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ENVIRONMENTAL RISK ASSESSMENT OF RAILWAYS USING DELPHI TECHNIQUE AND FUZZY TOPSIS - CASE STUDY: ISFAHAN-SHIRAZ RAILWAY IN IRAN

S. Ghorbani [1] B. Hatam Abadi [2] A. Zarekar [1] F. Jalaeifar [3]

1. Department of Environmental Planning and Management, University of Tehran, Tehran, Iran
sa_gh64@yahoo.com, azadeh_zarekar@ut.ac.ir
2. Department of Environment Management, Islamic Azad University, Tehran, Iran, bahareh_hatamabadi@yahoo.com
3. Department of Water Resources Environmental Engineering, University of Tehran, Tehran, Iran, fjalaeifar@ut.ac.ir

Abstract- With escalating population growth and subsequent transportation demand, the need for railways is increasing. Although transportation infrastructures have recently been by number improved, the quality has not met health and safety standards, which leads to social resistance against them. A strategy for enhancing the acceptance of such projects among both local people and governmental authorities is to guarantee the minimization of consequent adverse impacts. To achieve this goal, one approach can be applying precautionary measures, identified through risk assessment before implementation. This research aims at identification of risk factors and their environmental risks along the Isfahan-Shiraz railway. To do so, various factors were selected and utilized after examining different methods for Railroads risk assessment and integrating them to cover all objectives. Initially, study zone was divided into 4 zones based on specific environmental and socio-economic criteria. After reviewing related scientific literature, following techniques were then applied: Questionnaire for identifying risk factors, Delphi to sieve the risk factors, and finally FTOPSIS in order to prioritize the zones in accordance with environmental risks along the path. Results show zone 3 has the highest environmental risk followed by zones 4, 2 and 1. It was deducted that the highest environmental risks were in zones 3 and 1 because of disturbances for settlers in the vicinity of the railroad via noise pollution and also in zones 2 and 4 due to interference and misbalance in habitats again via noise pollution. According to the results, it seems mentioned methods enable managers to present managerial plans and prioritize controlling and mitigation measures.

Keywords: Railway, Environmental Risk, Delphi, Risk Assessment, Fuzzy, TOPSIS.

I. INTRODUCTION

Principal risks in the railway industry appear to be to people and property as a result of collision, derailment and fire. Recent structured hazard identification work within the industry has confirmed the high-risk scenarios of these types of accidents [1]. The figures of accidents and incidents include not only workers, but also a significant number of people not employed in the industry, including children and members of the public. This shows the dangerous nature of the railway industry and demonstrates the need for increased awareness and better safety management [2, 3]. Many accidents and incidents occurred in the railway depots over the years, demanding improvement in safety management. To assess how this can be effectively achieved is fundamental. Therefore, risk analysis plays a central role in the railway safety and health management framework.

The most common hazards in the railway depots identified by the railway industry over the years provide very useful information for risk analysis, for example, derailment hazards, collision hazards, fire hazards, train strike hazards, slip/trip hazards, platform train interface hazards, health hazards such as arc eye and toxic substance, and even environmental hazards [2, 4-7]. Therefore, railway safety analysts need to develop and employ safety assessment approaches for their safety case preparation. Additionally, the accident statistics also present not only human tragedy but also substantial economic cost. These cost can be incurred through, for example, damage to equipment and plants, damage to work already completed, delay in completion, increased insurance premiums, legal costs, fines, compensation, and even loss of reputation of the companies.

Risk assessment is a process to determine the risk magnitude to assist with decision-making. Many of the currently used railway risk assessment techniques are comparatively mature tools. The results of using these tools highly rely on the availability and accuracy of the risk data [5, 8, 9]. It may be extremely difficult to conduct probabilistic risk assessment to assess the occurrence likelihood of hazards and the magnitudes of their possible consequences because of the uncertainty with risk data. It is essential to develop new risk analysis methods to identify major hazard and assess associated risks in an acceptable way in various environments where such mature tools cannot be effectively applied [2].

Fuzzy logic provides a useful tool for modeling risks and other risk parameters for risk analysis [10-13]. Since the contribution of each hazardous event to the safety of a railway is different, the weight of the contribution of each hazardous event should be taken into consideration in order to represent its relative contribution to the risk level of the railway.

Besides, TOPSIS technique needs to be incorporated into the risk model to use its advantage in determining the relative importance of the risk factors so that risk assessment can be progressed. Current study aims at identification of risk factors by Delphi technique and their environmental risks using FTOPSIS method along the Isfahan-Shiraz railway in Iran.

II. MATERIALS AND METHODS

A. Study Area

Isfahan-Shiraz railway with the length of 506 km. and also with 125 km. side roads passes through Shah Reza, Sa'adat Shahr, Marvdasht and Eghlid and reaches Shiraz at the end of the road. In northern parts, it goes through mountains in south Isfahan, after crossing plateaus and hills in central regions, railway passes in the last 50 km through mountainous and difficult places.

It should be noted that this railway goes through Bamou National Park from 89 till 96 kilometers from starting point. From last decades, this National Park has been affected by human activities due to its special geographical position and also due to being in the vicinity of settlements, consequently there are various incompatible land uses in this area, such as highways. Figure 1 shows the Isfahan-Shiraz railways and the cities it goes through.

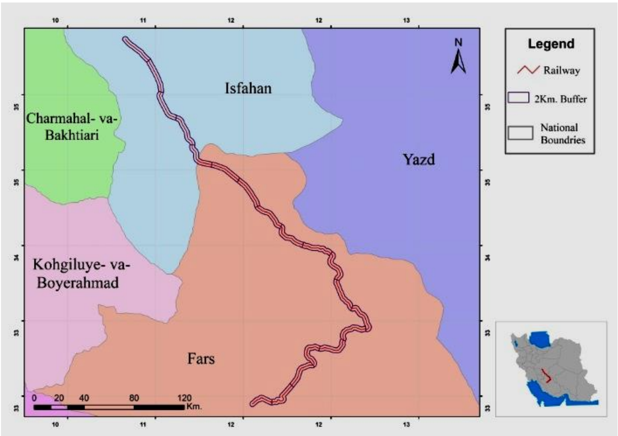


Figure 1. Study area

B. Methods

According to Figure 2, in stage 1 was initially risk factors identified and classified. In stage 2 the most important risk factors were selected through Delphi technique. Then in stage 3 environmental risks were recognized on the basis of selected risk factors. Finally, environmental risks were analyzed using Fuzzy TOPSIS method. Besides, this method was applied to prioritize study zone along the route regarding environmental risks.

B.1. Determination of the Most Important Risk Resources

In order to examine environmental risks thoroughly, the most crucial risk factors are to be selected from all identified ones. To do so, Delphi technique was applied in this study. Initially, a questionnaire was filled by six experts and after revising the deficiencies, the questionnaire was utilized in second stage, i.e. using quantitative methods. According to reviewed literature, usually 2 to 10 stages are reported [13], but here according to expert's ideas, 2 stages were anticipated. In sake of being precise, Cochran test was used to determine the number of experts needed to distribute the questionnaires among them. To integrate the results and prioritizing the final criteria, central mean index was used. Finally, to analyze the information acquired from questionnaires and come to a conclusion, geometric mean was calculated in SPSS software, following criteria with the highest importance were recognized.

B.2. Analysis of Environmental Risks

Multi Criteria Decision Making models are those utilized in complicated decision-makings, in them multiple criteria are used instead of single criterion [14, 15]. While assessing environmental risk of railways, researcher confronts numerous factors and consequent risks, hence applying these methods necessitates. Among various MCDM methods, TOPSIS has been elected on the basis of its flexibility during decision making. In order to incorporate uncertainties, Fuzzy Logic was also merged into TOPSIS method. The procedures for fuzzy TOPSIS analysis in this study are explained briefly as below [16].

Step 1: Establish the membership function of fuzzy data, and calculate the fuzzy weight of each criterion. This is done by setting up an interval value between zero and one and expressed by a triangular fuzzy number. The fuzzy weight for criterion j is defined as $\tilde{W}_j = (w_{j1}, w_{j2}, w_{j3})$.

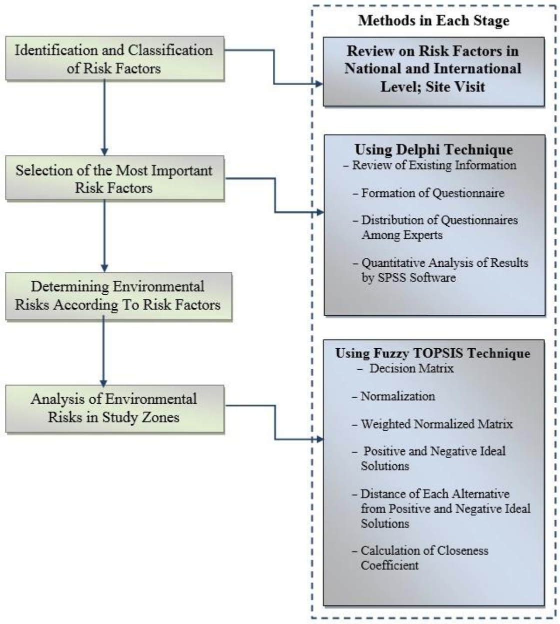


Figure 2. Schematic flowchart of methodology

Step 2: Establish the decision matrix $\tilde{D}$.

Step 3: Calculate the normalized decision matrix $\tilde{R}$ based on the type of value in decision matrix $\tilde{D}$. If the evaluation value $\tilde{x}_{\bar{y}} = (n_{1\bar{y}}, n_{2\bar{y}}, n_{3\bar{y}})$ is a fuzzy number, then the evaluation value $\tilde{r}_{\bar{y}}$ after normalization can be defined as follows:

$$\tilde{r}_{ij} = \left(\frac{n_{1ij}}{n_{3j}^*}, \frac{n_{2ij}}{n_{3j}^*}, \frac{n_{3ij}}{n_{3j}^*}\right), \qquad n_{3j}^* = \max_i n_{3ij} \tag{1}$$

$$\tilde{r}_{ij} = \left(\frac{n_{1j}^-}{n_{1ij}}, \frac{n_{1j}^-}{n_{1ij}}, \frac{n_{1j}^-}{n_{1ij}}\right), \qquad n_{1j}^- = \min_i n_{1ij} \tag{2}$$

where, j is the risk factor, n_{3j}^* is the largest and n_{1j}^- is the smallest ending value of the fuzzy number in all alternatives.

Step 4: Calculate weighted normalized decision matrix $\tilde{v}$. In Equation (3) $\tilde{v}_{ij}$ is the element evaluation value after normalizing decision matrix by including weight value.

$$\tilde{v}_{ij} = \tilde{r}_{ij} \times \tilde{W}_j = \left(\frac{n_{1ij}}{n_{3j}^*}.w_{j1}, \frac{n_{2ij}}{n_{3j}^*}.w_{j2}, \frac{n_{3ij}}{n_{3j}^*}.w_{j3}\right) \tag{3}$$

Step 5: Calculate the fuzzy positive ideal solution $\tilde{A}^*$ and the fuzzy negative ideal solution $\tilde{A}^-$.

$$\tilde{A}^+ = (\tilde{v}_1^*, \tilde{v}_2^*, \ldots \tilde{v}_n^*), \quad \tilde{v}_j^* = \max_i \tilde{v}_{ij}, \qquad \forall j \tag{4}$$

$$\tilde{A}^- = (\tilde{v}_1^-, \tilde{v}_2^-, \ldots \tilde{v}_n^-), \quad \tilde{v}_j^- = \min_i \tilde{v}_{ij}, \qquad \forall j \tag{5}$$

Step 6: Calculate the distance between each alternative and the fuzzy positive ideal solution $\tilde{A}^*$ and the distance between each alternative and the fuzzy negative ideal solution $\tilde{A}^-$. When given two triangular fuzzy numbers $\tilde{m} = (m_1, m_2, m_3)$ and $\tilde{n} = (n_1, n_2, n_3)$, the distance between the two can be calculated by the vertex method, which is defined as follows [19]:

$$d(\tilde{m}, \tilde{n}) = \sqrt{1/3[(m_1 - n_1)^2 + (m_2 - n_2)^2 + (m_3 - n_3)^2]} \tag{6}$$

Thus, the distance between $\tilde{v}_{ij}$ and the positive ideal solution is: $D_{ij}^* = d(\tilde{v}_{ij}, \tilde{v}_j^*), \forall i,j$ and, the distance between $\tilde{v}_{ij}$ and negative ideal solution is $D_{ij}^* = d(\tilde{v}_{ij}, \tilde{v}_j^-), \forall i,j$. On the other hand, the distance between the alternative i and $\tilde{A}^*$ is $S_i^* = \sum_{j=1}^{n} D_{ij}^*$ and, the distance between the alternative i and $\tilde{A}^-$ is $S_i^- = \sum_{j=1}^{n} D_{ij}^-$.

Step 7: Calculate the relative closeness to fuzzy positive ideal solution for each alternative. C_i^* is relative closeness for alternative A_i to fuzzy positive ideal solution $\tilde{A}^*$.

$$C_i^* = \frac{S_i^-}{S_i^- + S_i^*} \tag{7}$$

The closer C_i^* is to 1, the closer alternative i is to the positive ideal solution. Thus, the alternative has a higher/ superior ranking [18, 19].

C. Why Fuzzy TOPSIS and Delphi?

Multi Criteria Decision Making models are used for complicated decision-makings. These models are classified into two groups, compensatory (e.g. AHP, TOPSIS, and ELECTRE etc.) and non-compensatory (e.g. Maxi mean, Lexicography etc.) [3]. As there is interrelations between various factors in prioritizing risk factors, non-compensatory methods are not suitable [20]. Uncertainty in human thinking and its influence on decision making, ambiguity in classifying the options, restrictions in linguistic variables such as "Low", "Moderate" and "High" and also difficulty in determining the indices are the reasons of applying multi criteria methods under the Fuzzy environment. One of these methods is Fuzzy TOPSIS [21].

As in other methods such as classic TOPSIS, FMEA, ELECTRE, and others, scoring is based on a unique value, the precision of Fuzzy TOPSIS method is far higher. In comparison to AHP, which needs pairwise comparison, Fuzzy TOPSIS needs less data and reveals the results more quickly. For selecting the utmost important risk factors, in comparison to other methods such as brainstorming, checklists, and cause-effect diagrams, Delphi technique has more advantages. It is used when there are restrictions for data gathering and statistical and mathematical modeling [22]. Besides, as the information is obtained from technical experts, there is more precision and less disagreement in results [23].

III. RESULTS

A. Results of Using Delphi Technique

While examining risk factors regarding Isfahan-Shiraz railway, 56 factors were totally identified and classified into five categories. Figure 3 shows risk-causing factors in study area. After distribution and collection of questionnaires and calculating their reliability and validity, the most important risk factors among 56 factors were selected. In addition, risk factors with importance degree of higher than 2.6, were selected as most important (value 2.6 is geometric mean of Likert scale). Tables 1-5 show results of sieving risk factors in five categories, namely pollutants, technical, environmental, human, and other.

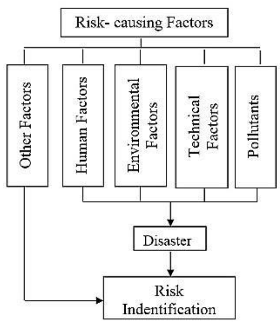


Figure 3. Risk-causing factors in Isfahan-Shiraz railway

Table 1. The result of sieving technical risk factors

Risk Factors (Technical)	Importance Degree	Cronbach's Alpha Coefficient
Drop rail link	3.0079	0.623
arc radius in railways	3.918	
Infrastructure	3.4324	
Not maintaining equipment according to minimum standards	3.1010	
incorrect switch setting	3.3801	
Imperfection in trains equipment	3.6615	
Train's velocity	3.6959	

Table 2. The result of sieving environmental risk factors

Risk Factors (Environmental)	Importance Degree	Cronbach's Alpha Coefficient
Floodway	3.5617	0.943
Earthquake incidence	3.6001	
Landslide &landfall	3.1636	
Land subsidence due to decline in groundwater level	2.8405	
	2.7631	
Passing through protected area	3.6511	

Table 3. The result of sieving human risk factors

Risk Factors (Human)	Importance Degree	Cronbach's Alpha Coefficient
Operator's response (mistakes in analysis, mistakes in decision making etc.)	3.1756	0.684
Preconditions for operator's response	2.8296	
Staffs professional skills	3.2178	

Table 4. The result of sieving other risk factors (pollutant along route)

Risk Factors (Pollutants along railway)	Importance Degree	Cronbach's Alpha Coefficient
Sound and vibration pollution	3.1511	0.723
Hazardous chemical material oozing due to transportation	3.5221	
Air pollutants: So_x, No_x, Co	2.7254	

Table 5. The result of sieving other risk factors

Risk Factors (Other)	Importance Degree	Cronbach's Alpha Coefficient
Railway-road intersection	3.0722	0.857
Illegal entrance into railway`s buffer	2.6773	
Combustion in stations or along the railway	3.162	

B. Identification of Environmental Risks in Study Area

Risks in the study area were identified according to the existing data of "Project" and "Environmental characteristics of the study area and also on the basis of comparing with similar projects. These risks comprise reduction of habitat's security due to noise of train, reduction of adjacent settler's security due to noise of train (including residential regions and workers in the stations), reduction of air quality, and its impact on biological environment, reduction of water and soil quality, increasing susceptibility of ecosystems. Figure 4 illustrates orientation of the railway in study area and its four zones. The relation between risk factors and environmental risks is presented in Table 6.

As far as the project is of length type, to examine the environmental risks along Isfahan-Shiraz railway thoroughly, the study area was divided into 4 zones. These zones were identified according to various criteria, on one hand, they must cover all environmental factors affecting risk, and they must involve on the other hand environmental factors that are influenced by risk. Hence, three major topographic regions were considered including mountainous, plain and hills, although it is impossible to separate these regions completely and usually they were like mountainous-plain or plain-hills. Besides, ecological sensitivity and biodiversity are not evenly distributed over the study area, consequently the density of some species is higher in some parts. Basiran protected area and Bamou national park are two examples of this assumption.

Table 6. Relation between risk factors and environmental risks

No.	Risk Factors Classification	Risk Factors	Environmental Risks	Indicator
1	Human and technical factors	Noise pollution	Misbalance and distribution in habitats	X_1
			Disturbing settlers in vicinity of railway	X_2
			Vocational disease of workers	X_3
2	Human and technical factors	High speed of train	Collision of animals with train	X_4
		Train crosses protected areas		
3	Human and technical factors	High speed of train	Collision with passengers	X_5
		Illegal entrance into railway buffer		
4	Railway crosses protected areas		Disturbing animals reproduction and migration	X_6
5	Human, technical and other factors	Pollutant emission along the train path	Affecting fauna and flora	X_7
			Affecting surrounding land use	X_8
		Fire (in path or in station)	Affecting workers and passengers	X_9
6	Human, technical and other factors	Hazardous material deposition during (un)loading	Reduction of water quality	X_{10}
		Hazardous material deposition due to incidents or derailment	Reduction of soil quality	X_{11}
		Chemical material deposition during repairs		

Pursuant to this criterion, habitat and biodiversity versatility, the study region makes up four zones. Moreover, population distribution does not follow an even pattern, so on the basis of soil fertility, access to water resources and also climatic and topographic conditions, population constitutes 4 domains: low, moderate, high and very high populations. Putting all these criteria together, we come up with the final map if study zones (Figure 4).

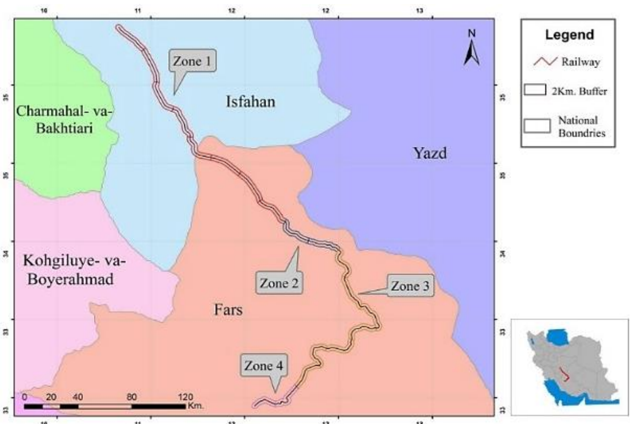


Figure 4. Zoning of study area

C. Application of Fuzzy TOPSIS Technique

In this stage, study zones of Isfahan-Shiraz railway will be prioritized according to probability and magnitude of risk using Fuzzy TOPSIS technique.

After decision matrix was completed by eight experts, their opinions were summed and finally weights of the criteria were calculated. Tables 7-14 show the results of applying FTOPSIS method.

Table 7. Selecting the highest Fuzzy number in each row

	X_1	X_2	X_3	X_4	X_5	
$C_j^*=\max C_{ij}$	(9,9,9)	(9,9,9)	(10,10,10)	(9,9,9)	(10,10,10)	
	X_6	X_7	X_8	X_9	X_{10}	X_{11}
$C_j^*=\max C_{ij}$	(10,10,10)	(7,7,7)	(7,7,7)	(7,7,7)	(7,7,7)	(7,7,7)

Table 8. Decision matrix of FTOPSIS method

	Zone 1	Zone 2	Zone 3	Zone 4
X_1	(5,1.5,0)	(1,3.75,7)	(1,3.75,7)	(3,6,9)
X_2	(7,3.25,0)	(0,3,7)	(3,6.25,9)	(0,1.12,5)
X_3	(10,7.25,3)	(3,5.5,9)	(3,6.25,9)	(1,4,7)
X_4	(0,3,7)	(1,3.75,7)	(1,4.25,7)	(3,6,9)
X_5	(9,5.75,3)	(1,5.25,9)	(3,7.75,10)	(3,7.75,10)
X_6	(0,3,7)	(3,7,10)	(1,4.75,9)	(3,7.25,10)
X_7	(0,1.5,5)	(0,2,5)	(1,4,7)	(0,2.75,5)
X_8	(0,2.25,5)	(0,2,5)	(1,4,7)	(0,3.25,7)
X_9	(0,3.5,7)	(0,2.5,7)	(0,2.5,5)	(0,2.25,7)
X_{10}	(0,3,7)	(0,1.75,7)	(0,2.25,5)	(0,1.75,5)
X_{11}	(1,4.25,7)	(1,3.75,7)	(0,3.75,7)	(1,4,7)

Table 9. Normalized matrix by FTOPSIS method

	Zone 1	Zone 2	Zone 3	Zone 4
X_1	(0,0.16,0.55)	(0.11,0.416,0.77)	(0.11,0.416,0.77)	(0.33,0.66,1)
X_2	(0,0.361,0.77)	(0,0.33,0.77)	(0.33,0.7,1)	(0,0.124,0.55)
X_3	(0.3,0.725,1)	(0.3,0.55,0.9)	(0.3,0.625,0.9)	(0.1,0.4,0.7)
X_4	(0,0.33,0.77)	(0.11,0.416,0.77)	(0.11,0.472,0.77)	(0.23,0.66,1)
X_5	(0.3,0.575,0.9)	(0.9,0.1,0.525)	(0.3,0.775,1)	(0.3,0.775,1)
X_6	(0.0.3.0.7)	(0.3,0.7,1)	(0.1,0.475,0.9)	(0.3,0.725,1)
X_7	(0,0.214,0.714)	(0,0.285,0.714)	(0.143,0.571,1)	(0.714,0,0.393)
X_8	(0,0.321,0.714)	(0,0.285,0.714)	(0.142,0.571,1)	(0,0.464,1)
X_9	(0.,0.5,1)	(0,0.357,1)	(0,0.375,0.714)	(0,0.321,1)
X_{10}	(0,0.43,1)	(0,0.25,1)	(0,0.321,0.714)	(0,0.25,0.714)
X_{11}	(0.143,0.6,1)	(0.143,0.535,1)	(0,0.535,1)	(0.143,0.571,1)

Table 10. Weighted normalized matrix in FTOPSIS method

Criteria (Risk)	Weights	Criteria (Risk)	Weights
X_1	(0.5,0.8,1)	X_7	(0,0.12,0.5)
X_2	(0.7,0.95,1)	X_8	(0,0.05,0.3)
X_3	(0.5,0.82,1)	X_9	(0,0.13,0.5)
X_4	(0.5,0.71,1)	X_{10}	(0,0.35,0.7)
X_5	(0.5,0.8,1)	X_{11}	(0.1,0.32,0.7)
X_6	(0.7,0.95,1)		

Table 11. Weighted normalized matrix in FTOPSIS method

	Zone 1	Zone 2	Zone 3	Zone 4
X_1	(0,0.128,0.55)	(0.055,0.332,0.77)	(0.055,0.338,0.77)	(0.165,0.528,1)
X_2	(0,0.343,0.77)	(0,0.313,0.77)	(0.231,0.665,1)	(0,0.118,0.55)
X_3	(0.15,0.6,1)	(0.15,0.451,0.9)	(0.15,0.512,0.9)	(0.05,0.328,0.7)
X_4	(0,0.234,0.77)	(0.055,0.3,0.77)	(0.055,0.335,0.77)	(0.165,0.47,1)
X_5	(0.15,0.46,0.9)	(0.05,0.42,0.9)	(0.15,0.62,1)	(0.15,0.62,1)
X_6	(0,0.285,0.7)	(0.21,0.665,1)	(0.07,0.451,0.9)	(0.21,0.7,1)
X_7	(0,0.026,0.36)	(0,0.034,0.36)	(0,0.07,0.5)	(0,0.048,0.36)
X_8	(0,0.016,0.214)	(0,0.014,0.214)	(0,0.03,0.3)	(0,0.023,0.3)
X_9	(0,0.07,0.5)	(0,0.05,0.5)	(0,,0.05,0.36)	(0,0.044,0.5)
X_{10}	(0,0.15,0.7)	(0,0.087,0.7)	(0,0.112,0.5)	(0.09,0.5,0)
X_{11}	(0.014,0.252,0.7)	(0.0143,0.225,0.7)	(0,0.225,0.7)	(0.0143,0.24,0.7)

Table 12. Positive and negative ideal solutions in FTOPSIS

	V^+	V^-
X_1	(1,1,1)	(0,0,0)
X_2	(1,1,1)	(0,0,0)
X_3	(1,1,1)	(0.05,0.05,0.05)
X_4	(1,1,1)	(0,0,0)
X_5	(1,1,1)	(0,0,0)
X_6	(1,1,1)	(0,0,0)
X_7	(0.5,0.5,0.5)	(0,0,0)
X_8	(0.3,0.3,0.3)	(0,0,0)
X_9	(0.5,0.5,0.5)	(0,0,0)
X_{10}	(0.7,0.7,0.7)	(0,0,0)
X_{11}	(0.7,0.7,0.7)	(0,0,0)

Table 11. Distance between each alternative and positive ideal solution in FTOPSIS

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	$\sum S_i^+$
Zone1	0.8	0.7	0.542	0.74	0.584	0.73	0.406	0.243	0.38	0.514	0.472	6.188
Zone2	0.68	0.712	0.59	0.7	0.645	0.5	0.403	0.244	0.388	0.536	0.481	5.87
Zone3	0.68	0.484	0.57	0.68	0.54	0.62	0.406	0.233	0.4	0.54	0.488	5.641
Zone4	0.55	0.812	0.7	0.57	0.54	0.5	0.4	0.236	0.4	0.55	0.476	6.029

Table 12. Distance between each alternative and negative ideal solution in FTOPSIS

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	$\sum S_i^-$
Zone 1	0.326	0.486	0.636	0.464	0.59	0.436	0.208	0.124	0.291	0.413	0.43	4.404
Zone 2	0.485	0.48	0.545	0.478	0.574	0.703	0.209	0.124	0.3	0.407	0.424	4.729
Zone 3	0.485	0.706	0.561	0.486	0.7	0.583	0.291	0.174	0.201	0.35	0.424	4.907
Zone 4	0.66	0.324	0.408	0.645	0.7	0.715	0.21	0.174	0.3	0.293	0.427	4.831

According to Equation (1), closeness coefficient for each zone will be:

C_1= 5.138, C_2= 5.539, C_3= 5.781, C_4= 5.678, where, C_3> C_4> C_2> C_1.

IV. DISCUSSIONS AND CONCLUSIONS

Fuzzy TOPSIS and Delphi techniques were exploited in this study to assess the environmental risk of Isfahan-Shiraz railway. Initially the utmost important risks factors among 56 parameters, which were classified into five categories, namely technical, human, environmental, pollutants etc. were determined. Utilizing Delphi method, 22 factors were finally selected. These factors were elected according to field studies along the railway and literature review in national and international scale. Then, environmental risks (11 cases) in the study area were recognized and the relationship between risk factors and environmental risks was tabulated.

Due to high length of the railway, Isfahan-Shiraz railway was divided into 4 zones so as to examine environmental risks in detail, according to identified environmental risks in the region, each zone was prioritized by Fuzzy TOPSIS method. It was deducted that zone three (C_3=5.781) and then zones four (C_4=5.678), two (C_2=5.539) and one (C_1=5.138) have respectively the highest environmental risk. It should be noted, the process of risk assessment was so conducted that the relationship between risk factors and environmental risk were initially determined and then according to them, the scores are assigned to study zones in prioritizing stage. In fact, techniques and the order of utilizing them were so arranged that one could reach the information in a descending order, i.e. from general to detail information.

Hence, superior decision makers will be able of recognizing the most substantial risk factors, the appearing risks from potential ones and also the zones with the highest risk. Finally, authors hope that managerial committee of Isfahan-Shiraz railway, having quantified data and the crucial risks into consideration, will benefit from the results of quantitative analysis of data and also prioritize mitigation and control measures in each zone.

REFERENCES

[1] F.A. Ahmadi, K. Nasiriyan, P. Abazari, "Delphi Technique - A Tool in the Study", Iranian Journal of Medical Education, Vol. 3, pp. 175-185, 2008.

[2] H. Rahimi, "Human Factors Affecting Rail Transport Accidents", Journal of Railway's Research, Vol. 31, pp. 17-20, 2007.

[3] M.J. Asgharpour, "Multi Criteria Decision Making", Tehran University Press, p. 398, 2009.

[4] A. Derakhshan Niya, "Actions in the Transport of Dangerous Goods by Rail after Accident", Journal of Railway's Research, Vol. 185, pp. 1-4, 2005.

[5] A. Oveisi, "Problems of Improving Rail Safety", Railway Research Center Management Research, 2009.

[6] J.A. Zakeri, S. Mokhtari, "Survey of the Natural Disaster Management System and Hazardous Earth in Iranian Railways Network", School of Railway Engineering Research, Iran University of Science and Technology, Tehran, Iran, Vol. 3, pp. 1-11, 2007.

[7] M.N. Edalat Haghi, M. Naderpour, "Safety Management Systems in Rail Transport Industry", Publication of Transportation Research Institute, p. 153, 2006.

[8] J.A. Zakeri, "Identification of Hazardous Rail Crossing According to Road Hazard Index", Journal of Transportation Research, Vol. 3, pp. 223-230, 2006.

[9] M. Atayi, "Fuzzy Multi-Criteria Decision Making", Shahrood University Press, Shahrood , Iran, p. 233, 2010.

[10] A.H. Ghazinoori, A. Tabatabaiyan, "Sensitivity Analysis of MADM Techniques According to Techniques Used", Knowledge Management Journal, Vol. 56, pp. 129-141, 2002.

[11] C.R. Che-Hassan, "Quantitative Risk Assessment for the Transport of Ammonia by Rail", Vol. 26, pp. 60-63, 2009.

[12] H. Barry, "Risk Modeling of Hazardous Materials Rail Movement to Include a Terrorist Incident", Journal of Academy of Business and Economics, Vol. 3, pp 150-156, 2005.

[13] M. Fry, G. Burr, "Using the Delphi Technique to Design a Self-Reporting Triage Survey Tool", Accid. Emerg. Nurs., Vol. 9, Issue 4, pp. 235- 241, Oct. 2001.

[14] A. Barati, S.J. Dastgheib, A. Movaghar, I. Attarzadeh, "An Effective Fuzzy Based Algorithm to Detect Faulty Readings in Long Thin Wireless Sensor Networks", International Journal on Technical and Physical Problems of Engineering (IJTPE), Vol. 3, No. 1, pp. 2077-3528, March 2012.

[15] A. Zarekar, H. Vahidi, B. Kazemi Zamani, S. Ghorbani, H. Jafari, "Forest Fire Hazard Mapping Using Fuzzy AHP and GIS, Study Area - Gilan Province of Iran", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 12, Vol. 4, No. 3, pp. 47-55, September 2012.

[16] M. An, S. Huang, C.J. Baker, "Railway Risk Assessment - The Fuzzy Reasoning Approach and Fuzzy Analytical Hierarchy Process Approaches - A Case Study of Shunting at Waterloo Depot", Journal of Rail and Rapid Transit, Vol. 221, Part F, pp. 365-383, April 2007.

[17] S.H. Chang, H.E. Tseng, "Fuzzy TOPSIS Decision Method for Configuration Management", International Journal of Industrial Engineering, Vol. 15, Issue 3, pp. 304-313, 2008.

[18] C.C. Hung, L.H. Chen, "A Fuzzy TOPSIS Decision Making Model with Entropy Weight under Intuitionistic Fuzzy Environment", International Multi-Conference of Engineering and Computer Scientists (IMECS), Vol. 1, Hong Kong, 18-20 March 2009.

[19] C.T. Chen, "Extensions of the TOPSIS for Group Decision-Making under Fuzzy Environment", Systems, Vol. 114, pp. 1-9, 2000.

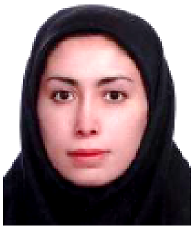
[20] M. Shafiee, "Environmental Risk Assessment of Heel Protected Area Using Multiple Decision Making", Thesis Master of Science in Environmental Science-Assessment and Land Use Planning, Science and Research Branch, Islamic Azad University, Khuzestan, Iran, 2009.

[21] S. Ebrahimi Nejad, "Risk Assessment Model for BOT Projects Based on Fuzzy Multiple Attribute Decision Making", Fifth International Conference on Industrial Engineering, pp. 1-3, February 2007.

[22] M. Gholami, M.H. Teymour Farhoosh, J. Ariyani, "Application Delphi Approach in Determining Strategic Priorities HSE Manager Oil, Gas and Petrochemical", First National Conference on Safety Engineering and HSE Management, pp.1-3, 2005.
[23] M. Zokayi Ashtiyani, "Practice Standard for Project Risk Management", Publication of Adineh, Iran, p. 172, 2009.

BIOGRAPHIES

Sareh Ghorbani was born in Tehran, Iran in 1985. She received the B.Sc. degree in the field of Natural Resources Engineering from Islamic Azad University, Iran and the M.Sc. degree in the field of Environment Planning and Management from University of Tehran, Tehran, Iran in 2006 and 2011, respectively. Her research interests are in the area of environmental impact assessment, social impact assessment, MDCM, urban ecology, remote sensing, and geographical information system.



Bahareh Hatam Abadi was born in Tehran, Iran in 1984. She received the B.Sc. degree in the field of Natural Resources Engineering from Islamic Azad University, Iran and the M.Sc. degree from Science and Research Branch, Islamic Azad University, Tehran, Iran in 2005 and 2010, respectively. Her research interests are in the area of environmental impact assessment, environmental risk assessment, and environmental management program.

Azadeh Zarekar was born in Tehran, Iran, in December 1986. She received the B.Sc. degree in the field of Natural Resources Engineering from Islamic Azad University, Iran and the M.Sc. degree in the field of Environment Planning and management from University of Tehran, Tehran, Iran in 2008 and 2012, respectively. Her research interests are in the area of environmental impact assessment, public participation, remote sensing, site selection, and geographical information system.

Farzad Jalaeifar was born in Sirjan, Iran, in September 1988. He received the B.Sc. degree in Civil Engineering in 2012 from in Abbaspur University, Tehran, Iran. Currently he is the M.Sc. student in Water Resources Environmental Engineering in University of Tehran, Tehran, Iran. Currently, he is a Research Assistant at Environmental Research Center, University of Tehran. His research interest is assessing the total maximum daily load to surface water.