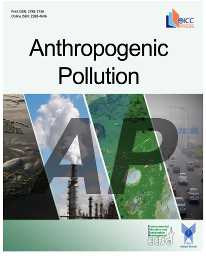

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Identification and prioritization of construction waste management strategies using an integrated FANP-DEMATEL/SWOT model in Tehran metropolis, Iran

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Abstract:

The purpose of the current work was to develop strategies suitable for the construction waste management for construction waste processing, recycling or landfilling plants in Tehran metropolis, Iran. This integrated methods study was of an applied type with an exploratory approach, which used a FANP-DEMATEL combined model as one of the most appropriate strategic planning methodologies. Thus, the environment of Tehran waste management organization (TWMO) was evaluated by preparing a SWOT matrix consisting of 10 strengths (S), 12 weaknesses (W), 9 opportunities (O), and 7 threats (T). According to the results, the TWMO was positioned in the WT box (IFE: 2.45 and EFE: 2.33), indicating the necessity of adopting a defensive strategy as the best priority. On the other hand, the FANP-DEMATEL technique also confirmed the accuracy of WT strategies with a score of 12.627. Results shown that the best determined WT strategy was "Preventing mixing or separating waste at the source for easier recycling at the plant site" (Weighting factor: 0.9). These findings showed the importance of the proposed strategy for the growth and success of construction and demolition waste management in Tehran.

Keywords: Construction waste management; FANP-DEMATEL; SWOT; Tehran

1. Introduction

In recent years and in many countries, special attention has been given to waste management due to the ever-increasing waste generation as a result of economic growth and expansion of consumerist lifestyles. Increased waste generation has led to a shortage of landfills and higher costs for waste management (Oduro-Appiah et al., 2020). According to reports, optimal waste management not only brings economic savings, but also can lead to direct profitability. Today, the process of optimizing waste management and recycling strategies tries to take organizational, economic and technological capabilities into account and even attract private sector to this field (Aslam et al., 2020). Construction activities generate a large amount of waste that must be disposed of afterwards. Construction and demolition waste has become a serious environmental concern in many countries. Construction, renovation and demolition (CRD) wastes include concrete, asphalt, wood, metals, glass, plaster, bricks, all kinds of stones, polymers, mosaics, ceramics, tiles and roofing materials (Moeinaddini et al., 2020). Building materials are almost half of all used materials and construction waste constitutes half of the solid waste (SW) on the planet (Mah et al., 2018). Construction and demolition waste often constitutes $10-30\%$ of the waste in many landfills around the world (Elshaboury et al., 2022). Today, the construction industry is seriously developing. The continuous increase in the number of buildings under construction and demolition has led to a growing amount of construction waste; most of which have the potential for secondary use and can be considered as a source of secondary material (Omotayo et al., 2019). One of the most important environmental concerns is the correct organization and recycling of construction waste, and ultimately saving resources. Many countries do not have specific regulations or systems to collect, dispose and recycle construction waste (Akhtar and Sarmah, 2018; Gálvez-Martos et al., 2018).

One of the main parameters in construction waste management is to pay attention to the protection of water and soil ecosystems. The continuous accumulation of non-degradable wastes in natural environments leads to the pollution of water and soil resources, which makes it necessary to choose suitable places for the sanitary disposal of waste. The waste management process needs to pay attention not only to the quantitative characteristics (generated volume) but also to the qualitative indicators (hazard classes) of waste (Wu et al., 2019). According to the "Global Waste Management Outlook (GWMO)" released by the United Nations Environment Program (UNEP) in collaboration with the International Solid Waste Association (ISWA), the commercial, residential, construction and other industries makes up seven to ten billion tons of solid waste annually. It is estimated that around 85% of the waste generated worldwide ends up in landfills. Hence, it is considered very important to estimate the amount of waste reuse and recycling (ISWA, 2015). Sustainable programs are being implemented globally to manage construction waste, which has encouraged many countries to even abandon the waste disposal approach and instead reduce waste disposal through alternative methods for more efficient waste management with life cycle assessment, especially in European countries and some Asian countries (Cook et al., 2022).

Construction projects can be generally divided into two categories: demolition activities and construction activities. Construction wastes are different from municipal wastes and usually generated during renovation, construction, modification and demolition of buildings and other facilities (Tam and Lu, 2016). Demolition activities include processes during which an existing structure or building, such as a road, building, facility, etc., is destroyed, and all or part of its components are discarded. Construction activities include the creation of new structures in which the raw materials are consumed and the wastes resulting from the consumption of these raw materials are thrown away (Safaee et al., 2024). Construction and demolition wastes are produced as a result of construction, renovation or demolition of constructs. The remaining components of these wastes mostly include concrete, asphalt, wood, metals, plaster walls and ceilings (Udawatta et al., 2015).

In recent decades, in developing countries, due to the unknown destructive effect of construction waste on the environment, lack of technology, absence of comprehensive laws and other parameters, not much importance was given to the accurate and optimal management of collecting, recycling and disposing of these materials (Hematti et al., 2019). The development of technology and raising the level of public awareness have further specified the problems and effects of these indiscriminate constructions that can affect the environment.

In England, construction waste is divided into ten categories: insulation and asbestos materials; (2) concrete, brick, tile, and ceramic; (3) wood, glass, and plastic; (4) asphalt, oil, coal, and bitumen; (5) metals; (6) soil, contaminated soil, stone, and soil from dredging; (7) gypsum; (8) cement, (9) paint and coating materials; and (10) glues and fillings (Liatas, 2011). United States Environmental Protection Agency (U.S. EPA) divides construction waste into 15 groups, including (1) asphalt-related materials, (2) soil related materials, (3) materials related to electrical works, (4) materials related to insulation, (5) materials related to bricks and concrete, (6) material related to steel, (7) materials related to paint work, (8) paper-related materials, (9) materials related to petroleum products, (10) materials related to roofing works, (11) materials related to vinyl, (12) gypsum related materials, (13) wood related materials, (14) materials related to wood containing contaminants, and (15) miscellaneous groups (Ma et al., 2020).

Research has shown that the techniques of SWOT (strengths, S, weaknesses, W, opportunities, O, and threats, T) analysis with the help of network models played an important role in discovering the potentials and ways of the initiative and successful implementation of an efficient municipal solid waste program (Fataei, 2020). In Iran, construction waste management is one of the concerns of urbanization, population explosion and rapid development of the construction industry. Despite all this, construction waste management has not received much attention. As a result, it is necessary to design an efficient management program for construction waste. Adequate and accurate access to information related to the characteristics and conditions of current management is one of the main requirements for the operation of any waste management program. Available information about the amount of construction and demolition waste production in Iran is rare. In addition, its accessibility is low (Naimabadi et al., 2016).

The excessive increase in the population of Tehran (the capital of Iran) and the expansion of civil construction as well as the destruction and renovation of buildings have led to a significant elevation in the amount of construction waste. The ever-increasing amount of municipal waste, especially the waste resulting from the demolition of buildings, worn-out fabric and urban and interurban roads, has caused many problems in megacities (Fard and Karimi, 2022). A significant amount of this type of waste is produced in the city of Tehran due to the construction and urban infrastructure projects. According to statistics 2021, an average of 30,000 tons of construction and civil waste was collected daily in Tehran, and only 1,750 tons (4% of the total) were sent to the recycling center and the rest were sent to the landfill. Unfortunately, during the past few decades, there has been no clear outlook for the management (reducing production, source separation, storage, transportation, processing, recycling and landfilling) of such waste in Tehran, or it has not been seriously implemented (Salari and Zohrai, 2017).

Accordingly, the present work aimed to develop appropriate strategies for the optimal management of construction waste in Tehran. The research question was how to achieve and prioritize optimal strategies using an integrated FANP-

DEMATEL/SWOT model.

2. Materials and methods

2.1 Study area

Tehran is the capital and the most populous city of Iran, which is located on the southern slopes of the Alborz mountain range. The city covers a total area of 730 square kilometers, 27th largest city in the world. This study was conducted in Tehran city (figure 1). According to the recent national census (2016), the population of Tehran was announced as 8,429,807 people. Its height from sea level ranges from 1050 to 1800 m. The average annual temperature and relative humidity of this city are about 15 °C and 40% respectively, with an average annual precipitation of about 242 mm. The terrains of Tehran include the Alborz mountain range in the north, the central parts and the southern foothills of Alborz and its plains, and it has a semi-arid climate. The climate of Tehran province is affected by the Alborz mountain range in the north, the desert plain in the south, and the western monsoons, which have created different climates in different regions of Tehran (Zarei et al., 2024).

2.2 Methodology

This research was of an applied type, an integrated type in terms of data collection method, and an interpretive-analytical type in terms of data analysis method. First of all, library and field studies were carried out in two areas of strategic management of construction waste and methods of developing strategies and in the area of multi-criteria decision-making. Thus, environmental factors (internal or external environment) were evaluated and identified. To this end, it was necessary to gain knowledge about the variables in the internal and external environments. Therefore, the influential strategic factors were determined and then the strategies were prioritized using the integrated FANP-DEMATEL/SWOT model as follows:

In the first step, internal and external environments were evaluated and analyzed by the SWOT technique, and the current situation of Tehran waste management organization (TWMO) was determined.

Then, total-relation matrix between objectives was formed based on the opinions of experts in the form of fuzzy numbers and their aggregation was done through the weighted arithmetic mean of the opinions; in the fuzzy matrix equation, Eq. 1, the direct relationship was expressed as follows:

$$\tilde{Z} = \begin{bmatrix} \tilde{Z}_{11} & \cdots & \tilde{Z}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{Z}_{n1} & \cdots & \tilde{Z}_{nn} \end{bmatrix}, \ \tilde{Z}_{ij} = (l_{ij}, m_{ij}, u_{ij}) \qquad (1)$$

The next step was to obtain the scaleless fuzzy direct relation matrix, so that $\tilde{Z}$ value was calculated by scaleless position estimation method based on equations 2 and 3.

$$\tilde{X} = \begin{bmatrix} \tilde{X}_{11} & \tilde{X}_{12} & \cdots & \tilde{X}_{1n} \\ \tilde{X}_{21} & \tilde{X}_{22} & \cdots & \tilde{X}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{X}_{n1} & \tilde{X}_{n2} & \cdots & \tilde{X}_{nn} \end{bmatrix}, \ \tilde{X}_{ij} = \left(\frac{l_{ij}}{r}, \frac{m_{ij}}{r}, \frac{u_{ij}}{r}\right) \qquad (2)$$

$$r = \max_{1 \le i \le n} \left(\sum_{j=1}^{n} u_{ij}\right) \qquad (3)$$

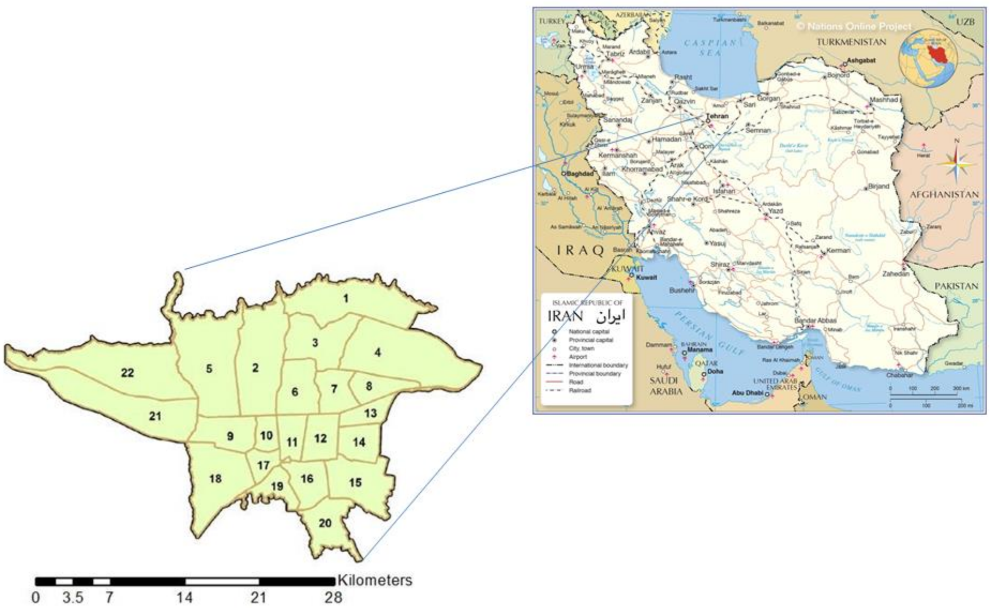

Figure 1. Location of Tehran on the map of Iran.

In the deterministic state of the DEMATEL method, equation 4 was established for at least one i (Yang et al., 2013).

$$\sum_{j=1}^{n} u_{ij} < r \tag{4}$$

In the continuation of the calculation of the total-relation matrix, to calculate fuzzy total-relation matrix ($\tilde{T}$), the scaleless matrix of $\tilde{X}_{ij} = (l'_{ij}, m'_{ij}, u'_{ij})$ was calculated as three deterministic matrices of X_l, X_m and X_u, whose components were extracted from the elements of the $\tilde{X}$ matrix, according to equation 5.

$$\begin{cases} \text{and } X_l = \begin{bmatrix} 0 & l'_{12} & \cdots & l'_{1n} \\ l'_{21} & 0 & \cdots & l'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ l'_{n1} & l'_{n2} & \cdots & 0 \end{bmatrix} \\ \text{and } X_m = \begin{bmatrix} 0 & m'_{12} & \cdots & m'_{1n} \\ m'_{21} & 0 & \cdots & m'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ m'_{n1} & l'_{n2} & \cdots & 0 \end{bmatrix} \\ \text{and } X_u = \begin{bmatrix} 0 & u'_{12} & \cdots & u'_{1n} \\ u'_{21} & 0 & \cdots & u'_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ u'_{n1} & l'_{n2} & \cdots & 0 \end{bmatrix} \end{cases} \tag{5}$$

The total-relation matrix was obtained through equations 6, 7 and 8:

$$\tilde{T} = \lim_{k \to \infty} (X + \tilde{X}^2 + \ldots + \tilde{X}^K) \tag{6}$$

$$\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \cdots & \tilde{t}_{1n} \\ \tilde{t}_{21} & \tilde{t}_{22} & \cdots & \tilde{t}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{t}_{n1} & \tilde{t}_{n2} & \cdots & \tilde{t}_{nn} \end{bmatrix} \tag{7}$$

where, $\tilde{t}_{ij} = (l''_{ij}, m''_{ij}, u''_{ij})$ and

$$\begin{cases} \text{and } [l''_{ij}] = x_l \times (I - X_l)^{-1} \\ \text{and } [m''_{ij}] = x_m \times (I - X_m)^{-1} \\ \text{and } [u''_{ij}] = x_u \times (I - X_u)^{-1} \end{cases} \tag{8}$$

Finally, the normalized fuzzy direct relation matrix was determined. ($\tilde{R}$) was equal to the fuzzy sum of elements of the rows and $\tilde{S}$ was equal to the columns of the fuzzy matrix in the total-relation matrix. In order to form a cause and effect diagram, each of the above components were calculated using equation 9 (Fataei and Safavian, 2017).

$$\bar{X}(\tilde{A}) = \frac{1}{4}(l + 2m + n), \ \tilde{A}(l, m, u) \tag{9}$$

The statistical population of the research included the managers of the Construction Waste Organization of Tehran Municipality, who had sufficient knowledge and experience. The statistical sample of the research was also determined to be available experts (n = 22) in order to identify internal factors (strengths and weaknesses) as well as external factors (opportunities and threats); the opinions of these subjects were further used in compiling, weighting and prioritizing waste management strategies. The Delphi process was carried out in three rounds. Kendall's Coefficient of Concordance (W-value) was used to measure the agreement between experts. The W value varied from 0 to 1, where 0 indicated "no agreement" and 1 meant "complete agreement", which was calculated as 0.91 in this research.

3. Results

The SWOT model was used to present a strategic plan for construction waste management through the construction of processing, recycling and landfilling plants. First, a list of internal and external factors was prepared by the TWMO[1] experts and the evaluation of related studies, which was subsequently provided to the expert group consisting of university professors and TWMO employees. The result of the expert group's performance was the prediction of 10 strengths, 11 weaknesses, 9 opportunities and 7 threats in the field of strategic construction waste management. Then, the determined internal and external factors were evaluated and weighted. Finally, W, S, O and T components of SWOT analysis in the field of construction waste management were prepared according to Tables 1 and 2. The results of this part of the research were obtained after 3 rounds of the Delphi process.

According to Table 1, the final score of Internal Factor Evaluation (IFE) calculated for construction waste management (2.45), compared to the average coefficient of 2.5, indicating that the weaknesses outweigh the strengths.

According to Table 2, the final score of External Factor Evaluation (EFE) was 2.33, meaning that threats outweigh opportunities.

Figures 2 to 4 show the weighted distribution of the four SWOT factors.

One of the matrices used in strategic planning is the IFE-EFE matrix. Table 3 shows the corresponding data of IFE-EFE matrix in construction waste management and the location of the construction waste processing, recycling and landfilling plants in Tehran. According to the scores of

1. Tehran Waste Management Organization

Figure 2. The final weight of the weaknesses of construction waste management in Tehran.

Table 1. Internal Factor Evaluation (IFE) Matrix.

Items	Strengths	W-value	Rank	Score
1	High risk factor in innovation activities	0.05	4	0.20
2	Taking advantage of the experience and equipment of TWMO in the control of pollution in the construction waste processing, recycling and landfilling plants	0.07	4	0.28
3	Developing the human resources management systems	0.05	3	0.15
4	Developing the quality and expertise of human resources	0.05	3	0.15
5	Increasing employee welfare and loyalty	0.06	4	0.24
6	Optimizing technologies and strengthening technical infrastructure and equipment for recycling construction waste	0.06	3	0.18
7	Developing the human resources management systems	0.05	3	0.15
8	Developing customer service measures in the field of recycled products and increasing their satisfaction and loyalty	0.07	3	0.21
9	Greater attention to Communications Regulatory Authority (CRA), environmental and other stakeholder requirements	0.05	4	0.20
10	Management and maintenance of equipment and financial assets of TWMO	0.04	4	0.16
Items	**Weaknesses**	**W-value**	**Rank**	**Score**
1	The presence of toxic substances or hazardous chemicals in the construction waste processing, recycling and landfilling plants	0.05	1	0.05
2	Problems with geographical location and relocation of CRD waste (processing, recycling, landfilling)	0.05	1	0.05
3	Bulk volume of CRD waste (processing, recycling, landfilling)	0.06	1	0.06
4	Insufficient studies on the chemical composition and risk level of CRD waste (processing, recycling, landfilling)	0.03	1	0.03
5	The need for investment to build the construction waste processing, recycling and landfilling plants	0.04	1	0.04
6	The necessity of training the workforce and the public on the construction waste processing, recycling and landfilling plants and the allocation of related costs	0.02	2	0.04
7	Weakness in the internal rules and guidelines of TWMO regarding the construction waste processing, recycling and landfilling	0.04	1	0.04
8	High costs of research, development and equipment needed in recycling construction waste (recycling)	0.03	2	0.06
9	Mixing different types of wastes, some of which cannot be separated (processing and recycling)	0.04	2	0.08
10	Low diversity of undergraduate courses in TWMO	0.05	1	0.05
11	Outbreak of diseases caused by exposure to CRD waste (processing, recycling, landfilling)	0.04	1	0.04
Total		1	-	2.45

Table 2. External Factor Evaluation (EFE) Matrix.

Items	**Strengths**	**W-value**	**Rank**	**Score**
1	The growing market for the sale of products and services obtained from construction waste due to their economic value (recycling)	0.06	3	0.18
2	The motivation and desire of TWMO for sustainable development	0.05	3	0.15
3	Creating and maintaining competitive knowledge advantages and providing different, up-to-date and efficient innovations	0.07	4	0.28
4	The motivation and desire of TWMO for sustainable development	0.07	3	0.21
5	Entrepreneurship and job creation (processing, recycling, landfilling)	0.07	3	0.21
6	Establishment and expansion of efficient management systems and application of international standards	0.06	4	0.24
7	Providing the necessary platforms for continuous organizational learning	0.06	3	0.18
8	The possibility of obtaining plant start-up loans with very low interest (processing, recycling, landfilling)	0.06	3	0.18
9	Maintaining and promoting the reputation and brand of TWMO	0.04	3	0.12
Items	**Weaknesses**	**W-value**	**Rank**	**Score**
1	Change in the quantity and quality of groundwater resources due to the construction waste management plants (landfilling)	0.07	2	0.14
2	Occupying land to build plants and destroy agricultural land and pastures (processing, recycling, landfilling)	0.06	1	0.06
3	Soil contamination caused by landfilling	0.05	2	0.10
4	Visual pollution of natural landscapes and destruction of the landscape in the region (landfilling)	0.07	1	0.07
5	Issues related to the safety and health of the workers of the construction waste management plants and the possibility of adverse effects of emptying and storing wastes on their health (processing, recycling, landfilling)	0.07	1	0.07
6	Air pollution (greenhouse gas emissions) and dust release in the construction waste management plants (processing and recycling)	0.08	1	0.08
7	The tendency to migrate to the areas around the construction waste management plants and the growing population of marginal residents (processing, recycling, landfilling)	0.06	1	0.06
Total		1		2.33

Table 3. IFE-EFE matrix.

The final score of EFE matrix 1 2.5 4	The final score of IFE matrix 4 2.5 1	
	Aggressive strategy (SO)	Conservative strategy (WO)
	Competitive strategy (ST)	Defensive strategy (WT)

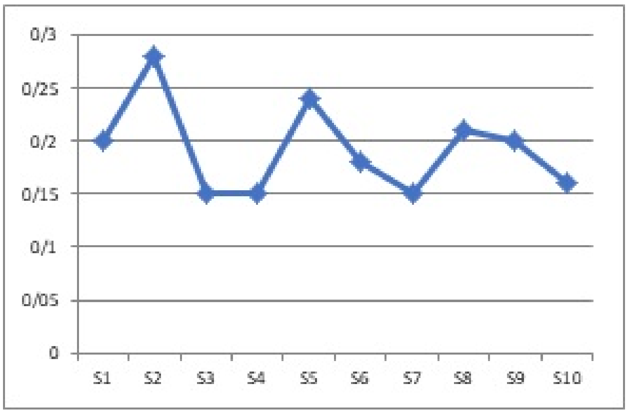

Figure 3. The final weight of the strengths of construction waste management in Tehran.

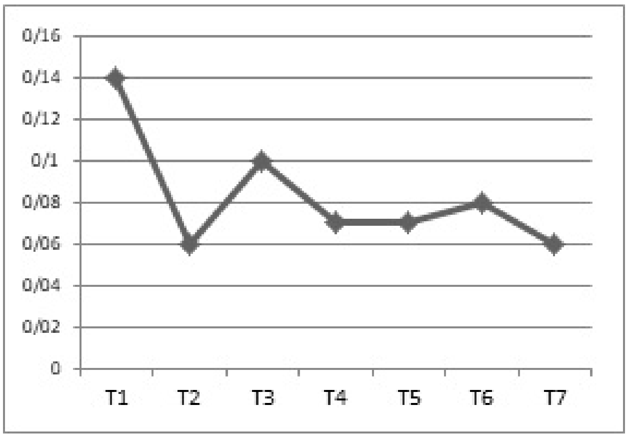

Figure 4. The final weight of the threats of construction waste management in Tehran.

Figure 5. The final weight of the opportunities of construction waste management in Tehran.

IFE (Strengths and Weaknesses) and EFE (Opportunities and Threats) matrices, the strategic position of construction waste with the approach of building plants (processing, recycling, landfilling) in Tehran in the mentioned matrix was in the WT area, suggesting the need to implement defensive strategies.
In the next step, the problem was first transformed into a hierarchical structure according to Table 4, so that it could be evaluated by FANP. The model consisted of four levels. The first level was related to choosing the best strategy and the second level was related to SWOT analysis factors. Subfactors were placed at the third level and strategy options at the fourth level.
Table 5 presents the evaluation results based on experts' opinions.

$$w = \begin{bmatrix} SO \\ WO \\ ST \\ WT \end{bmatrix} = \begin{bmatrix} 0.266718 \\ 0.275527 \\ 0.244427 \\ 0.245428 \end{bmatrix}$$

$$\text{C.R.} = \frac{\text{C.I}}{\text{I.I.R}} = 0.017$$

The calculated compatibility rate (CR = 0.017) showed that the formed pairwise comparison matrix was compatible and less than 0.1. The obtained matrix was normalized using equation 10.

$$\tilde{H}_{ij} = \frac{\tilde{z}_{ij}}{r} = \left(\frac{l'_{ij}}{r}, \frac{m'_{ij}}{r}, \frac{u'_{ij}}{r}\right) = (l''_{ij}, m''_{ij}, u''_{ij}) \qquad (10)$$

where, r is obtained according to equation 11.

$$r = \max_{1 \le i \le n}\left(\sum_{j=1}^{n} u_{ij}\right) \qquad (11)$$

Tables 6 to 8 show the results of the normalized matrices and the overall relationships of the strategy comparisons.
Table 9 and figure 6 show the obtained interdependence between SWOT strategies using FANP-DEMATEL.
In this step, pairwise comparison matrix was formed based on these interdependencies (Table 10).
In the next step, the final priority of the SWOT factors was obtained by multiplying the relative priorities of the SWOT groups calculated in the fourth step by the relative priorities of the SWOT factors calculated in the fifth step (Table 11).

4. Discussion

The construction industry is one of the most important economic sectors of any society. This industry annually consumes a huge amount of raw materials of each country and produces a large amount of construction waste, which has become one of the concerns of environmentalists and one of the problems of urban service management. Improper construction waste management from the design stage of a building to its construction and operation can cause not only an increase in the waste of resources and an increase in the per capita costs of new constructions, but also lead to a waste of resources and national funds. In order to solve the problems with construction waste and to control the large amounts of waste production and resulting pollution,

Table 4. Formulation of the SWOT matrix.

SO strategies	WO strategies
1- Economic exploitation of construction waste in local and global markets to improve the financial resources of the TWMO in the field of control and management of construction waste 2- Planning for the construction of a recycling plant from ceramics, tiles, building stones, soil and plaster while observing health and economic considerations. 3- Necessary measures to reduce the production of construction waste at the source (reduction, reuse and recycling)	1- On-site observation of environmental considerations 2- Studying and benefiting from the experiences of other countries in the field of better management and disposal of hazardous waste 3- Planning for the use of modern technologies in order to reduce plant costs and improve the efficiency of processing, recycling and reducing waste disposal.
ST strategies	**WT strategies**
1- Reviewing studies on construction waste management in order to minimize the pollution resulting from landfilling and improving the appearance of the land and environment (water, soil, air and vegetation). 2- Controlling and monitoring building demolition in cooperation with other organizations to prevent manual demolition to prevent the destruction of materials, bricks and illegal dumping 3- Providing the required funds from the sale of recycled waste to purchase the necessary land and appropriate equipment and technology	1- Studying the chemical composition of waste in order to control its effects on the quality and quantity of groundwater 2- Preventing mixing or separating waste at the source for easier recycling at the plant site. 3- Training the workforce to improve the personnel health 4- Developing detailed rules regarding attracting investment and facilitating private sector participation

Table 5. Pairwise comparison matrix of SWOT strategies.

Geometric mean of the expert opinions	SO			WO			ST			WT			Weight
SO	0	0	0	5	6	6.5	3	4	5	5	6	7	0.266718
WO	3	4	5	0	0	0	5	5	7	3	4	5	0.275527
ST	7	8	8.5	1.5	2	2.5	0	0	0	3	4	5	0.244427
WT	3	4	5	3	4	5	5	6	7	0	0	0	0.245428

Table 6. Normalized matrix.

	SO			WO			ST			WT		
SO	0	0	0	0.270	0.342	0.351	0.162	0.216	0.270	0.270	0.324	0.378
WO	0.162	0.216	0.270	0	0	0	0.270	0.324	0.378	0.162	0.216	0.270
ST	0.378	0.432	0.459	0.081	0.108	0.135	0	0	0	0.162	0.216	0.270
WT	0.162	0.216	0.270	0.162	0.216	0.270	0.270	0.324	0.378	0	0	0

Table 7. Total-relation matrix.

	SO			WO			ST			WT		
SO	0.351	0.890	3.365	0.490	0.954	2.941	0.493	1.058	3.585	0.524	1.048	3.419
WO	0.462	0.993	3.364	0.233	0.627	2.493	0.519	1.033	3.419	0.409	0.897	3.141
ST	0.623	1.139	3.369	0.346	0.762	2.554	0.312	0.792	3.033	0.437	0.922	3.055
WT	0.462	0.993	3.364	0.373	0.805	2.705	0.519	1.033	3.419	0.269	0.719	4.928

Table 8. Importance coefficient of strategies (decisive influence coefficient).

Strategies	$(\tilde{D}_i + \tilde{R}_i)^{def}$	$(\tilde{D}_i - \tilde{R}_i)^{def}$
SO	11.617	-0.815
WO	11.897	-0.667
ST	11.028	-0.542
WT	12.627	-0.053

Table 9. Interdependence between SWOT strategies.

	SO	WO	ST	WT
SO	1	0	1	1
WO	1	0	1	0
ST	1	0	0	0
WT	1	1	1	0

Table 10. pairwise comparison matrix for the main factors of WT and the weight of each factor.

Strengths	ST			WT			Weight
ST	1	1	1	5	6	7	1
WT	-	-	-	1	1	1	0
CR	0.00						

Table 11. Calculation of final priorities of SWOT factors.

SWOT groups	Group priorities	SWOT factors	Relative priorities of factors	Final priority of invoices
WT	0.4453	WT1	0.85	0.252316
		WT2	0.94	0.273300
		WT3	0.77	0.246001
		WT4	0.58	0.177630

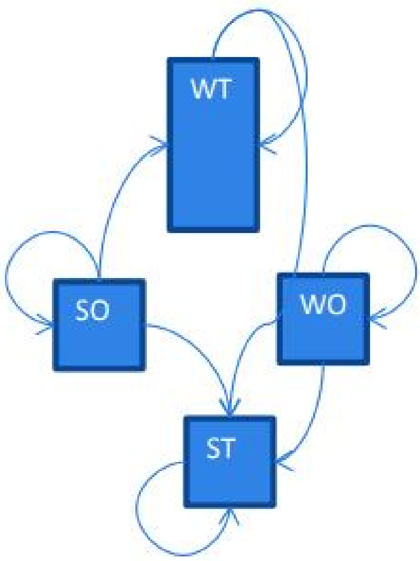

Figure 6. Interdependence between SWOT strategies.

it is necessary to formulate and implement a suitable and pioneering model for the comprehensive management of all types of construction waste in a way that responds to the existing problems. In the current research, while paying attention and emphasizing the prevention of controlled and optimal production and consumption of resources through the correction of common wrong methods and the reduction of construction waste production, the management of these wastes has been taken into consideration with an emphasis on separation, reuse and recycling.

Since the inconsistency rate in the paired comparison method was 0.017, the accuracy of this method can be confirmed. In addition, given that the effectiveness of the strategies WT was greater than other cases (12.627), it is possible to express an opinion with certainty about the priority of this group of strategies over other cases. According to the results obtained from the priorities of the SWOT group and the decisive influence coefficient of 12.627, it was found that WT strategies had the highest priority compared to other strategies. Correspondingly, construction waste management with the approach of building construction waste processing, recycling and landfilling plants should take steps towards improving weaknesses and removing threats to the growth and success of construction waste management systems in Tehran.

As can be seen from our results, the final weight of the strategy "Preventing mixing or separating waste at the source for easier recycling at the plant site" was higher compared to other strategies. It can be concluded that this solution was a priority for formulating a strategic management model of construction waste by locating waste processing, recycling or disposal plants. The final prioritization of WT strategies were:

1. Preventing mixing or separating waste at the source for easier recycling at the plant site
2. Studying the chemical composition of waste in order to control its effects on the quality and quantity of groundwater
3. Training the workforce to improve the personnel health
4. Developing detailed rules regarding attracting investment and facilitating private sector participation

The findings of the present research could be compared with some studies. Khadem et al. (2022) also followed SWOT-AHP combined method to develop a strategic urban waste management plan. Also Fataei et al. (2022) used the SWOT method to analyze the internal and external environmental factors in urban waste management. In terms of the type of proposed strategies, there was no significant difference between the findings of this research and other studies, while, in terms of the weight and importance of the strategies and their implementation priority, a difference was observed with all previous researches.

The innovation of the present research, in addition to the novelty of the subject, is summarized in the research methodology, in that several methods were used simultaneously to achieve the results.

5. Conclusion

According to the findings of the present study, the construction waste management system of Tehran has a defensive position. Therefore, Tehran waste management organization must address threats while strengthening weaknesses. Due to the weaknesses of the SWOT model and the fact that it only includes an incomplete list of external and internal factors and cannot comprehensively evaluate the strategic decision-making process, this study employed SWOT and FANP-DEMATEL combined model to evaluate strategies using selected and superior strategic factors.

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Authors Contributions

Study concept and design: Hossein Aligholizadeh, and Saeed Motahari; analysis and interpretation of data: Maryam Farahani, and Hasan Samadyar; drafting of the manuscript: Hossein Aligholizadeh.; critical revision of the manuscript for important intellectual content Saeed Motahari.

Availability of Data and Materials

All data generated or analysed during 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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