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Analysis Indicators of Health-Safety in the Risk Assessment of Landfill with the Combined Method of Fuzzy Multi-Criteria Decision Making and Bow Tie Model

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Abstract: The study and analysis of safety, health and environmental indicators in the risk assessment of landfill sites are essential to improving performance and reducing injuries. This study is essential in identifying effective criteria and providing useful solutions for proper waste control and management. In Gilan province, 2200 tons of waste enter landfills every day, and this has created a lot of pollution in the area. The methodology of this research was chosen using the opinions of experts and the Delphi technique. Factors affecting the risk assessment in the construction and operation phases were investigated in two phases. The risks of a landfill project were identified by combining (FANP) and (FTOPSIS) using a multi-criteria decision bow tie technique to rank and prioritize criteria. The results show that urban landfills are one of the environmental risk factors in cities. They often contaminate water sources. This has caused a disturbance in the stability of ecological systems. Using the bow tie model can control and prevent environmental health-safety risks caused by urban waste disposal. This can be a threat and a big factor in the destruction of ecosystem resources and services. The integrated approach used in this study provides a flexible tool for evaluating and developing municipal landfills. The risk assessment study proves that the most involved areas in the landfill are environment and health-safety, respectively. Socio-economic and cultural fields are in the next categories. Due to their nature and working process, lancets face many environmental, safety and health risks. The integrated approach (FANP) and (FTOPSIS) with bow ties are suitable methods for risk assessment in landfills. It is very important to use the bow tie technique in analyzing, examining and prioritizing risk sources for management and also control measures such as preventing and limiting high-risk sources.

Keywords: analysis indicators; risk assessment; Delphi method; bow tie model; fuzzy (ANP); fuzzy TOPSIS

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1. Introduction

Moving to a more sustainable society requires the use of more complex and effective methods in waste management. The traditional reductionist approach is unsustainable because it lacks flexibility and long-term effective planning. Transitioning to a sustainable waste management system requires the identification and use of leverage points that affect change [1]. Risk assessment refers to the systematic identification, analysis, and addressing of the right issues [2]. The bow tie model is a structured technique for risk assessment in cases where qualitative performance approaches seem inappropriate and/or insufficient. The rapid increase in waste production in recent years due to economic prosperity and rapid urbanization has significantly exacerbated environmental and social problems [3]. Today, various methods are available to assess the local, regional and global impacts of human activities on ecosystems. However, none by themselves can comprehensively assess the positive and negative effects of human activities at different geographical scales [4].

Multi-criteria decision-making techniques make it possible to evaluate quantitative and qualitative characteristics and analyze and eliminate subjective biases. They can be useful in terms of making objective decisions [5]. MCDM methods can simultaneously consider all relevant criteria, including conflicts of interest and lack of sufficient and correct information, hence helping to solve problems easily [6,7]. In all MCDM techniques, it is necessary to have a working group of different people [8], therefore MCDM can be used to organize these types of decisions [9].

Although problem detection technologies have been widely studied and used, they can only support in-event inspection and post-event control [10]. The research by Aliabadi et al. (2022) and its results have shown that some primary events can lead to many secondary events, and this can increase the severity and consequences of the first event. Therefore, safety analysis is necessary to prevent such possible scenarios and limit their consequences on personnel, society and the environment [11]. Based on the analysis of industrial accidents by the Ministry of Employment and Labor, the annual average number of injured people has increased from the year 2015 to 2019. This indicates that special attention should be paid to possible future risks and preventive measures toward major causes of accidents, should they be developed. The bow tie model is useful in assessing the main risk factors for any industry [12].

Multi-criteria decision-making (MCDM) encompasses a wide range of methods to support decision-making to reach a compromise solution when there are multiple criteria. A common weakness of these methodologies, such as Analytic Hierarchy Process (AHP) and Top-Ranked Procedures and Techniques for Priority Ordering Based on Similarity to Ideal Solution (TOPSIS) methods, is that the evaluation criteria set by decision makers are generally subjective [13]. All organizations are vulnerable to unexpected and uncertain events. It requires them to plan for emergencies as part of their overall health and safety, plus the entire management framework. While specialists' input and advice may be required, health and safety indicators play an important role in facilitating and monitoring planning. The use of bow tie analysis in emergency management projects in the manufacturing industry helps organizations to prevent or minimize the effects of emergencies [14]. The use of an analytical network process (ANP) in calculating the weight of each criterion, as well as the scoring of multiple experts to reduce a criterion is vital. The results (ANP) have proven that this method is highly accurate in evaluations [15] and (ANP) the model that clarifies the influence relationship between criteria [16]. The results of the Fuzzy Analytical Network (ANP) process optimization for cluster head selection showed that the performance evaluation shows a 5% improvement compared to the fuzzy AHP clustering method and a 10% improvement compared to the traditional method in terms of stability, energy consumption, throughput and control overhead [17].

The result of using the fuzzy analytical network process (ANP) in the evaluation of railway construction projects shows that it is compatible with the real engineering situation, and the evaluation model is overall effective. It can be used as a theoretical basis for the safety management of construction projects, and a complete process analysis method has been developed based on the theory of flexibility [18]. Kharat et al. [19] in India used three integrated models of TOPSIS Russian Hierarchy and Fuzzy Process to prioritize suitable landfill sites [19].

In research, El-khateeb et al. [20] used techniques of analytical network process (ANP) and (TOPSIS) in fuzzy logic to unify all different criteria. The results show that this model is robust and helps to minimize the inaccuracy of railway condition assessment by applying intensity, uncertainty reduction and strong aggregation.

An important aspect of bow tie analysis (BTA) is the inclusion of managerial controls. The management effectiveness of controls determines the extent of the effects of human pressures on ecological components and how their impacts can be reduced. Is this reduction an obstacle for the management to achieve their goals? [21]. The bow tie model with causal relationship is modeled using fault tree and event tree methods, and reliability theory was used to determine the total risk [22]. Combining bow tie analysis and ecological risk assessment enables managers, scientists, and stakeholders to ensure that management controls and evaluates risks and options in response to risk factors and tracks the effectiveness of the management system [21]. Tušer and Oulehlová [23] risks were applied to the application of risk management procedures on the municipal wastewater treatment plant. The risk identification phase included the identification of existing assets and risks. They used the bow tie analysis method to show the causes and consequences of one of the major risks. The result of this study showed that the bow tie analysis was preferred in risk assessment to identify undesirable and unacceptable risks [23]. It logically links the relationships between management objectives and controls, the potential effects of threats on financial resources and their consequences in achieving management objectives and impacts in the bow tie analysis method [21].

Despite the simplicity and prevalence of TOPSIS, it has often been criticized by experts for its inability to deal with cases of uncertainty and inaccuracy in the process [24]. This problem is suggested using the TOPSIS Fuzzy method [25]. Using multi-criteria combination decision-making methods, the range of social, economic, and environmental impacts can be accurately combined, measured, and evaluated, and accurate results can be achieved by validating the results with other methods [5].

Risk assessment is a process that includes the assessment, ranking, and classification of hazards and related hazards from the perspective of safety and health [26]. In various processes of waste sites, dangerous substances, such as lead, furan, dioxin, nitrogen oxides, sulfur, etc. are produced, and each one has dangerous side effects. For example, among the side effects of lead produced from the process of burning waste, we can mention the disturbance in the enzymatic reactions of the body, the reduction of the life of red blood cells, negative effects on the fetus, hallucinations and memory loss, anemia, kidney cancer, etc. The immune hair system of the human body has can be negatively affected as well [27]. Therefore, health-safety criteria are an important factor in risk assessment. In today's economic conditions, the share of environmental investments in the total national economic investments in countries is very small (less than 1%). The slow dynamics of investment processes lead to the insufficient launch of major environmental funds in countries. Unfortunately, the situation has worsened in connection with the suspension of the national "Ecology" project due to the problems of the epidemic [28]. These issues and problems will affect the evaluation of socio-economic and cultural factors.

More and more waste of different types of materials is produced every day, and it creates a significant problem in its management and disposal [29]. Environmental hazards include a wide range of issues. Mineral effluents, industrial wastewater, polluted fish and rice, and polluted air have led to serious health problems worldwide [30]. The groundwater level in the northern cities of Iran is very high with such contaminants in leachate, and water can be a very fast carrier of various diseases. Therefore, different contaminants may potentially enter landfills. High humidity can affect biological waste storage and processing systems and is, therefore, a serious risk parameter. Many industrial and municipal wastes and effluents contain significant amounts of heavy metals that enter water systems in various ways.

In this research, to overcome the problem of data uncertainty, we used result-based probabilistic analysis and fuzzy theory to quantify the risks related to the probability of occurrence of events and superior results in terms of experts' judgments of waste. Therefore, we used fuzzy ANP and fuzzy TOPSIS methods. The most relevant MCDM methods and tools are described and discussed, focusing on their function in landfill risk assessment. The most relevant identified in this research methods are Delphi and Fuzzy Network Analysis Process, Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and bow tie.

When it comes to the analysis of multi-criteria health-safety indicators in research, a compromise is made between the goals; not all of those factors are necessarily optimal, but some of them are appropriate nonetheless. On the other hand, when it comes to improving a factor (for example, leachate infiltration, or water pollution), the final output is necessarily optimal from the point of view of the mentioned factor. Fuzzy multi-criteria modeling and optimization have not been performed in any of the research while considering the bow tie model. The novelty of this article has been investigated in the deterministic and fuzzy space. The results of this study can be used by city managers to control and manage the risks of waste landfills to reduce its negative effects, especially in the area of environment, health and safety. Considering the high efficiency of the bow tie in risk assessment, while also considering the multiplicity of criteria involved in decision-making and various methods of fuzzy multi-criteria decision-making support system, it can be very useful as a powerful work tool in the field of risks in landfills. Combining Fuzzy and bow tie methods makes an important contribution to the new body of knowledge.

The practical contributions and innovation of the present study are as follows: The new decision algorithm and a comparison of TOPSIS, ANP and bow tie models with fuzzy logic based on group decision structure are presented. They can provide sufficient results to assess the risk of municipal landfilling in large volumes of data of different natures at different times. We did not find any studies using the combined approach to assess the risk of urban landfills in the construction or operation phase, in particular concerning health-safety, environmental and socio-economic, and cultural factors. The bow tie method has been used for the first time to manage high-risk risks in landfills [31].

2. Materials and Methods

The general trend of risk assessment of environmental, health-safety, economic, social, and cultural aspects in municipal solid waste in this study is not included in the above lists, yet it is equally important in planning while some risks may be very vital. The ability of risk identification methods to identify risks is quantitatively and qualitatively different. Although no technique can be considered or labelled as the ultimate best or worst among the MCDM methods, the presented fuzzy ANP method has been used due to its comprehensiveness, high flexibility, and consideration of the internal relationships between variables in different contexts to solve problems [32,33]. Fuzzy ANP provides an executive framework for general analysis and decision-making collaboration. It takes into account all tangible and intangible factors and criteria that have a significant impact on making the best decisions. It can conceivably present the necessary priorities for decision-making [34,35]. Fuzzy TOPSIS has been used as a practical method that compares risks according to their data values in each criterion and weight for sanitary landfill risk assessment. Therefore, in this study, the bow tie method was used as the main method, while the fuzzy network analysis process fuzzy (ANP) and fuzzy TOPSIS methods were used as complementary methods. Figure 1 shows the flow chart of the methodology.

2.1. Delphi Technique of Identifying Experts and Validating Questionnaires

To determine the number of required experts, 10 questionnaires were completed as a pre-test [31]. According to the obtained standard deviation, 1 degree of freedom and 0.95 confidence limits were calculated by Cochran's relation. A value of 9.6 was obtained. To increase accuracy, 10 people were considered experts (number of samples). Figure 2 shows the distribution of urban waste landfills in Gilan province.

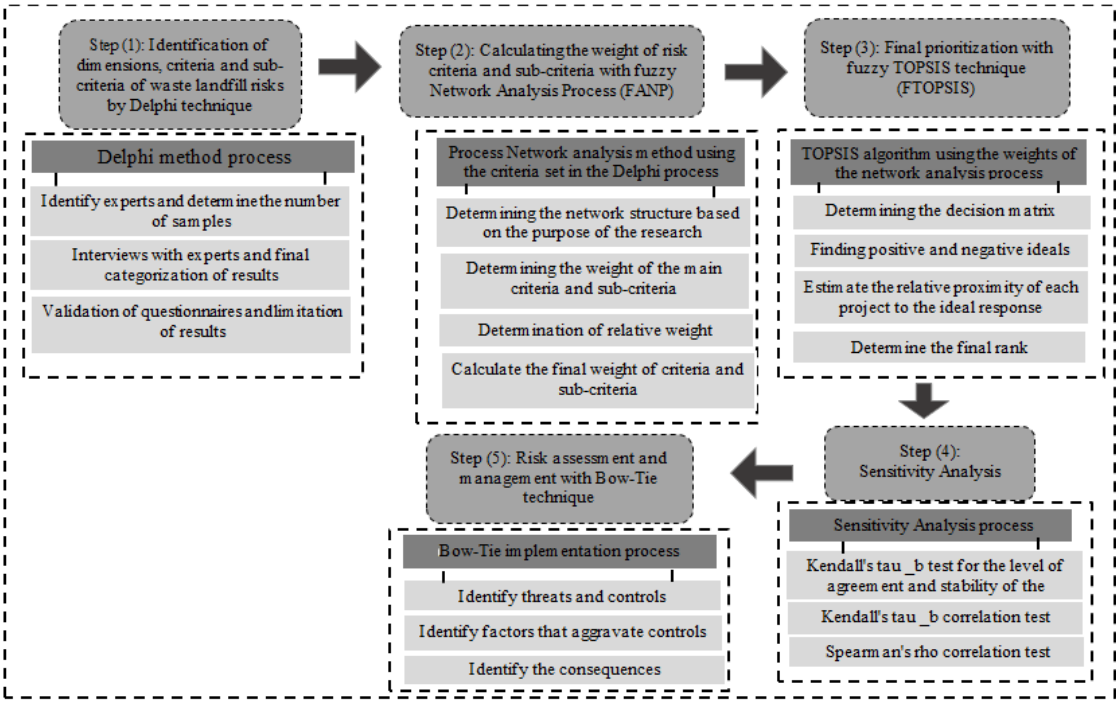

Figure 1. Methodology flow chart.

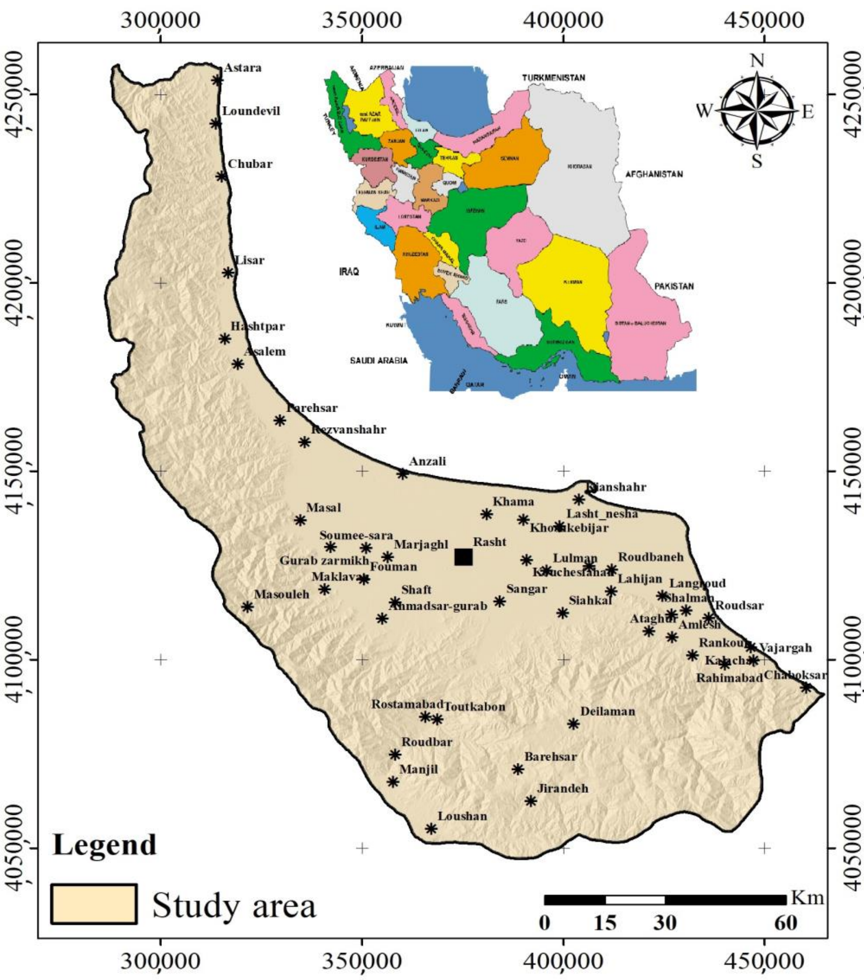

Figure 2. Distribution of municipal landfills.

2.2. Fuzzy Network Analysis Process (FANP)

The weights of the criteria and sub-criteria in the fuzzy network analysis were obtained based on the following steps [36].

Step 1: First, pairwise comparisons were performed by experts using fuzzy numbers listed in Table 1. Then, for the consensus of the experts, the geometric mean was taken from the pairwise comparisons of the respondents.

Table 1. Fuzzy spectra and corresponding expressions.

Code	Verbal Expressions	Fuzzy Numbers
1	Equal preference	(1,1,1)
2	Low to medium preference	(1,1.5,1.5)
3	Medium preference	(1,2,2)
4	Medium to high preference	(3,3.5,4)
5	High preference	(3,4,4.5)
6	High preference for very high	(3,4.5,5)
7	Preference is very high	(5,5.5,6)
8	Preference is very high to quite high	(5,6,7)
9	Quite a preference	(5,7,9)

Step 2: Calculating the special vector: To calculate the special vector of each of the pairwise comparison tables according to the following formula, the least-squares logarithmic equation was used.

$$W_K^S = \frac{\left(\prod_{i=1}^{n} a_{kj}^s\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{i=1}^{n} a_{kj}^s\right)^{1/n}},\ S \in \{l, m, u\} \tag{1}$$

$$\widetilde{W}_k = \left(W_k^l, W_k^m, W_k^u\right)\ k = 1, 2, 3, \ldots, n \tag{2}$$

Step 3: Formation of special matrices (w_{ij}): These matrices are special vectors that are obtained from pairwise comparisons of the second step. Due to a large number of tables, the authors were not able to present them in this study.

Step 4: Calculating the final weights: To do this, the components of each level (W_i^*) must be multiplied by the special vector matrix of internal relations in the special vector of the same level in the final weight of the higher level.

$$W_i^* = W_{ii} \times W_{i(i-1)} \times W_{i-1}^* \tag{3}$$

If there is no (W_{ii}) matrix for a surface, it is necessary to replace the matrix with a degree using the formula (7).

$$W_i^* = I \times W_{i(i-1)} \times W_{i-1}^* \tag{4}$$

2.3. Fuzzy TOPSIS Process

Step 1: Create a decision matrix for ranking including the criterion m option and n criterion. The relative importance of the options for each criterion is indicated by triangular fuzzy numbers. First, all linguistic expressions must be converted to triangular fuzzy numbers that form the decision matrix of the ranking problem.

Step 2: Normalize the decision matrix.

If we show each decision matrix cell as a triangular fuzzy number $\left(a_{ij}, b_{ij}, c_{ij}\right)$, in this step, we must perform the normalization operation to remove the scale effect of each criterion. With the help of the following relations, a normal $(\widetilde{R})$ a decision matrix is obtained.

$$\widetilde{R} = \left[\widetilde{r}_{ij}\right]_{m \times n} \tag{5}$$

$$\widetilde{r}_{ij} = \left(\frac{a_{ij}}{c_j}, \frac{b_{ij}}{c_j}, \frac{c_{ij}}{c_j}\right), \ j \in B; \tag{6}$$

$$\widetilde{r}_{ij} = \left(\frac{a_{\bar{i}}}{c_{ij}}, \frac{a_{\bar{j}}}{b_{ij}}, \frac{a_{\bar{j}}}{a_{ij}}\right), \ j \in C$$

$$C_j^* = \max_i c_{ij}, if \ j \in B; \tag{7}$$

$$C_j^* = \max_i a_{ij}, if \ j \in C;$$

Step 3: Formation of fuzzy balanced normalized decision matrix multiplying the normalized decision matrix $(\widetilde{r}_{ij})$ by the standard fuzzy weights $\left(\widetilde{W}\right)$ gives the fuzzy weighted normalized matrix $\left(\widetilde{V}\right)$.

$$\widetilde{v}_{ij} = \widetilde{r}_{ij} \bigotimes \widetilde{w}_i \tag{8}$$

$$\widetilde{V} = [\widetilde{v}_{ij}]_{m \times n}, i = 1, 2, \ldots, m, j = 1, 2, \ldots, n \tag{9}$$

At this stage, the preference of experts over each other is equal.

Step 4: Determine the ideal positive solution $\widetilde{v}_j^+$ and the negative ideal solution $\widetilde{v}_j^-$.

$$\widetilde{v}_j^+ = \begin{cases} \max\limits_{i=1,\ldots,m} \widetilde{v}_{ij}; j \in B \\ \max\limits_{i=1,\ldots,m} \widetilde{v}_{ij}; j \in C \end{cases} \tag{10}$$

$$\widetilde{v}_j^- = \begin{cases} \max\limits_{i=1,\ldots,m} \widetilde{v}_{ij}; j \in B \\ \max\limits_{i=1,\ldots,m} \widetilde{v}_{ij}; j \in C \end{cases}$$

$$\widetilde{A}^+ = (\widetilde{v}_1^+, \widetilde{v}_2^+, \ldots, \widetilde{v}_n^+) \tag{11}$$

$$\widetilde{A}^- = (\widetilde{v}_1^-, \widetilde{v}_2^-, \ldots, \widetilde{v}_n^-)$$

Step 5: The distance of each option to positive (d_i^+) and negative (d_i^-) ideals were determined.

$$d_i^+ = \sum_{j=1}^{n} d\left(\widetilde{v}_{ij}, \widetilde{v}_j^+\right), \ i = 1, \ldots, m \tag{12}$$

$$d_i^- = \sum_{j=1}^{n} d\left(\widetilde{v}_{ij}, \widetilde{v}_j^+\right), \ i = 1, \ldots, m$$

If the ideal positive fuzzy solution is considered to be A^+ and the ideal fuzzy negative solution is considered to be A^-. The distance between each option is A^+, the positive distance and the distance between each option is A^-, the negative distance, both of which are calculated by Equation (12). The distance between two triangular fuzzy numbers $\widetilde{M} = (m_1, m_2, m_3)$ and $\widetilde{N} = (n_1, n_2, n_3)$ is determined by Equation (13) [31,37].

$$\left(\widetilde{M}, \widetilde{N}\right) = \sqrt{\frac{1}{3}\left[(m_1 - m_1)^2 + (m_2 - m_2)^2 + (m_3 - m_3)^2\right]} \tag{13}$$

Step 6: Determine the coefficient of proximity for each of the options.

The coefficient of the proximity of each option (Cc_i) is calculated by Equation (14). For each option, the closer the coefficient, the higher the priority.

$$Cc_i = \frac{d_i^-}{d_i^- + d_i^+} \tag{14}$$

TOPSIS fuzzy questionnaires typically use a five-point Likert scale with linguistic expressions (very low, low, medium, high, and very high) as decision matrix data. TOPSIS questionnaires became fuzzy TOPSIS.

Step 7: The outcome rate, risk probability, contact rate and affected area in the criteria of safety-health effects and environmental and socio-economic effects are calculated in Table 2.

Table 2. Linguistic expressions and their fuzzy equivalents.

Fuzzy Numbers for Negative Items	Fuzzy Numbers for Positive Items	The Linguistic Phrase of the Questionnaire
(7,9,9)	(1,1,3)	very little
(5,7,9)	(1,3,5)	Low
(3,5,7)	(3,5,7)	medium
(1,3,5)	(5,7,9)	Much
(1,1,3)	(7,9,9)	very much

2.4. Bow Tie Implementation Process

The bow tie diagram in this technique has been created as a practical and successful tool for risk identification and qualitative analysis. Considering the necessity of landfilling and the range of consequences of its occurrence in terms of safety, health, environmental, socio-economic and cultural, it was considered as the main high-risk events and criteria in the bowtie method. The bow tie method is created by combining the two methods of fault tree analysis and event tree analysis. In making a bow tie diagram, the causes and threats of the event are placed on the left side, the main event is placed in the center of the diagram as a node, and the consequence of the main event is placed on the right side. Consequently, the resulting diagram is formed in the shape of a bow tie. The bow tie method is a method that analyzes the event by determining two phases, one before and one after the event. Activities that are identified in the pre-event phase are called causes or threats. The activities that lead to the development of the event scenario in the post-event phase are called consequences. In the pre-event phase, the FTA method is used and in the post-event phase, the ETA method is used. To implement the bow tie method, there are five main steps (identification of the main event, identification of threats or causes, identification of preventive barriers or control methods, identification of consequences, and identification of mitigating barriers or compensatory measures).

3. Results

Due to the short history of risk assessment of urban landfills, there are not many theoretical studies in this field. Production and increase in the volume of leachate produced, the complexity of waste disposal projects, and the constraints on funding and resources required, their success depends on the identification, assessment, prioritization, and risk management. The results obtained in the two rounds of the Delphi method questionnaire are in Table 3. Due to the sample size, (n = 10), the tests cannot be performed using a multivariate model, and therefore, it was performed using a single-level variable approach. To reduce the possibility of statistical error, Kendall's tau-b correlation was used [38].

Table 3. Characteristics of Delphi panel members and identified risks in research.

Number of Risks Identified	Number of Experts	Group	Round
82	6	Member of the faculty of a university or research institute	first round
	4	Managers and senior advisors in the public sector	
	5	Experts active in consulting engineering companies	
59	8	Member of the faculty of a university or research institute	second round
	4	Managers and senior advisors in the public sector	
	5	Experts active in consulting engineering companies	

3.1. The Final Results Delphi Technique

It is necessary to mention that the selected factors and indicators have been determined according to the critical conditions of the region, and the characteristics of the landfill sites under study. In practice, different indicators may be chosen for a product in other organizations.

Considering the damaged environments and the types of risks caused by landfill projects, the network structure was drawn based on the purpose of the research in two phases of construction and operation. The weight of the criteria and sub-criteria obtained in the construction and operation phases are shown in Tables 4 and 5.

Table 4. The relative and final weight of landfill risks in the construction phase.

Weight Factors	Sub-Risk Factors	Relative Weight	Final Weight
Health-safety 0/329482	Lack of safety equipment in the Landfill	0.1335201	0.0439924
	Machinery colliding with equipment	0.1068005	0.035188
	Bad control (improper management)	0.1078410	0.035531
	Explosion and fire	0.0984710	0.032444
	Excavation and embankment operations, construction of camps, structures, sheds, land acquisition	0.1131184	0.0372704
	Delays in providing the required tools and equipment	0.1096259	0.036119
	Collision of machinery with the pipes of the leachate guidance system	0.1298495	0.042783
	Incidence various diseases	0.1155012	0.0380555
	Damage to facilities, equipment, and tools available at the landfill site	0.1084312	0.035726
	Falling of concrete pipes, electric poles, and concrete walls during handling and installation	0.1198705	0.0394951
	Injuries (deaths) or acute hurts to human resources	0.1106588	0.036460
	Incidence of skin complications and respiratory injuries	0.1068450	0.035203
Environmental 0/385634	Destruction of wildlife and bird habitats	0.098405	0.0379483
	Disease transmission	0.104754	0.0403967
	Increase in airborne particles and aerosols	0.106511	0.0410742
	Decreased biodiversity	0.099412	0.0383366
	Creating noise pollution caused by vehicle and machine traffic	0.098431	0.0379583
	Determining the distance between critical areas for protection and watershed management operations	0.136755	0.0527373
	Disruption of the stability of ecological systems	0.1408672	0.0543231
	Soil pollution	0.111497	0.0429970
	Geographical events (floods, earthquakes, and landslides)	0.132582	0.0511281
	Leakage of oil and petroleum products (fuel) from machinery and fuel storage tanks	0.103211	0.0398016
Economic, social, and cultural 0/284884	High costs of the landfill project	0.083212	0.0237056
	Lack of timely approval of plans at the time of the project implementation	0.098241	0.0279872
	Lack of scale for the cost of activities	0.123212	0.0351011
	Confronting the nature of the project with cultural and social values	0.119232	0.0339672
	Lack of regulatory and legal system	0.093775	0.0267149

Table 5. The relative and final weight of landfill risks in the operation phase.

Weight Factors	Sub-Risk Factors	Relative Weight	Final Weight
Health-safety 0/31229	Intensification of carcinogenicity and toxicity	0.1011234	0.0315798
	Damage to humans, plants, and animals due to gases emitted from the landfill	0.1052502	0.0328685
	Blockage of leachate collection and conduction channels	0.0856520	0.0267482
	Occurrence of fire	0.0864205	0.0269882
	Collision of waste handling machines with leachate system pipes	0.0953113	0.0297647
	Accumulation of insects and flies and increase in pathogenic microorganisms	0.0753145	0.0222072
	Noise pollution from the operation of moving vehicles such as forklifts and garbage trucks	0.0942351	0.0294286
	Noise pollution from pneumatic tools and equipment for trench drilling	0.0827225	0.0258334
	Malfunctioning of leachate recirculation pumps	0.0925434	0.0289003
	Respiratory injuries and skin complications	0.0764223	0.0238659
	Blockage of the aeration ducts	0.0829453	0.0259029
	Enter chemical contaminants into the food chain	0.1037212	0.0323910
Environmental 0/38645	Contaminants such as diesel fuel or unrefined oils, and industrial and petroleum wastes on the roads can cause pollution and spills.	0.0924031	0.0357091
	Leachate production and pollution of water and soil resources	0.1041105	0.0402335
	Increased stress on wildlife and birds	0.0964312	0.0372658
	Disease transmission	0.0910324	0.0351794
	Dissolution, suspension of materials and products resulting from biological changes of waste in leachate	0.0921316	0.0356042
	Increasing penetration of volatile and semi-volatile organic compounds into the environment, increasing heavy metals	0.1021125	0.0394613
	Evaporation of water and chemical compounds in gases from municipal waste	0.0852302	0.0329372
	Halogen release and decomposition of organic matter and oxidation and reduction reactions on metals and metal salts	0.0912435	0.0352610
	Insulating and covering pipes to prevent chemical reactions	0.0823243	0.0318142
	Lack of leachate drainage, treatment storage, and lack of monitoring systems	0.0916425	0.0354152
	Breakage and disruption of facilities and equipment settings	0.0841211	0.0325085
	Blockage of the aeration ducts	0.0847457	0.0327499
	Increase of suspended particles due to traffic and activity of excavation and construction machines, such as bulldozers, scrubbers, graders, and tools and equipment with an internal combustion engine	0.0917832	0.0354696
	Improper operation of the leachate recirculation system	0.0857236	0.0331278
Economic, social, and cultural 0/30126	High costs of control and development of engineering-sanitary landfill	0.0896546	0.0270093
	Use of consulting engineers with inadequate experience in project monitoring	0.1053756	0.0317454
	Risk of lack of government support for the project	0.0898794	0.0270770
	Market conditions and price fluctuations	0.0787189	0.0237148
	Inconsistent economic situation	0.1152868	0.0347313
	Psychological tensions between workers and employees	0.0879878	0.0265072

The results of the fuzzy (ANP) show that in the construction phase, the safety and health factor of lack of safety equipment in landfills is the priority. Prioritizing the environmental factor risks of the disruption of the stability of ecological systems is the priority. The results of the prioritization of economic, social, and cultural factors show that the lack of scale for the cost of activities is the priority.

According to the operation phase results, damage to humans, plants, and animals due to gases emitted from the landfill is the priority. According to prioritization of risks in the operation phase of the environmental factors, leakage from the landfill floor is the priority. In the economic, social, and cultural index, it was found that an inconsistent economic situation is a priority.

These four factors are the leading risk of equal importance. (Environmental risks = affected area × consequence × probability rate). (Health-safety risk = exposure rate × consequence × probability). Environmental risks are greatest in landfills.

The results have higher risk consequences and probability in the operation phase than in the construction phase. The consequence rate of the environmental weighing 0.458 is higher than the safety and health index. The risk probability in the environment weighing 0.641 is higher than the security and health index.

After identifying the safety-health, environmental, socio-economic, and cultural aspects by a team of risk assessment experts, their opinions are collected to evaluate the risk factors of each environmental, safety-health, economic-social, and cultural aspect in a definite way and in a classical way, and the classic risk number is calculated.

Classic environmental risk number = (Affected range × Risk probability × consequence)

Classic socio-economic and cultural risk number = (Exposure rate × Risk probability × consequence)

Classic economic-social and cultural risk number = (Risk probability × consequence)

3.2. Prioritization of Health and Safety Risks of the Construction Phase

Among the safety-health risks, the construction phase is prioritized in terms of excavation and embankment operations, construction of camps, structures, sheds, and land acquisition with a weight of 0.143, which have a more destructive effect than other risks. In the matrix of comparing health-safety to the risk probability index, the excavation and embankment operations, construction of camps, structures, sheds, and land acquisition weighing 0.131 is given priority first. In health-safety factors, the risk of falling on concrete pipes, electric poles, and concrete walls during handling and installation is the priority exposure. The highest classical risk in the health-safety criterion is related to excavation and embankment operations, construction of camps, structures, sheds, and land acquisition, with a risk number of 0.0013.

Among the environmental risks, the construction phase is prioritized in terms of disruption of the stability of ecological systems, with a weight of 0.143, a more destructive effect than other risks. In the matrix of comparing to the risk probability index, the risk of destruction of wildlife and bird habitats weighing 0.145 is given priority in the first place, and the rest are placed in the following priorities. The risk of an increase in airborne particles and aerosols is the priority in exposure, with a weight of 0.139. The highest classical risk in the environmental criterion is related to disruption of the stability of ecological systems, with a risk number of 0.0014. The lowest risk is the classic geographical events (floods, earthquakes, and landslides), with a risk number of 0.0005.

Among the five socio-economic and cultural risks in the construction phase, the risk of lack of scale for the cost of activities, with a weight of 0.298, has a higher destructive rate, so it is the priority risk over the consequences. Matrix of comparing economic-social and cultural risks concerning the probability index, the risk of confronting the nature of the project with cultural and social values with a weight of 0.357 is the priority; the rest are in the following priorities. The highest classical risk in the socioeconomic and cultural criterion is related to confronting the nature of the project with cultural and social values with a risk number of 0.0699. The lowest risk is the classic lack of timely approval of plans at the time of the project implementation, with a risk number of 0.02645.

A matrix comparing health and safety risks concerning the consequence rate, the risk of accumulation of insects and flies, and an increase in pathogenic micro-organisms with a weight of 0.125 is the priority, and the rest are less of a priority. Health and safety risks of the operation phase and the risk of noise pollution from pneumatic tools and equipment for trench drilling are the highest priority according to the risk index weighing 0.138. Health and safety risks are in focus compared to the exposure rate index, intensification of carcinogenicity, and toxicity with a weight of 0.117. The highest classical risk in the health-safety criterion is related to the intensification of carcinogenicity and toxicity, with a risk number of 0.0009.

Environmental risks, weighing at 0.102, are the top priority when compared to the consequence being the risk of leachate production. Since landfills do increase penetration of volatile and semi-volatile organic compounds into the environment, increasing heavy metals, this factor with a weight of 0.101 has been the priority among all other risks in terms of probability. The increase of suspended particles due to traffic and activity of excavation and construction machines, such as bulldozers, scrubbers, graders, and tools and equipment with an internal combustion engine weighing 0.112, among other risks, is the priority of the affected area. The highest classical risk in the environmental criterion is related to contaminants, such as diesel fuel or unrefined oils; industrial and petroleum wastes on the roads can cause pollution and spills, with a risk number of 0.0005. The lowest risk is the classic lack of leachate drainage, treatment storage, and lack of monitoring systems, with a risk number of 0.0002.

As can be seen from the six socio-economic and cultural risks in the operation phase, the risk of market conditions and price fluctuations with a weight of 0.228 has a higher destructive rate, so it is the priority in terms of the consequence. Socio-economic and cultural risks rank first in the probability index in which inconsistent economic situation weighs 0.267. The highest classical risk in the socio-economic and cultural criterion is related to an inconsistent economic situation, with a risk number of 0.0459. The lowest risk is the classic psychological tensions between workers and employers, with a risk number of 0.02645.

3.3. Results of Prioritization of Landfill Risks Using TOPSIS Method

In Table 6, the proximity coefficient of each option in the construction phase is calculated. Each choice that has a closer coefficient has a higher priority. The results of ranking the options with the fuzzy TOPSIS technique in the construction phase of the health-safety criterion showed that the variables of incidence of various diseases, a collision of machinery with the pipes of the leachate guidance system, the incidence of skin complications and respiratory injuries with the highest coefficients of proximity, which were ranked from first to third, respectively.

The results of ranking the options with the TOPSIS technique in the construction phase of the environment criterion showed that the variables of decreased biodiversity, disease transmission, increase in airborne particles, and aerosols with the highest coefficients of proximity were ranked from first to third, respectively. Economic, social, and cultural criteria showed the variables of lack of regulatory and legal system, lack of timely approval of plans at the time of the project implementation, and lack of scale for the cost of activities with the highest coefficients of proximity, which were ranked from first to third respectively. The results of ranking the options with the fuzzy TOPSIS technique in the operation phase of the health-safety criterion showed that the variables of chemical contaminants entering the food chain, damage to humans, plants, and animals due to gases emitted from the landfill, blockage of leachate collection and conduction channels, with the highest coefficients of proximity which were ranked from first to third, respectively. In addition, the results of ranking the environment criterion showed the variables of insulating and covering pipes to prevent chemical reactions, increasing penetration of volatile and semi-volatile organic compounds into the environment, increasing heavy metals, leachate production, and pollution of water and soil resources, with the highest coefficients of proximity, which were ranked from first to third, respectively. Economic, social, and cultural criteria showed the variables of the inconsistent economic situation, risk of government policy support from the project, use of consulting engineers with inadequate experience in project monitoring, with the highest coefficients of proximity, which were ranked from first to third, respectively.

Table 6. Distance of options to the ideal positive and negative solution and proximity coefficient.

	Rank	$(\mathbf{CL^*})$	$(\mathbf{d_i^-})$	$(\mathbf{d_i^+})$	**Risks of Municipal Landfill**
					Safety and Health
construction phases	1	1	0.1838	0.000	Incidence various diseases
	2	0.6258	0.1309	0.0783	Collision of machinery with the pipes of the leachate guidance system
	3	0.5273	0.1250	0.1112	Incidence of skin complications and respiratory injuries
					Environmental
	1	0.7685	0.1684	0.0535	Decreased biodiversity
	2	0.5161	0.1215	0.1139	Disease transmission
	3	0.5080	0.9978	0.3488	Increase in airborne particles and aerosols
					Economic, social, and cultural risks
	1	0.7766	0.2439	0.0775	Lack of regulatory and legal system
	2	0.2768	0.0707	0.1844	Lack of timely approval of plans at the time of the project implementation
	3	0.2573	0.0606	0.1947	Lack of scale for the cost of activities
					Safety and health
operation phases	1	0.8612	0.1765	0.0461	Enter chemical contaminants into the food chain
	2	0.6943	0.1307	0.0892	Damage to humans, plants, and animals due to gases emitted from the landfill
	3	0.6471	0.1051	0.0836	Blockage of leachate collection and conduction channels
					Environmental
	1	0.5814	0.1741	0.1254	Insulating and covering pipes to prevent chemical reactions
	2	0.5414	0.1750	0.1482	Increasing penetration of volatile and semi-volatile organic compounds into the environment, increasing heavy metals
	3	0.4585	0.1460	0.1528	Leachate production and pollution of water and soil resources
					Economic, social, and cultural
	1	0.7517	0.1562	0.0517	Inconsistent economic situation
	2	0.5684	0.1548	0.1176	Risk of lack of government support for the project
	3	0.3562	0.0776	0.1404	Use of consulting engineers with inadequate experience in project monitoring

Kendall's tau_b test was used to test the level of agreement and stability. Its value is between 0 and 1, and a value greater than 0.5 indicates consensus [38–42]. Kendall's coefficient was calculated to check the level of consensus among the unique ranking of experts in the field of importance of each indicator in each round. The result shows that the level of Kendall's coefficient is satisfactory enough and the level of agreement is very high, and the ranking of indicators has occurred with high confidence. Kendall's coefficient of the agreement was 0.773, so it can be said that the stability of the agreement is good and strong [39].

After calculating the average obtained from the fuzzy TOPSIS methods, the fuzzy ANP ranking of the risks of waste landfills was obtained. These ratings were entered into

SPSS software. Due to the ranking of the numbers and the non-parametric nature of each analysis, Spearman's correlation and then B-Kendall's correlation was used. Based on Spearman's non-parametric correlation method, the variables are correlated with only a 99% error probability. The Table 7 shows the correlation values.

Table 7. Kendall's tau_b and Spearman's rho test for agreement and stability test.

			FANP	**FTOPSIS**
Kendall's tau_b	FANP	Correlation Coefficient	1.000	0.773
		Sig. (2-tailed)		0.001
		N	32	32
	FTOPSIS	Correlation Coefficient	0.773	1.000
		Sig. (2-tailed)	0.001	
		N	32	32
Spearman's rho	FANP	Correlation Coefficient	1.000	0.882
		Sig. (2-tailed)		0.000
		N	32	32
	FTOPSIS	Correlation Coefficient	0.882	1.000
		Sig. (2-tailed)	0.000	
		N	32	32

Kendall's tau_b correlation coefficient shows that there is a significant relationship between fuzzy TOPSIS and fuzzy ANP methods (r = 0.773, p = 0.001). Spearman's rho coefficient shows that there is a significant relationship between the fuzzy TOPSIS method and the fuzzy method (r = 0.882, p = 0.000).

3.4. Risks Analysis and Management, Using the Bow Tie Method

This research investigated the risk assessment of urban landfills in the construction and operation phase. In the bow tie method, activities were introduced in three criteria: health-safety, environmental, socio-economic, and cultural. The priorities of experts' evaluation and rating criteria are included in the proposed bow tie algorithm. The optimization of the multi-criteria evaluation system was done using intuitive fuzzy correlations between the criteria and also changing the ranking of experts depending on the correctness of their evaluation in a similar way [43,44]. According to this method, the factors that played a threatening role, damage to human resources, environmental damage, and economic and social damage, were also identified as consequences of the main event. For each threat, several barriers (preventive measures) and for the consequences of health-safety, environmental and economic-social, and cultural harms, several improvement measures were adopted. It should be noted that in this study, in several preventive and remedial measures, aggravating factors and their control were considered. Additional information about the results of the bow tie method are provided in Figures 3–5.

The bow tie is a new and effective safety management tool for identifying the causes of risk. Quantification in the bow tie method suffers from a lack of information, insufficient data, and uncertainty [45]. Therefore, it used the opinions and knowledge of experts on the probability of occurrence of events, the probability of risk, environmental risks measures, and health safety to deal with the lack of information and insufficient data issues. Experts prefer to comment on linguistic variables that are prone to uncertainty. To address these uncertainties the data used in this study were presented using network analysis fuzzy (ANP) and fuzzy TOPSIS methods to convert expert opinions to quantitative value. The purpose of the comprehensive waste management plan is to optimize the waste management system to achieve sustainability.

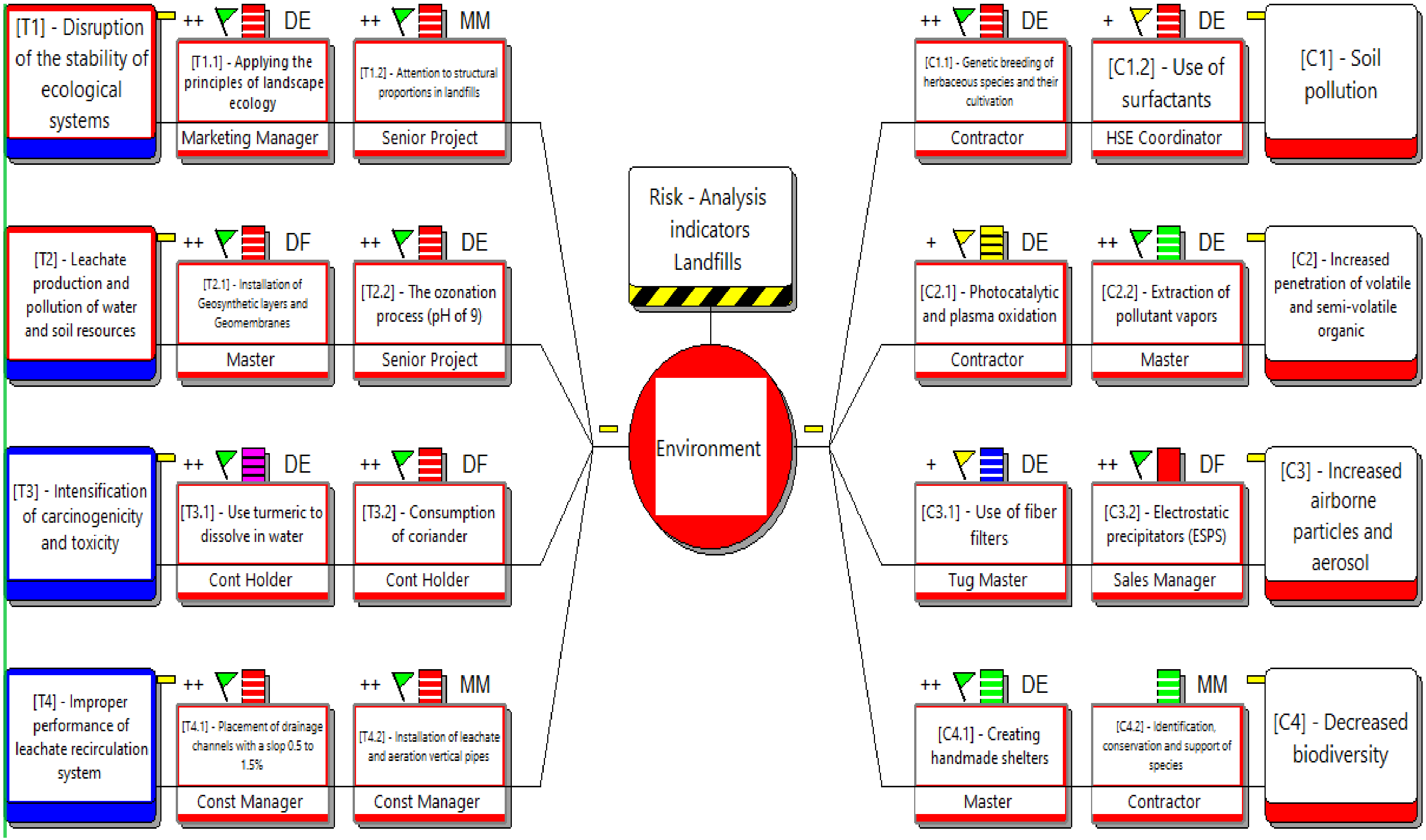

Figure 3. Environmental risks of municipal solid waste in the bow tie model.

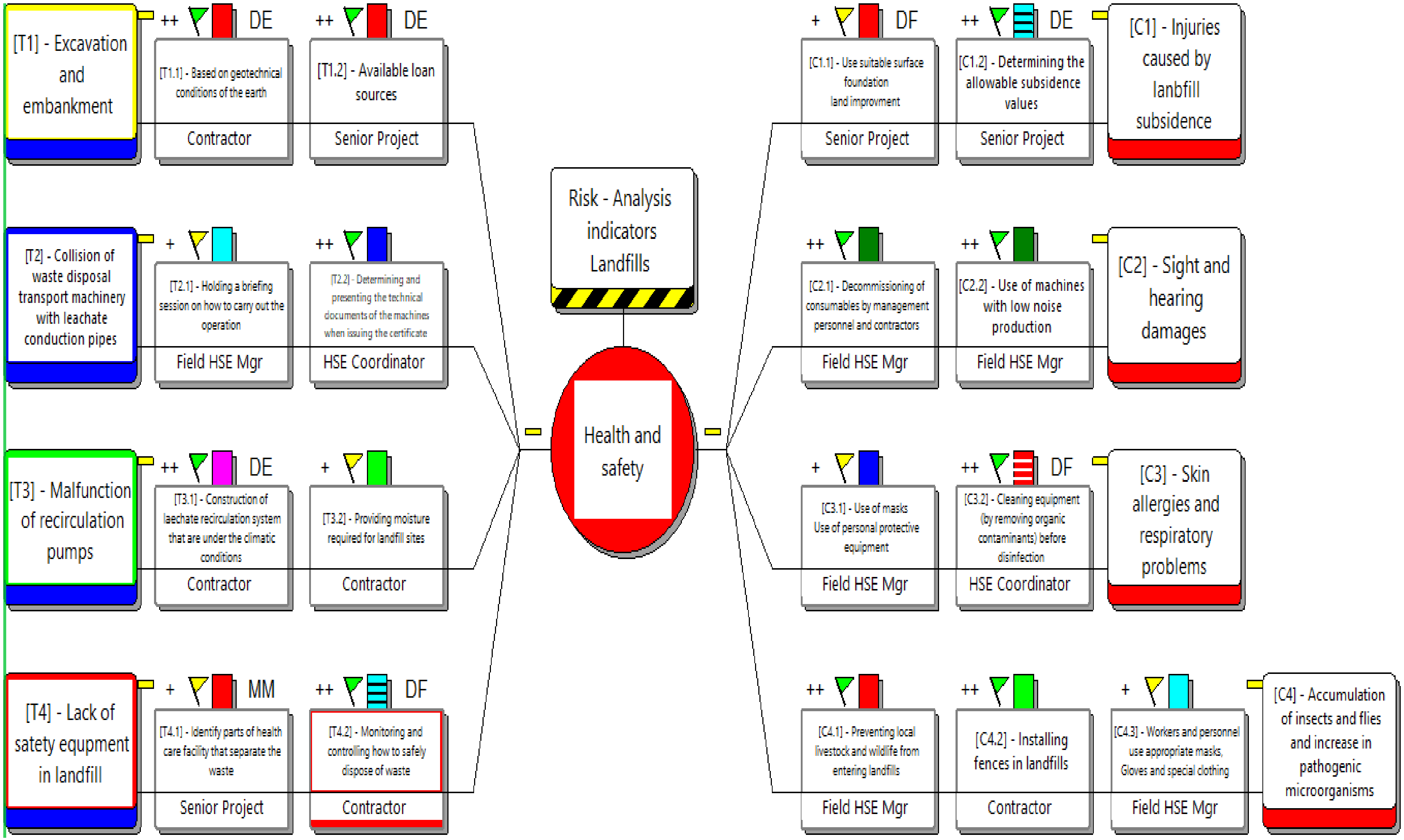

Figure 4. Health and safety risks of municipal solid waste in the bow tie model.

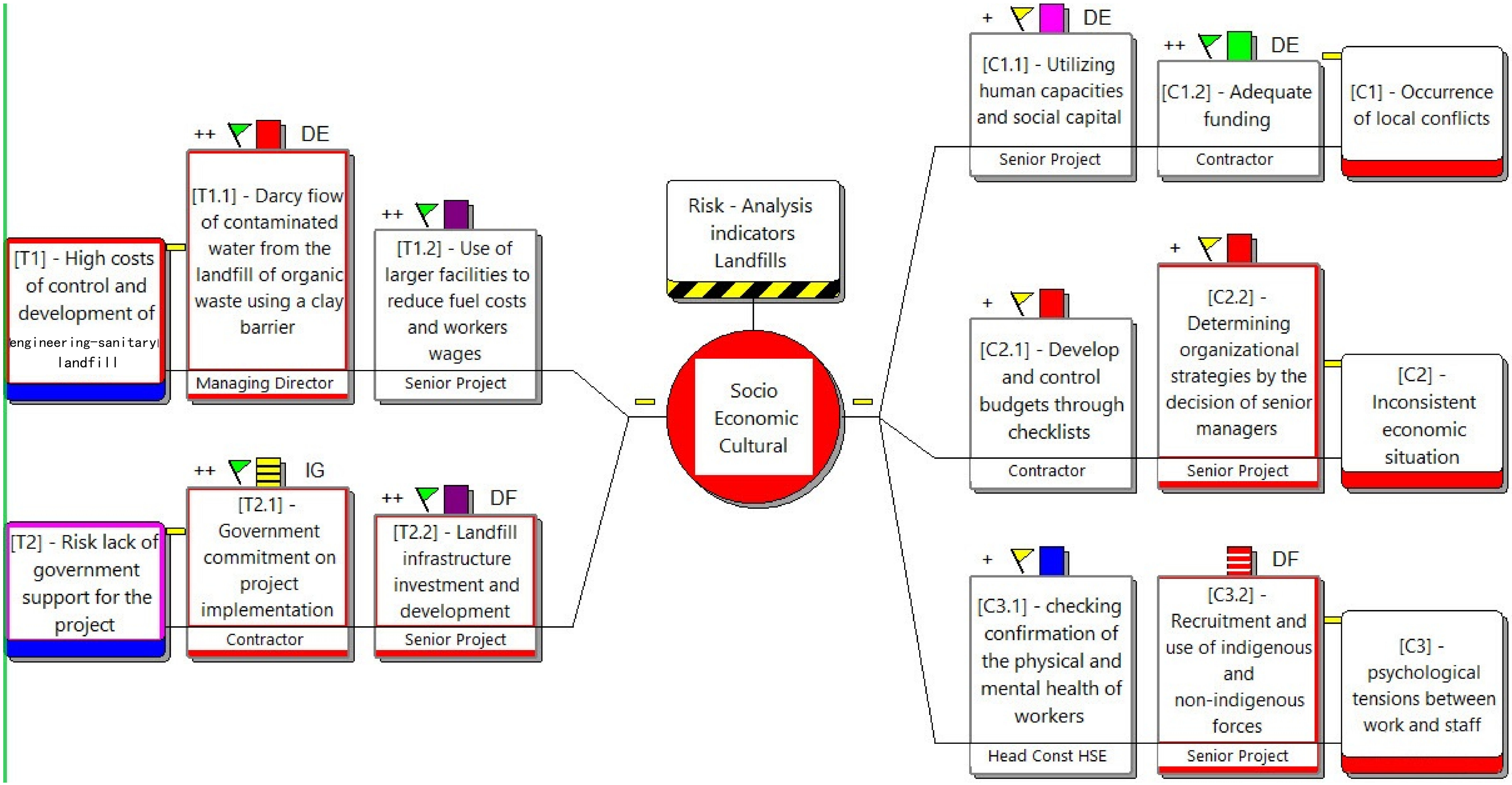

Figure 5. Socio-economic and cultural risks of municipal solid waste in the bow tie model.

Environmental pollution in all cases is not considered an environmental risk in the landfill but depends on the extent of the pollutants, which are considered a risk. Risk management involves performing processes to identify and evaluate the risks that the project faces in the construction and operation phases. Heavy elements are among the most persistent and toxic pollutants, and their monitoring and investigation are of particular importance. In addition, heavy elements have the ability to bio-enlarge and bio-magnify in the food chain [46–48]. The reactions of heavy metals in leachate depend on the pH of the receiving medium. Behaviors of heavy metals in wastes are cationic, which causes them to be soluble or absorb the controllers in the environment. Increasing the dissolution of residual mineral phases and decreasing the adsorption of dissolved cationic ions increases the concentration of heavy metals in soluble acidic conditions.

As the pH decreases, the acidity increases. The burial site has accelerated the destruction of habitats in this area. One of the solutions presented in Bowtie software is to use hydrological assessment. This method is designed and implemented to achieve a better design for waste landfill leachate treatment. It also has high efficiency for proper operation [49]. The results of the prioritization of the environmental risks of the operation phase show that the improper disruption of the leachate recirculation system has the highest priority [50]. In risk assessment studies, the main objectives include finding environmental, health and safety, socio-economic, and cultural drivers for managing the optimal use of resources and changing land cover, and their understanding of how they affect the structure and performance of terrestrial systems.

4. Discussion

Identifying risks and prioritizing them is the most important and perhaps the most difficult part of the risk management process because if risks cannot be identified and prioritized well, the next steps of risk management will be ineffective and an appropriate response cannot be given.

Failure mode and effects analysis (FMEA) is one of the most important techniques for identifying and analyzing risks that can help us to improve issues and problems. This technique, which is a qualitative analysis, examines the system or subsystems to identify possible defects in all its components and tries to evaluate the effects of possible defects on other parts of the system. The FMEA method has shortcomings, which include: considering the same weight for risk parameters, because in examining risks and prioritizing them, we are faced with multiple criteria and interrelationships between them. In the FMEA model, in addition to not paying attention to multiple criteria, it does not consider the interaction of factors. These problems do not exist in the proposed consolidated model. FANP and FTOPSIS weighting and prioritization are not the same. Criteria have been prioritized according to interactive relationships. The definitive results of FANP and FTOPSIS were entered into the Bow tie software.

Today, environmental changes in landfills pose a serious threat to global communities from global to local levels. Meanwhile, the vulnerability of local communities and their resilience to the crisis has become a sustainable principle among ecological and social systems. In recent years, changes in natural ecosystems and industrial waste have led to biological death and ecological imbalance in the region.

Bow tie analysis is a powerful tool for predicting the safety and risk of urban landfills. The model can well combine two techniques FTA (Fault Tree Analysis) and ETA (Event Tree Analysis)) to quantitatively assess the risk of landfills. The results show that the bow tie model in quantitative analysis is still difficult to estimate the probability of accurate occurrence of critical events as well as outcome events. Because the possibility of incoming events is often lost and with the help of the network analysis process and TOPSIS model, more definite results can be achieved. Continuous improvement of environmental risk assessment and management frameworks is necessary not only to review standards but also to improve the methods used for risk assessment, mainly based on scientific risk assessment management plans based on preventive approaches. These policies should include further consideration of the future environment and its social impact. Factors related to financial and managerial sustainability must be considered. Landfills require the processing of a variety of location data. Municipal waste sites are a vital issue in urban planning due to their important role in the economy, ecology, and environmental health of the region. Landfill assessment is very complex and requires a variety of social and environmental experts [51,52]. As it was determined from the results of this research in the exploitation phase, due to the high level of underground water, the high amount of rainfall in the area and the high organic and chemical compounds in the leachate, the best option for protection from underground water is the option of geosynthetic cover. The study by Rotaru et al. [53] on groundwater pollution caused by waste storage and collection centers showed that the risk of groundwater pollution is the most dangerous among geological risks. In this research, it was stated that the parameters of the target range, such as soil type, depth of underground water, the proximity of surface water sources, and the concentration of elements and heavy metals in leachate precipitation, play an important role in the risk of water pollution. The Geosynthetic cover was suggested as the preferred option for the landfill under study. The use of clay on the floor of the landfill prevents leachate from leaking into the underlying layers and soil and groundwater pollution. If the underground water level is high, it will have the greatest effect [54]. The results of this research are consistent with the results of research [53–55]. The results of the work of Kharat and et al. colleagues showed a high agreement between the model with the field visits [19]. The concentration of heavy metals may be high compared to the standard concentration in underground water. The presence of heavy metals is due to the high amount of rainfall, the high depth of the waste landfill, the high volume and type of hospital and hazardous waste, and the distance from the waste landfill to the leachate pond. Based on the current study, it can be suggested that reducing the volume of waste is the separation of household waste from hazardous waste before entering the landfill. Atmospheric precipitation in the form of rain in the waste management system has a significant effect on leachate production and pollution. Waste management processes are one-way related to time, which means that most post-implementation management decisions can hardly be reversed. Therefore, their effect is not neutralized. In the multi-criteria decision-making methods that have received attention in recent decades, several criteria are used instead of using one criterion for measuring optimality [56]. In the systematic risk assessment approach sustainable community, natural factors, health and safety, social, economic, cultural, balanced distribution, and socio-economic activities are carried out by the capabilities and natural and human resources. According to the ranking, the most important risks obtained in the construction phase are respectively related to the environment and health-safety, economic, social, and cultural risks.

ANP is an advanced generalization of AHP. ANP considers the relationship between different hierarchical criteria and the complex interrelationships between decision-making levels and features. In addition, clearly in the two-by-two comparison process, the inability of ANP, as AHP, to deal with subjectivism, has been replaced by a fuzzy method such as ANP (FANP) with an uncertainty model in the conditions of inaccuracy and ambiguity in the judgment process [57].

Based on the flexibility of fuzzy and ANP methods, it is possible to use the Fuzzy-MCDA framework and their combination in complex decision-making problems, such as landfill risk assessment. On the other hand, the use of linguistic variables makes the process evaluation more realistic because the process evaluation is not definite and contains fuzzy behavior in its body. As a result, the use of fuzzy ANP weighting makes the investigation process more realistic and reliable. There are different criteria for choosing the landfill risk analysis method, and the importance of the criteria has a great difference. On the other hand, incident analysis methods have their strengths and weaknesses.

Is the difference between this research and AbdolkhaniNezhad et al. [31] the fuzzy nature of the methods presented? The results of this research show that fuzzy logic is considered a powerful tool for solving problems that are difficult to understand. In fuzzy logic, uncertainties can be well displayed. In systems, if the degree of complexity and uncertainty is low, it is modelled with mathematical equations with high accuracy. In landfills, due to the complexity issue, lack of sufficient data, available and ambiguous data, and uncertainty in the fuzzy logic system, we, therefore, used FANP and FTOPSIS methods. Sometimes the thoughts of experts are associated with uncertainty, which affects decision-making. In many cases, all or part of the data of a multi-criteria decision problem in landfills can be fuzzy. In this case, if the risk assessment is modelled and formulated using definitive data, a correct and accurate answer will not be obtained. As a result, the preferred option will not be selected. In such imprecise decisions, the goal of the research cannot be reached. In the decision-making models in assessing the risk of landfills, whose data are random or fuzzy, despite the calculations and operations, they are dealt with more rationally and accurately, and uncertainty is considered in the decision-making model.

Fuzzy logic along with bow tie can be used as an efficient tool in risk assessment. In the end, it is important to mention that the occurrence of some risks at low levels of vulnerability and risk does not indicate the ideal situation in landfills and only determines the position and ranking of the mentioned risks concerning other risks. The special conditions of Gilan province in terms of climate and geography, the lack of proper and sanitary burial of waste in the current places, and the non-compliance of the conditions of the current places with the standards accepted by the Environmental Protection Organization, and subsequently causing pollution and disturbance to the residents of neighboring areas and harmful effects in the short and long term in the cities of this province, it is necessary to choose new places by considering the relevant standards. Most of the current landfills in these cities have left an unbalanced landscape for a long time, and many problems have occurred due to the lack of proper equipment and failure to consider environmental, health-safety, and social economic criteria. On this basis, in this research, FTOPSIS methods were used as a practical method that compares the options according to their data values in each criterion and the weight of the criteria, to assess the risk in landfills. This model has valid explanations (it explains well the logic of people's choices), calculating the numerical value for the best and worst options, having a simple calculation process and the multifaceted performance of the options in the criteria (at least in two aspects). It is very interesting [58].

Heavy metals are unwanted pollutants that directly and indirectly enter the biological environment and ecological streams through the discharge of industrial effluents, decomposition of waste, and discharge of factories. Heavy metals are stable pollutants that, unlike organic compounds, do not decompose through chemical or biological processes in nature and have many destructive effects on plant and animal environments [59–62].

According to the findings of the research, the increase in penetration of volatile and semi-volatile organic compounds into the environment and the increase in heavy metals, which obtained a high rank, increase the need to pay attention to the increase in heavy metals in landfills. The use of different weighting and prioritization methods in location studies is a common and completely practical matter, in the meantime, the use of each of the methods can have advantages or limitations. For example, AHP and ANP methods are not applicable when the number of options is large. Regarding the characteristics of multi-criteria ranking methods such as TOPSIS, ARAS VIKOR, ASPAS, and COPRAS in risk assessment studies, it is also possible to mention the ranking based on the nature of positive and negative criteria in the TOPSIS and COPRAS methods or the ranking [31,63]. On the other hand, experts (respondents) have an important role in determining the weight of the criteria and they are given the possibility to choose the considered priorities [64] In general, it can be acknowledged that the method of combining FTOPSIS-FANP methods, as two objective methods of rating criteria, is among the methods that provide more accurate results compared to the mentioned methods with a smaller number of comparisons. The important result of the stability of heavy metals is the large biological extent in the food chain. So, as a result of this process, their amount in the food chain can increase several times the amount found in water or air. The results show that operating costs are an important factor in landfilling. Strategies for reducing consumption are important in sustainable management. Economic development is compatible with sustainable and economic principles. Investment activities to protect the natural environment are necessary to change the conditions. The results of this research are consistent with researchers [28,41,65]. These issues and problems are very influential in the evaluation of socioeconomic and cultural factors. This causes disturbances in the municipal landfill systems. Economic issues are important components in the evaluation. This requires further investigation into new insights and policies for risk assessment of waste landfills in the long-term management and implementation plans and technological applications to establish favorable economic conditions.

5. Conclusions

In this paper, the integrated method of the fuzzy network analysis process and fuzzy TOPSIS method were used to evaluate and prioritize landfills in the construction and operation stage based on risk factors. The proposed fuzzy integrated method solves the inability to measure uncertainty. In addition to the simplicity and ease of understanding of the proposed method, other important advantages are support for network analysis structure to describe complex systems, consideration of the importance and weight of criteria in the risk assessment process and selection of waste disposal projects, and support for the fuzzy concept (ambiguity and uncertainty). With the ability to rank (help to make better decisions), the model provided with Bowtie software helps people in charge to make more precise decisions. A combination of fuzzy ANP, fuzzy TOPSIS and bow tie models provide different information at different levels of decision-making. The combination of these three models is very effective in evaluating landfills. The bow tie model is a great help in monitoring environmental changes. The bow tie model is very valuable in providing risk management and an ecosystem.

In this research, a combined approach of fuzzy ANP and fuzzy TOPSIS was presented to formulate and solve the problems in the risks of operation and construction phases in bow tie. Solving such issues is traditionally done by using experts' opinions, while in this article with the will of a systematic procedure an attempt was made to make bow tie efficient as a vital tool for designing and improving the process in the construction and operation phase. The intentional methodology of research is this important by considering the interrelationships of the local people's demands, technical requirements and internal dependence. On the other hand, considering other design goals, such as resource limitations, and technological feasibility, the degree of development of a need has been followed as systemic limitations governing the determination of effective factors in landfills. Combining fuzzy logic with ANP and TOPSIS to assess landfill risks was a new point that was paid attention to in this research. The use of fuzzy logic has played a significant role in reducing the ambiguity in the linguistic words used to perform the required comparisons and their ranking. The use of fuzzy logic in risk assessment in this research has created two basic benefits: 1- Since human judgments are fuzzy, the use of fuzzy numbers is preferable to definite numbers. 2- The use of fuzzy numbers has allowed team members and experts to have more freedom of action in the tools of their preferences. To actualize the potential of the bow tie model, the interaction of different approaches should be used. By combining fuzzy ANP, fuzzy TOPSIS and bow tie, this paper has created a more feasible, flexible and compatible solution than ANP and TOPSIS. In this research, as observed, to reduce the ambiguity in linguistic data, fuzzy logic was used in the form of the analysis indicators of the health-safety method to perform ANP, TOPSIS and bow tie calculations. It is suggested that in future research, using methods different from fuzzy and comparing the final results obtained from various methods, the most appropriate fuzzy model to reduce the inherent ambiguity in landfills should be presented. Considering the influence of several factors on the appropriateness of an area to introduce as a landfill site, it is necessary to use a method that can include all parameters in decision-making and also the ability to use expert opinions. On this basis, the combination of FTOPSIS-FANP methods and Bowtie software was used as a powerful analytical tool for risk assessment and prioritization, ranking and risk management. The strength of this methodology is that the assessment criteria set in landfills by decision-makers are generally field-based and it is recommended to integrate different methods and tools and use new proprietary methods for risk assessment in landfills.

The risk of landfill leachate production and the contamination of water and soil resources with toxic substances is that the toxins that enter water and soil resources are stored for many years and affect the processes of water and soil resources, such as agricultural, agrophysical, biological, microbiological, and nutrient properties, and affect and finally enter our bodies through food. The existence of uncertainties has turned the surrounding environment into an environment full of crises. Paying attention to the uncertain nature of waste landfill projects and the need to use resources optimally reveals the undeniable importance of project risk management.

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