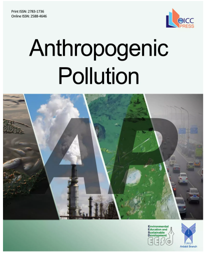

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Presenting a new model of municipal waste management cost reduction priorities based on the Gray-TOPSIS model

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Abstract:

The role of economic factors is significant in the municipal waste management. The present descriptive-applied study aimed to present a new model of municipal waste management cost reduction priorities based on the Gray-TOPSIS model in Ahvaz City in 2022. Following the collection of data on the current municipal waste management, effective criteria influencing cost reduction in municipal waste management were determined through document analysis. Expert analysis was also utilized to identify factors impacting cost reduction in municipal waste management. The Gray-TOPSIS methodology was applied to prioritize solutions for cost reduction in municipal waste management. Through calculating the Kendall agreement index, 20 solutions for cost reduction in waste management were categorized and prioritized into educational, political, cultural, and executive groups. The findings revealed that while political measures such as approving laws related to municipal waste management and incentive and punitive policies with special weightings of 0.804 and 0.799, respectively, are the most effective solutions for reducing waste management costs, overall, educational process-related solutions with an average weighting of 0.686 have a higher priority than other processes. Government support and public education through various means, especially non-governmental media and social networks, are potential solutions for reducing municipal waste management costs in Ahvaz City under current conditions.

Keywords: Waste management; Cost control; Sustainable development; Environment

1. Introduction

The increasing in amount and diversity of waste on one side, along with the intricacies involved in its collection and disposal, have become significant concerns for urban managers (Fataei et al., 2004; Aleluia and Ferrao, 2016; Sekhavati and Yengejeh, 2021; Heydarian et al., 2023).
It is estimated that global waste production will exceed 3.4 billion tons annually by 2050, more than double the rate of population growth during the same period (Masoumi and Yengejeh, 2020; Kazemi Pirsara et al., 2022). The average per capita waste production worldwide is approximately 740 grams per day, ranging from 110 to 4540 grams across different countries (Hemmati et al., 2019). In Iran, the average per capita waste production is around 700 grams (Maleki and Kharrat Sadeghi, 2022; Hashemi, 2022). The increasing waste production resulting from population growth and heightened consumption among various societal segments has made waste management a primary concern (Pardini et al., 2019; Jalalzadeh et al., 2022). The environmental and municipal system implications of this waste increase are so significant that the UN Office for Sustainable Develop-

ment has identified it as one of the three major challenges faced by urban managers in recent decades (Leal Filho et al., 2016).

To assess resources, determine optimal management approaches, and maximize efficiency, it is essential to estimate the full cost of municipal waste management (Mohsenizadeh et al., 2020). Full cost accounting is a systematic approach that involves identifying, summarizing, and reporting the actual costs associated with municipal waste management, including past and future costs, monitoring and support expenses, and operational costs (Kubota et al., 2020; Khayat et al., 2023). Various methods, such as accounting and engineering economics, have been proposed for calculating the cost of municipal waste management (Boskovic et al., 2016). Yuan et al (Yuan et al., 2011) proposed using the cost-benefit analysis method for managing municipal waste costs. Lu and colleagues (Lu et al., 2015) considered estimating waste management costs to require calculating environmental management costs. Hui et al (Hui et al., 2006) also stated that accurately calculating municipal waste management costs poses multiple challenges, and therefore, current calculation methods only include apparent costs. In municipal waste cost management, cost reduction is one of the most important goals (Mian et al., 2017; Da Silva et al., 2019). Reducing municipal waste management costs requires estimating minimum health and environmental standards (Rodseth et al., 2020). In most cities in industrialized countries, less than 0.5% of the gross national product is spent on municipal waste services (Sharma et al., 2021). The cost of municipal waste management varies in different countries depending on various economic, social, cultural, climatic, geographical, technological, and political factors (Di Foggia and Beccarello, 2019).

Financial constraints, particularly prevalent in developing countries, underscore the importance of finding solutions to curtail municipal waste management costs (Khan et al., 2022). Diverse limitations, including financial constraints, dictate the prioritization of programs aimed at reducing waste management costs (Martinez-Sanchez et al., 2017). Various methodologies have been put forth for prioritizing factors, including multi-criteria decision-making techniques like TOPSIS (Lai et al., 2023; Fataei and Seiied Safavian, 2017; Sekhavati and yengejeh, 2023).

The use of mathematical methods to reduce uncertainty can increase the accuracy of results. One of these methods is gray analysis. Compared to other multi-criteria decision-making methods, the gray topsis method has advantages such as the potential of applying negative weights, variable weights for criteria, the use of uncertain data, and the inclusion of uncertainty data in calculations. (Liu et al., 2019).

Providing solutions to reduce municipal waste management costs is a desirable method to optimize urban management. Ahvaz is one of Iran's major cities that have faced numerous challenges in waste management, particularly in terms of funding related to waste management elements. In the previous researches, mainly the implementation and technical solutions of municipal waste management have been emphasized. Meanwhile, waste management costs are considered a key factor in improving the system. Therefore, the cost factor is a serious challenge in municipal waste management in Iran. Achieving waste management goals, such as cost reduction, tailored to the climatic, geographical, economic, political, and even cultural conditions of each region has various dimensions. By presenting a combined model of gray analysis and TOPSIS decision-making method, desirable results can be achieved in determining waste management solutions. Prioritizing these solutions can play an effective role in optimizing the waste management system. Therefore, in this study, TOPSIS gray analysis method was used to prioritize waste management cost reduction methods in Ahvaz City.

2. Materials and methods

The present research which is descriptive-applied, was conducted as library study and document analysis. In the analytical section, after presenting quantitative and qualitative information on the status of municipal waste management, effective criteria for prioritizing the components affecting the reduction of municipal waste management costs have been identified based on document analysis and expert opinions. The identification of components affecting the reduction of municipal waste management costs has also been carried out through expert assessment (15 municipal waste management experts). The Gray-TOPSIS method was used for prioritizing the components.

2.1 Study area

Ahvaz is a metropolis and the capital of Khuzestan province, located in the southwest of Iran. The city is situated between 31 degrees and 13 minutes to 31 degrees and 23 minutes north and 48 degrees and 32 minutes to 48 degrees and 47 minutes west. It is divided into eight municipal districts. The population of this city is 1,184,788, making it the eighth most populous city in Iran. Ahvaz metropolitan area is also the thirty-fourth most populous metropolitan area in the Middle East. With an area of 18,650 hectares, Ahvaz is considered the fourth-largest city in Iran (Khodadadi et al., 2022). The geographical location of this city is presented in Figure 1.

In Ahvaz, municipal waste is collected in a mixed form. Therefore, accurate quantitative and qualitative information about waste from administrative, commercial, and other sectors is not available separately. According to the report of the Planning and Development Deputy of Ahvaz Municipality (2022), considering the current population of this city, the average daily production of municipal waste in Ahvaz in 2022 is about 1000 tons. Therefore, the per capita production of waste per citizen in Ahvaz is estimated to be 0.843 grams. The results of the qualitative analysis of municipal waste in Ahvaz carried out by the Ahvaz Municipality Waste Organization in 1400 are presented in Table 1. The highest type of waste is related to food waste (65.85%). Waste collection in Ahvaz City is carried out by 65 garbage trucks daily. Currently, there is no specific program for recycling waste using various methods such as composting, energy production, RDF (Refuse-derived fuel), etc. The recycling process is mainly carried out by native and unregulated individuals. Waste disposal sites are considered

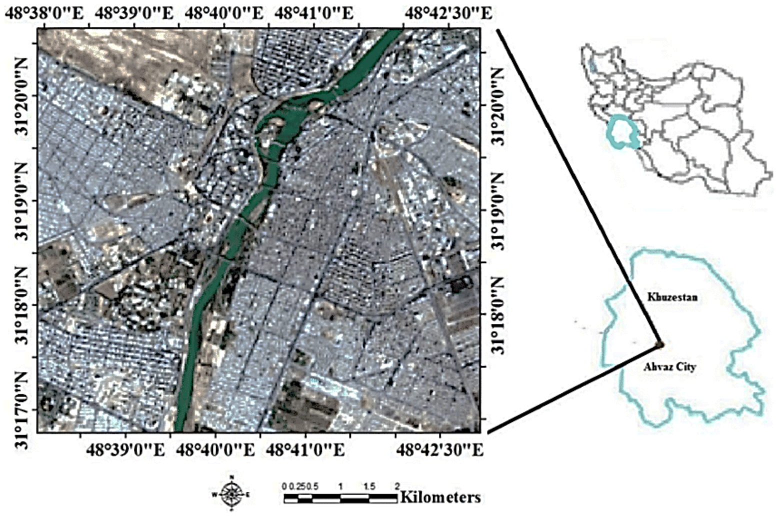

Figure 1. The geographical location of Ahvaz City (reference: current research).

one of the sources of groundwater pollution. In Ahvaz City, due to the traditional burial method, soil conditions, and high levels of groundwater, these problems are much more severe. The general slope in this city is 0.5 per thousand, resulting in the stability of groundwater and the presence of multiple layers of dunes and desert sediments, fine sediments, and waterlogging beneath the main soil layer. The leachate produced from Ahvaz City's waste contains various chemical compounds (Zarea et al., 2019).

2.2 Prioritizing solutions based on the gray TOPSIS method

Gray-TOPSIS is a multi-criteria decision-making method based on gray analysis for prioritizing options based on decision criteria. In this approach, an effort is made to calculate the distance between options and positive and negative ideals using gray operators. The extension of multi-criteria decision-making with gray logic has been proposed in some articles under the name Gray-TOPSIS. This analytical method is used to select the ideal option based on several criteria. In this analysis, m options are evaluated based on n criteria (Zhao et al., 2022). The steps of prioritizing the components in this method are explained in detail in the present research.

2.3 Gray Topsis steps

2.3.1 Gray decision matrix

The gray decision matrix is G_{ij}. In the gray matrix, each importance level of the i-th option is based on the i-th criterion. This matrix is formed based on Equation (1):

$$\Gamma_i = \sum_{j=1}^{n} \gamma(r_i - r_j) \tag{1}$$

Assessment and prioritization of the solutions in this research were done by 15 experts. The range of Table 2 was used to quantify the experts' verbal expressions. The weight of the criteria was also determined in the Gray-Topsis method based on Table 3.

2.3.2 Normalization of gray decision matrix

In this step, the gray decision matrix should be converted to a normal gray matrix. Normalization is done using the following equations 2 and 3:

$$G^*_{ij} = \left[\frac{L_{ij}}{G_j^{max}}, \frac{U_{ij}}{G_j^{max}}\right], \quad G_j^{max} = max\langle U_{ij}\rangle \tag{2}$$

$$G^*_{ij} = \left[\frac{G_j^{max}}{U_{ij}}, \frac{G_j^{max}}{L_{ij}}\right], \quad G_j^{min} = min\langle L_{ij}\rangle \tag{3}$$

Table 1. The waste quality of Ahvaz City by material in 2022.

Type of waste	Percent of total
Food waste	65/85
Paper and cardboard	9/72
Wood	1/88
Plastic	9/08
Pat	0/73
Textiles	3/53
Metals	2/5
Glass	3/23
Construction debris	2/3
Bone	1/18

Table 2. The gray spectrum of options evaluation based on criteria.

Verbal phrases	Very low	Low	Almost low	Medium	Almost high	High	Very high
Gray equivalent	[1-0]	[3-1]	[4-3]	[5-4]	[6-5]	[9-6]	[10-9]

By normalizing the decision matrix, it is ensured that each gray number belongs to the interval [0,1]. After normalization, the normalized gray matrix should be weighted. For this purpose, the weights of the criteria were multiplied in the normalized matrix.

2.3.3 Determining the degree of gray feasibility

In the third step, reference ideals are calculated. If we represent the set of possible solutions with $A = \{A_1, A_2, \ldots, A_m\}$, the reference and ideal set A_{max} is calculated through the gray possibility degree. The main element of decision-making is the grey possibility degree. When two gray numbers G_1 and G_2 are compared, the probability that $G_1 \leq G_2$ must be calculated. In this case, there are four possibilities:

- If the upper bound of G_1 is smaller than the lower bound of G_2, the probability is one.
- If the lower bound of G_1 is greater than the upper bound of G_2, the probability is zero. If both the upper and lower bounds of G_1 are equal to both the upper and lower bounds of G_2, the probability is 0.5.

Here, L (G_i) represents the length or support interval of the gray number (the distance between the upper and lower bounds).

2.3.4 Determining positive ideal and negative ideal solutions

The ideal positive solution and ideal negative solution are defined as follows:

- Vector of best values for each index of matrix V) = Ideal positive solution (V_{J+})
- Vector of worst values for each index of matrix V) = Ideal negative solution (V_{J-})

The best values for positive indices are the smallest values, and for negative indices, the largest values. The Euclidean distance of each option from the ideal positive solution and the distance of each option to the ideal negative solution is calculated based on Equations (4) and (5).

$$S_i^* = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j*) i = 1, 2, \cdots, m, \tag{4}$$

for the ideal positive distance from the option

$$S_i^- = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j) i = 1, 2, \cdots, m, \tag{5}$$

for negative distance from the ideal option

2.3.5 Proximity coefficient of an option to the ideal solution

Determining the coefficient that is equal to the distance of the minimum alternative, divided by the sum of the distance of the minimum alternative and the distance of the ideal alternative S_i^*, which is represented by C_i^* and is calculated from Equation (6).

$$C_i = \frac{Si}{Si + Si-} i = 1, 2, \cdots, m \tag{6}$$

The lower the probability, the better rank option A_i will have. Accordingly, options can be ranked and the best option can be chosen.

3. Results

In this study, the Gray TOPSIS method was used to prioritize methods for reducing municipal waste management costs. The prioritization criteria for the methods were determined based on the document method. These factors include existing potentials, government support, private sector support, and cost factors (Jamasb and Nepal, 2010; Weng and Fujiwara, 2011; Parthan et al., 2012). These criteria are presented in Table 4.
The identified methods were classified into 4 educational, cultural, political, and executive groups. The hierarchical

Table 3. Gray spectrum for determining the weight of criteria.

Verbal phrases	Very low	Low	Almost low	Medium	Almost high	High	Very high
Gray equivalent	[0.0-0.1]	[0.11-0.3]	[0.31-0.4]	[0.41-0.5]	[0.51-0.6]	[0.61-0.9]	[0.91-1]

Table 4. Effective criteria in prioritizing solutions to reduce municipal Waste management costs.

Criteria	Cost factor	Non-governmental support	Governmental support	Present potentials
Weight of criteria (gray number)	0.91-1	0.41-0.5	0.61-0.9	0.91-1

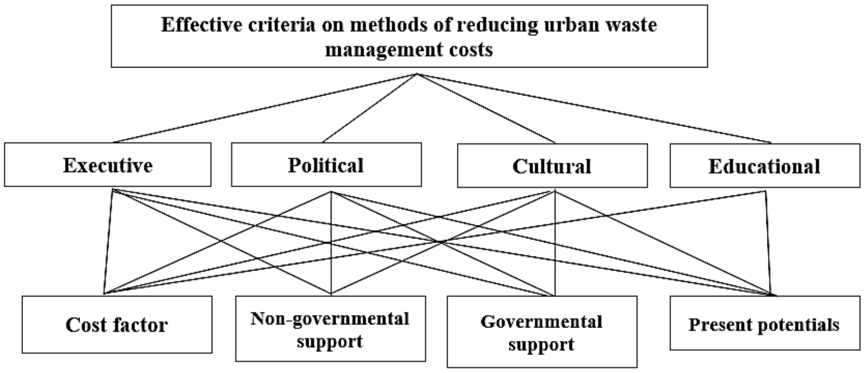

Figure 2. Hierarchical structure including goal, criteria, and sub-criteria.

structure of the research problem and providing solutions to reduce municipal waste management costs is presented in Figure 2.

The expert method was used to identify solutions for reducing municipal waste management costs. In the first step, 29 solutions were identified through a questionnaire. After content analysis and the removal of similar options, 24 solutions were extracted and evaluated using Kendall's coefficient of concordance, which indicates the level of agreement among experts. The solutions that obtained a minimum level of agreement (0.7) are presented in Table 5.

3.1 Prioritizing solutions using the gray TOPSIS method

A: Creating a decision matrix

To prioritize options (solutions for reducing waste management costs in Ahvaz city) based on quantitative indicators, exact numbers are used, which include a set of real numbers. The decision matrix, with dimensions of m*n (20*4 in the current research), containing real and gray elements, is formed using Equation (1). The decision matrix is presented in Table 6.

3.2 Normalization of the decision matrix

In the classic TOPSIS method, the Euclidean method is used for normalization; however, in the gray TOPSIS method, the eigenvector method (Equations (2) and (3)) is used to scale the decision matrix. In this method, each number in the set is divided by the sum of the elements in that set. Therefore, the total weight of each criterion after normalization is one. The results of normalizing the decision matrix are presented in Table 7.

3.3 Determining positive ideal and negative ideal solutions

Positive and negative ideal solutions were calculated through Relations (4) and (5) (Table 8). The two virtual options created are the worst and best solutions.

3.4 Determining the size of the distance from the positive and negative ideal solution

The calculated coefficient based on the distance of each option from the intended use was calculated from Equation (6), the results of which are presented in Table 9. The distance between each option was measured by the special vector method. In this process, the distance of options from positive and negative ideal options is determined.

3.5 Ranking options

In the last step of the gray TOPSIS method, the options are ranked based on the coefficient of closeness to the ideal state. Its results are presented in Table 10. Based on this, the option of "Approving laws related to executive policies of waste management" with a special vector weight of 0.804 of political factors, was determined as the most important solution to reduce municipal waste management costs.

The results of the study showed that by considering various factors such as existing potentials, cost factors, and government and private sector support, although two political solutions including the approval of laws related to municipal waste management and incentive and punitive policies with special weight vectors of 0.804 and 0.799 are the most effective in reducing waste management costs, overall, solutions related to the training process with an average weighted score of 0.686 have a higher priority than other processes. Political, cultural, and executive solutions with average weighted scores of 0.630, 0.488, and 0.302 have also been other priorities of waste management in Ahvaz in reducing costs. The results of prioritizing solutions based on grouping classification are presented in Figure 3.

4. Discussion

Considering the production of millions of tons of waste per day, determining and implementing optimal waste management solutions is an absolute necessity.

Factors such as environmental impacts and technological capabilities play a crucial role in determining these solutions. Economic considerations and cost minimization have always been key criteria in deciding management strategies across various sectors, including waste management. Given the financial limitations of governments, approaches to reduce waste management costs appear essential. The findings of this study indicate that education-based solutions hold the highest importance among strategies for reducing waste management costs. Various researches such as Damghani et al. (2008), Adogu et al. (2015), and Samsudin and Don (2013), have highlighted the lack of education as a major hurdle in municipal waste management. Desa et al. (2012)

Table 5. Kendall's coordination index for identified solutions to reduce municipal waste management costs.

Row	Sub-criteria	Agreement index
1	Citizenship education (public media)	0.81
2	Citizenship education (individual and group training workshops)	0.73
3	Citizenship education (social networks and informal media)	0.86
4	Citizenship education (municipal waste collection department workers)	0.81
5	Citizenship education (public and private sector employees in the field of waste management)	0.75
6	Citizenship education (schools and academic centers)	0.83
7	Cultivation (interacting with citizens to remove waste at the right time)	0.73
8	Cultivation (interacting with garbage pickers to prevent the release of waste and buying recyclable waste from them)	0.71
9	Cultivation (collaboration with NGOs, artists, documentaries, etc. to produce content in the field of waste management)	0.75
10	Political (using incentive and punitive policies based on the performance of service and industrial sectors in waste production and management)	0.87
11	Political (approval of laws related to executive policies of waste management)	1
12	Political (Notification of regulations prohibiting the use of disposable containers in organizations and service centers)	0.75
13	Political (supporting investment in municipal waste management)	0.91
14	Political (employing contractors with favorable and committed executive history with favorable monitoring of their performance)	0.95
15	Executive (implementation of waste separation plans by the municipality)	0.95
16	Executive (feasibility assessment and implementation of compost production plan in Ahvaz city)	0.73
17	Executive (feasibility and implementation of energy recovery plans from waste in conventional ways)	0.71
18	Executive (continuous improvement of municipal waste transportation fleet)	1
19	Executive (use of digesters and waste incinerators in hospitals and industrial centers)	0.73
20	Executive (improving the performance of municipal waste recycling)	1

Table 6. Decision matrix in gray TOPSIS method (solutions to reduce waste management costs).

solutions	A weighted average of options in each criterion based on the gray cap			
	Present potentials	Governmental support	Non-governmental support	Cost factor
Citizenship education (public media)	6.6	3.4	4.8	6.4
Citizenship education (individual and group training workshops)	3.6	3	5.8	5.8
Citizenship education (social networks and informal media)	5.8	4.8	7.8	7.4
Citizenship education (municipal waste collection department workers)	4.8	5	5.6	5.6
Citizenship education (public and private sector employees in the field of waste management)	5.8	5.8	5.2	6.2
Citizenship education (schools and academic centers)	5.6	4.8	5	8
Cultivation (interacting with citizens to remove waste at the right time)	3.8	4.2	4.8	5.4
Cultivation (interacting with garbage pickers to prevent the release of waste and buying recyclable waste from them)	3.2	3.8	3.6	4.4
Cultivation (collaboration with NGOs, artists, documentaries, etc. to produce content in the field of waste management)	3.8	4.8	3.8	4.4
Political (using incentive and punitive policies based on the performance of service and industrial sectors in waste production and management)	5.6	6	3.8	5.2
Political (approval of laws related to executive policies of waste management)	7.4	6	4.8	5.8
Political (Notification of regulations prohibiting the use of disposable containers in organizations and service centers)	7.2	5.8	3.8	6.4
Political (supporting investment in municipal waste management)	3.4	3.6	4.8	3.8
Political (employing contractors with favorable and committed executive history with favorable monitoring of their performance)	4.4	3.8	3	5
Implementation (implementation of waste separation plans by the municipality)	3.4	3.6	5.8	2.8
Executive (feasibility assessment and implementation of compost production plan in Ahvaz city)	2.4	1.4	4.4	1.2
Implementation (feasibility and implementation of energy recovery plans from waste in conventional ways)	1.8	2	6.6	1.8
Executive (continuous improvement of municipal waste transportation fleet)	3.4	2.8	3.8	2.2
Executive (use of digesters and waste incinerators in hospitals and industrial center)	5.4	3.6	3.8	2.4
Executive (improving the performance of municipal waste recycling)	6	3	4.6	2.2

Table 7. Normalized matrix for the options in the determined criteria.

Present potentials	Governmental support	Non-Governmental support	Cost factor	Solitions
0.070	0.041	0.050	0.069	Citizenship education (public media)
0.038	0.036	0.060	0.062	Citizenship education (individual and group training workshops)
0.062	0.059	0.081	0.080	Citizenship education (social networks and informal media)
0.051	0.061	0.058	0.060	Citizenship education (municipal waste collection department workers)
0.062	0.071	0.054	0.067	Citizenship education (public and private sector employees in the field of waste management)
0.060	0.059	0.052	0.086	Citizenship education (schools and academic centers)
0.040	0.051	0.050	0.058	Cultivation (interacting with citizens to remove waste at the right time)
0.034	0.046	0.037	0.047	Cultivation (interacting with garbage pickers to prevent the release of waste and buying recyclable waste from them)
0.040	0.059	0.039	0.047	Cultivation (collaboration with non-people organizations, artists, documentaries, etc. to produce content in the field of waste management)
0.060	0.073	0.039	0.056	Political (using incentive and punitive policies based on the performance of service and industrial sectors in waste production and management)
0.079	0.073	0.050	0.062	Political (approval of laws related to executive policies of waste management)
0.077	0.071	0.039	0.069	Political (Notification of regulations prohibiting the use of disposable containers in organizations and service centers)
0.036	0.044	0.050	0.041	Political (supporting investment in municipal waste management)
0.047	0.046	0.031	0.054	Political (employing contractors with favorable and committed executive history with favorable monitoring of their performance)
0.036	0.044	0.060	0.030	Implementation (implementation of waste separation plans by the municipality)
0.025	0.017	0.046	0.012	Executive (feasibility assessment and implementation of compost production plan in Ahvaz city)
0.019	0.024	0.069	0.019	Implementation (feasibility and implementation of energy recovery plans from waste in conventional ways)
0.036	0.034	0.039	0.023	Executive (continuous improvement of municipal waste transportation fleet)
0.057	0.044	0.039	0.025	Executive (use of digesters and waste incinerators in hospitals and industrial centers)
0.064	0.036	0.048	0.023	Executive (improving the performance of municipal waste recycling)

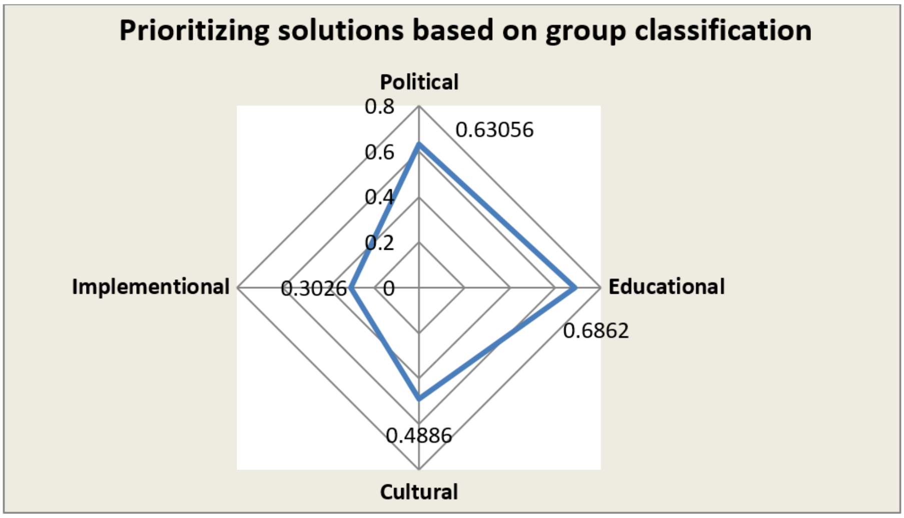

Figure 3. Prioritization of solutions based on group classification.

proposed that incorporating waste management education into school curricula could foster a culture of public participation in waste management among Malaysians. The results of this research show that education through social networks and informal media has a special weight of 0.7892 compared to other education methods such as public workshops and specialized training for municipal staff in reducing waste management costs. Alzamora and Barros (2020) state that there is a significant relationship between the level of general waste management knowledge and waste management costs. Berenjkar et al. (2021) also showed a significant correlation between citizen participation and the reduction of waste management costs. Yeh et al. (2018) evaluated the significant impact of social networks on improving the performance level of industrial waste management in China.
In this study, the solution of enacting laws was identified as the most important solution for reducing municipal waste management costs. The government can effectively lower these costs by enacting supportive laws such as offering tax exemptions to private waste recycling companies and providing them with necessary facilities (Moh, 2017). Additionally, imposing fines on producers of excessive waste (Joshi and Ahmed, 2016) and encouraging non-governmental investments in this sector (Garlapati, 2016) are recommended. Thi et al. (2015) also suggest providing educational and media resources to the non-governmental sector.
Cultural components with a weighted average of 0.488 were identified as the third group of solutions for reducing municipal waste management costs in Ahvaz. Cultural solutions are somewhat related to the training process. Given the large number of waste pickers in Ahvaz, interacting with them and striving to improve waste management culture from the family environment are effective solutions in municipal waste management. Barles (2014) concluded in his study that consumer culture is significantly related to the amount of waste produced in society. Iyamu et al. (2020) also stated that between 1960 and 2000, there was a significant correlation between per capita income and waste production in European countries. However, due to the growth of public participation culture in these countries, waste management costs have decreased. Therefore, it can be expected that with the growth of public culture in municipal waste management, waste management costs will decrease. The research results showed that the use of digesters and incinerators in hospitals and industrial centers with a special weighting of 0.464 is the most important practical solution for reducing waste management costs.
The research results of Vijayalakshmi (2020) showed that there is a significant relationship between the use of modern technologies and municipal waste management costs.
Yukalang et al. (2018) showed that investing in technology and industry in waste management will lead to a long-term reduction in municipal management costs by reducing health and environmental effects (Yukalang et al., 2018). Also, reducing waste volume through incineration and digestion leads to a reduction in transportation and burial costs. According to the results obtained in this research, a regular program can be developed to reduce the costs of municipal waste management in Ahvaz city and improve the current situation.

5. Conclusion

Overall, the results of this study indicate that government support and public education through various means,

Table 8. Determination of positive ideal and negative ideal solution.

Cost factor	Non-governmental support	Governmental support	Present potentials	Optimized solution
0.1421	0.0942	0.1396	0.1787	+
0.0178	0.0353	0.0233	0.0447	-

Table 9. Determining the size of the distance from the positive and negative ideal solution.

Distance	Positive	Negative
Citizenship education (public media)	0.065	0.171
Citizenship education (individual and group training workshops)	0.121	0.115
Citizenship education (social networks and informal media)	0.050	0.188
Citizenship education (municipal waste collection department workers)	0.086	0.147
Citizenship education (public and private sector employees in the field of waste management)	0.067	0.173
Citizenship education (schools and academic centers)	0.055	0.182
Cultivation (interacting with citizens to remove waste at the right time)	0.112	0.123
Cultivation (interacting with garbage pickers to prevent the release of waste and buying recyclable waste from them)	0.140	0.102
Cultivation (collaboration with non-people organizations, artists, documentaries, etc. to produce content in the field of waste management)	0.116	0.125
Political (using incentive and punitive policies based on the performance of service and industrial sectors in waste production and management)	0.074	0.171
Political (approval of laws related to executive policies of waste management)	0.050	0.199
Political (Notification of regulations prohibiting the use of disposable containers in organizations and service centers)	0.050	0.207
Political (supporting investment in municipal waste management)	0.153	0.077
Political (employing contractors with favorable and committed executive history with favorable monitoring of their performance)	0.113	0.120
Implementation (implementation of waste separation plans by the municipality)	0.160	0.071
Executive (feasibility assessment and implementation of compost production plan in Ahvaz city)	0.219	0.023
Implementation (feasibility and implementation of energy recovery plans from waste in conventional ways)	0.195	0.055
Executive (continuous improvement of municipal waste transportation fleet)	0.162	0.067
Executive (use of digesters and waste incinerators in hospitals and industrial centers)	0.133	0.115
Executive (improving the performance of municipal waste recycling)	0.139	0.105

Table 10. Ranking of strategies to reduce municipal waste management costs.

Result	Proximity factor
Political (approval of laws related to executive policies of waste management)	0.804
Political (using incentive and punitive policies based on the performance of service and industrial sectors in waste production and management)	0.799
Citizenship education (social networks and informal media)	0.789
Citizenship education (schools and academic centers)	0.766
Citizenship education (public media)	0.724
Citizenship education (public and private sector employees in the field of waste management	0.720
Political (employing contractors with favorable and committed executive history with favorable monitoring of their performance)	0.699
Citizenship education (municipal waste collection department workers)	0.628
Cultivation (interacting with citizens to remove waste at the right time)	0.523
Cultivation (collaboration with non-people organizations, artists, documentaries, etc. to produce content in the field of waste management)	0.519
Political (Notification of regulations prohibiting the use of disposable containers in organizations and service centers)	0.513
Citizenship education (individual and group training workshops)	0.487
Implementation (use of digesters and waste incinerators in hospitals and industrial centers)	0.464
Implementation (improving the performance of municipal waste recycling)	0.429
Cultivation (interacting with garbage pickers to prevent the release of waste and buying recyclable waste from them)	0.422
Political (supporting investment in municipal waste management)	0.336
Implementation (implementation of waste separation plans by the municipality)	0.309
Implementation (continuous improvement of municipal waste transportation fleet)	0.294
Implementation (feasibility assessment and implementation of compost production plan in Ahvaz city)	0.221
Implementation (feasibility and implementation of energy recovery plans from waste in conventional ways)	0.096

especially non-governmental media and social networks, are potential solutions for reducing the costs of municipal waste management in Ahvaz. Economic limitations in the current situation demonstrate the necessity of employing these solutions and developing plans for their implementation.

Weakness in recording data related to the current state of municipal waste management is an important limitation in conducting related research. Examining the methods of updating municipal waste management technologies in order to reduce municipal waste management costs can be considered in future research.

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Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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