors, technical factors, and economic conditions, respectively for the waste dump site selection. Both researchers provide similar rankings except the ranking of environmental and social factors. In this paper, for considering alternative locations with evaluation criteria, the most suitable location is obtained as Tunceli (province center) using the fuzzy AHP-based TOPSIS method. By examining all sub locations of the Tunceli (province center) three locations are decided to install for the MSW facility. Also, the results are verified using the sensitivity analysis.

Sensitivity Analysis

This section presents the proposed method effectiveness developing a sensitivity analysis of the proposed mathematical modelling. Sensitivity analysis is conducted to examine the changes in the objective function regarding the changes on the parameters, coefficients. In this section, the model results are examined by changes on the parameter *a*. The *a* parameter specifies the location capacity. Table 5 presents the effects of this parameter change on the results. Table also shows the results of x_{ij} decision variables when *a* parameter is 50, 100, 125, 150, 175 and 200.

Table 5. Change of x_{ij} decision variable

Change of x_{ij} decision variable for a	**a=50**			**a=100, a=125, a=150**		**a=175, a=200**
i / j	**İsmet İnönü**	**Aktuluk**	**Moğultay**	**Aktuluk**	**Moğultay**	**İsmet İnönü**
Tunceli (province center)			1		1	1
Çemişgezek		1		1		1
Hozat		1		1		1
Mazgirt		1		1		1
Nazımiye	1				1	1
Ovacık			1		1	1
Pertek		1		1		1
Pülümür	1				1	1
Change of y_j decision variable		32035430		16035600		8040140

In this analysis, extra MSW facility is installed when location capacity for landfill is lower than the available capacity and this means extra financial source and investment cost. However, similar results are obtained in some different capacity scenarios. In addition, the use of distances, different costs and waste amounts within the mathematical programming model and the use of many real data increase the effectiveness of the study.

CONCLUSION

Optimal waste management has a detrimental impact on sustainability and ecological balance all the world. Most of the preliminary papers address the waste treatment methods to mitigate the waste effects on environment. However, waste treatment technologies cannot be optimal due to financial resources. This paper seeks to prevent the negative impacts of the unregular storage of the waste. Landfilling of MSW is the most well-known method to dispose waste. Location selection is the first phase of a landfilling process. Integrated Fuzzy AHP and TOPSIS methods are utilized to decide the main locations for landfilling regarding some environmental, economic, social, and technical criteria. In this study, eight districts of Tunceli are considered in this first phase. The most important criteria in the model are environmental criteria, social criteria, technical criteria, and economic criteria, respectively. The most important sub criteria are obtained as the waters criteria. Following this criteria, biodiversity, population, public acceptance, soil and topography, waste amount, land value, road network/access and agricultural field criteria are obtained, respectively. Tunceli (province centre) is obtained as the most suitable regular solid waste facility location. By the mathematical programming model, the most suitable area is Aktuluk location, İsmet İnönü location and Moğultay location in the centre of the province. The computational results demonstrate the proposed method effectiveness developing a systematic approach by integrating MCDM and mathematical modelling. Limitations and directions for future research are also presented in this section. This study addresses the proposed alternatives utilizing integrated method, in which generalizing the effectiveness of all alternatives is excluded. Besides, the study only examines the waste management at the city level. Third, this paper focuses the only location aspect of the waste system. Routing of the waste collection vehicles can be addressed in the future works. Finally, some other criteria to select the MSW landfill are included into the model such as soil depth, distance from rivers, drinking wells, wind direction (Eskandari et al., 2012); land prices, climatic condition (Beskese et al., 2015).

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Conflict of Interest

The article authors declare that there is no conflict of interest between them.

Author's Contributions

The authors declare that they have contributed equally to the article.

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