Ranking repair and maintenance projects of large bridges in Kurdestan province using fuzzy TOPSIS method

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Abstract: In this paper multi criteria decision making tools have been used for bridge risk assessment and for planning the investigation, repair and maintenance of bridges. For this purpose, at first, risks that influence bridges have been recognized and they have been classified in six groups as risks arising from earthquake and their effect on the sphere, design and traffic insufficiency, flood, structural system, structural resistance against earthquake and different design, building or maintenance problems. The risks have been assessed based on their consequence on four criteria as safety, functionality, cost and environment. Finally, a method has been proposed for planning the bridges repair and maintenance projects using multi criteria decision making tools. In a case study, large bridges in kurdestan province have been ranked based on the intensity of recognized risks using fuzzy TOPSIS method.

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1. Introduction

Transportation as one of the most important substructures for developing economical, political and social aspects of societies has a fundamental role in development of countries, and overland transportation is one of the most important parts of transportation. Building and maintenance of overland transportation network is one of the costliest projects of construction, and a large amount of this cost is allocated for elements like bridges and tunnels.

Bridges are structures for passing from natural and artificial obstacles such as rivers and roads. They are important elements of roads and their destruction or collapse lead to problems in transportation and wasting the initial building investment, and need to spend much money for rebuilding them. Furthermore, destruction of bridges during the natural disasters make relieving operation hard and it increases damages of disasters. Recognizing the structural problems of bridges and implementation of appropriate and opportune repair and maintenance programs is a fundamental step for preventing the destruction of bridges and damages arising of it.

In this study destruction factors that influence the bridges and their risks have been recognized, and an appropriate method has been proposed for ranking the
Investigation, fund allocation programs and prioritization of bridge repair and maintenance projects.

In recent years number of researches has been done to bridge risk assessment. For example in a research done on prioritization of bridges and tunnels in earthquake risk mitigation, following the MAKBETH approach a multi criteria model was constructed and applied in a zone of high seismic hazard in the city of Lisbon to appraise the relative benefit of retrofitting each bridge and tunnel. The model Prioritized structures according to vulnerability and strategic importance of bridges and tunnels (Bana et al., 2008). A Fuzzy Analytical Hierarchy Process (FAHP) has been used as an efficient decision making tool for condition evaluation of existing reinforced concrete bridges (Sasmal, Ramanjaneyulu, 2008). Wang and Elhagh have done several researches about bridge risk assessment during 2006 until 2008. They utilized multi criteria decision making methods and other mathematical models for bridge risk assessment and prioritization of bridge maintenance projects. They proposed a fuzzy TOPSIS method based on alpha level sets, and They compared neural network, evidential reasoning and multi regression analysis in modeling bridge risks. In another research a fuzzy group decision making approach for bridge risk assessment was proposed. (Wang & Elhagh, 2006, 2007, 2008).

In a case study of two bridges in Lisbon, project back ground was overviewed and main risks were recognized. Throughout the project a great attention was given to whole life cycle costs, and gain in efficiency and cost control (Lemos et al. ,2003). A risk based approach was used to determine the optimal intervention for bridges affected by multiple hazards. It was based on levels of service to be provided by the bridges (Adey et al. ,2003). In another research for bridge risk assessment, a broad overview of reliability–based assessment methods was presented and decision making tools were applied for updated time-dependant estimates of bridge reliabilities considering a risk-ranking decision analysis. The reliability-based safety assessment was related to the effects of bridge age, current and future traffic volume and loads, and deterioration on the reliability and safety of ageing bridges (Stewart et al. 2001). The Literature review shows that multi criteria decision making tools are efficient for bridge risk assessment.

The remainder of this paper is organized as follows. Section 2 briefly introduces the fuzzy TOPSIS method. Section 3 presents the method to recognizing, assessment and modeling the bridge risks. Section 4 investigates a case study including the application of the proposed model for prioritization of bridges. The paper is concluded in section 5.

2. The fuzzy TOPSIS method

TOPSIS method is a technique for order preference by similarity to ideal solution and proposed by Hwang and Yoon (1981). The ideal solution (also called positive ideal solution) is a solution that maximizes the benefit criteria/attributes and minimizes the cost criteria/attributes, whereas the negative ideal solution (also called anti- ideal solution) maximizes the cost criteria/attributes and minimizes the benefit criteria/attributes. The so-called benefit criteria/attributes are those for maximization, while the cost criteria/attributes are those for minimization. The best alternative is the one, which is closest to the ideal solution and farthest from the negative ideal solution (Wang & Elhagh, 2006).

This method and other classic multi criteria decision making methods don't handle the uncertainty of issues. By using fuzzy theory and assimilate it with multi criteria decision making tools, uncertainty in problem is modeled in fuzzy environment and produce more accurate answers.

The fuzzy TOPSIS method used in this study can be summarized as follows:

Step1: Every MCDM problems have m alternatives ($A_1, \dots, A_m$) and n criteria ($C_1, \dots, C_n$). It concisely expressed in matrix format as follows:

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \cdot \\ \cdot \\ \cdot \\ A_m \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & C_2 & C_3 & \dots & C_n \end{array} \\ \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \tilde{x}_{13} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \tilde{x}_{23} & \cdots & \tilde{x}_{2n} \\ \tilde{x}_{31} & \tilde{x}_{32} & \tilde{x}_{33} & \cdots & \tilde{x}_{3n} \\ \cdot & \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdot & \cdots & \cdot \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \tilde{x}_{m3} & \cdots & \tilde{x}_{mn} \end{bmatrix} \end{array}$$

Numbers in fuzzy MCDM problems are fuzzy numbers. Triangular fuzzy numbers are used to express linguistic variables. It can be defined by a triplet ($a_1 1, a_1 2, a_1 3$) where: $0 \le a < b < c \le 1.$

Step2: Weights of attributes reflect the relative importance in decision making process. We can not assume that each evaluation criterion is of equal importance. Weights vector is defined as $\tilde{W} = [\tilde{w}_1, \tilde{w}_2, \dots, \tilde{w}_n]$.

Step3: The normalized fuzzy decision matrix denoted by $\tilde{R}$ is indicated as:

$$\tilde{R} = [\tilde{r}_{ij}]_{m*n}$$

If ($\tilde{x}_{ij}$, I =1, 2,…, m, j=1,2,…,n)are triangular fuzzy numbers, then normalization process can be performed by

$$\tilde{r}_{ij} = \left(\frac{a_{ij}}{c_j^*}, \frac{b_{ij}}{c_j^*}, \frac{c_{ij}}{c_j^*}\right) \quad i = 1, 2, \dots, m, j \in B, \qquad (2-2)$$

$$\tilde{r}_{ij} = \left(\frac{a_j^-}{c_{ij}}, \frac{a_j^-}{b_{ij}}, \frac{a_j^-}{a_{ij}}\right) \quad i = 1, 2, \dots, m, j \in C, \qquad (2-3)$$

Where B and C are the set of benefit criteria and cost criteria, respectively, and

$$c_j^* = \max_i c_{ij} \quad j \in B \qquad (2-4)$$

$$a_j^- = \min_i a_{ij} \quad j \in C \qquad (2-5)$$

Step4: The weighted fuzzy normalized decision matrix denoted by $\tilde{V}$ is calculated from (2-6):

$$\tilde{V} = \tilde{R} * \tilde{W} \qquad (2-6)$$

Step5: Positive ideal solution A^+ and negative ideal solution A^- are determined from (2-7), (2-8):

$$A^+ = \{(\max_i \tilde{v}_{ij} \mid j \in J_1), (\min_i \tilde{v}_{ij} \mid j \in J_2) \mid i = 1, 2, \dots, n\} \quad (2-7)$$

$$A^- = \{(\min_i \tilde{v}_{ij} \mid j \in J_1), (\max_i \tilde{v}_{ij} \mid j \in J_2) \mid i = 1, 2, \dots, n\} \quad (2-8)$$

$$A^+ = (\tilde{v}_1^+, \tilde{v}_2^+, \dots \tilde{v}_k^+)$$

$$A^- = (\tilde{v}_1^-, \tilde{v}_2^-, \dots \tilde{v}_k^-)$$

Step6: The distance from the positive ideal solution and the negative ideal solution for each alternative are calculated from (2-9), (2-10), (2-11). The distance between two triangular fuzzy numbers $A_1 = (a_1 1, b_1 1, c_1 1)$ and $A_2 = (a_1 2, b_1 2, c_1 2)$ is calculated as:

$$d(A_1, A_2) = \sqrt{\frac{1}{3}[(a_1 - a_2)^2 + (b_1 - b_2)^2 + (c_1 - c_2)^2]} \quad (2-9)$$

$$d_i^+ = \sum_{j=1}^{k} [d(\tilde{v}_{ij}], \tilde{v}_j^+), \quad i = 1,2,\dots,m \qquad (2-10)$$

$$d_i^- = \sum_{j=1}^{k} [d(\tilde{v}_{ij}], \tilde{v}_j^-), \quad i = 1,2,\dots,m \qquad (2-11)$$

Step7: The closeness coefficient (CC) is calculated from (2-12) for each alternative and they are ranked in descending order. The alternative with the highest CC value will be the best choice.

$$CC_i = \frac{d_i^-}{d_i^- + d_i^-} \qquad (2-12)$$

3. Modeling the bridges risk

In this study according to technical reports and the researches have been done by Ministry of Road and Transportation, the most important risks which influence bridges have been recognized and they have been classified in six main groups. They are risks arising from earthquake and their effect on the sphere, design and traffic insufficiency, flood, structural system, structural resistance against earthquake and different design, building or maintenance problems. These risks have been assessed considering their effect on four main criteria. These criteria determined based on literature review and engineering judgment. They are safety, functionality, cost and environment. The recognized risks are indicated in table1.

Table 1. Recognized risks

X1	Risks arising from earthquake and their effect on the sphere
X2	Risks arising from design and traffic insufficiency
X3	Risks arising from flood
X4	Risks arising from structural system
X5	Risks arising from structural resistance against earthquake
X6	Risks arising from different design, building or maintenance problems

Relative importance of risks have been determined on the basis of interview with e team of bridge experts (DMs). They expressed the consequences of each defined risk event on safety, functionality, cost and environment of bridge by linguistic terms indicated in table2.

Table 2. Consequences rating of risk events

Consequence rating	Symbol	Fuzzy number
Very High	VH	(0.85,0.85,1)
High	H	(0.5,0.85,1)
Medium	M	(0.15,0. 5,0.85)
Low	L	(0,0.15,0.5)
Very Low	VL	(0,0,0.15)
None	N	(0,0,0)

Consequences rating assessed by seven DMs have been indicated in table3.

Table 3. Consequences rating assessed by seven DMs

		X1	X2	X3	X4	X5	X6
DM1	C1	VH	H	H	VH	VH	VH
	C2	VH	H	H	VH	VH	VH
	C3	VH	M	M	M	VH	M
	C4	VH	M	M	M	VH	H
DM2	C1	VH	VH	VH	H	VH	VH
	C2	VH	VH	H	L	VH	VH
	C3	VH	VH	M	VH	VH	L
	C4	VL	VL	VH	M	L	L
DM3	C1	H	H	VH	H	M	M
	C2	M	H	H	M	H	L
	C3	H	L	H	H	H	L
	C4	M	L	H	VL	VL	N
DM4	C1	VH	VH	H	H	M	H
	C2	VH	M	VH	VH	VH	H
	C3	VH	M	VH	VH	VH	M
	C4	M	L	H	M	M	L
DM5	C1	VH	H	VH	H	VH	VH

	C2	H	VH	VH	VH	VH	H
	C3	H	H	VH	H	H	H
	C4	M	M	H	M	M	M
DM6	C1	M	M	L	M	VH	H
	C2	M	H	M	M	H	VH
	C3	H	H	VH	H	VH	H
	C4	M	VH	M	VH	M	H
DM7	C1	VH	VH	VH	VH	VH	H
	C2	VH	H	H	H	H	H
	C3	H	H	VH	H	H	M
	C4	L	H	M	M	M	L

According to fuzzy numbers in table 2 and consequences rating in table 3, relative importance of risk events have been calculated by averaging of seven DMs assessment. They are indicated in table4.

Table 4.The relative importance weights of risk events for each criterion

risks	$C1$	$C2$	$C3$	$C4$
$X1$	W_{11} = (0.7,0.8,0.98)	W_{12} =(0.6,0.75,0.96)	W_{13} =(0.65,0.85,1)	W_{14} =(0.21,0.43,0.72)
$X2$	W_{21} =(0.7,0.85,1)	W_{22} =(0.5,0.75,0.96)	W_{23} =(0.38,0.65,0.89)	W_{24} =(0.19,0.43,0.69)
$X3$	W_{31} =(0.63,0.75,0.93)	W_{32} =(0.55,0.8,0.98)	W_{33} =(0.6,0.75,0.96)	W_{34} =(0.4,0.7,0.94)
$X4$	W_{41} =(0.55,0.8,0.98)	W_{42} =(0.48,0.65,0.89)	W_{43} =(0.55,0.8,0.98)	W_{44} =(0.23,0.48,0.77)
$X5$	W_{51} =(0.65,0.75,0.96)	W_{52} =(0.7,0.85,1)	W_{53} =(0.7,0.85,1)	W_{54} =(0.21,0.43,0.72)
$X6$	W_{61} =(0.55,0.8,0.98)	W_{62} =(0.53,0.75,0.93)	W_{63} =(0.21,0.5,0.79)	W_{64} =(0.16,0.38,0.62)

Bridge risks have been assessed as the product of likelihood and consequences of defined risk events as follows:
Risk= Likelihood*Consequences

$$X1 = L1 * C1 \qquad (3-1)$$

Where L1 and C1 Likelihood and Consequence of risk event X1 for each criterion. Likelihood fuzzy numbers are indicated in table 5.

Table 5. Likelihood rating of risk events

Consequence rating	Symbol	Fuzzy number
Certain	C	(1,1,1)
Very High	VH	(0.85,0.85,1)
High	H	(0.7,0.85,1)
Slightly High	SH	(0.5,0.7,0.85)
Medium	M	(0.3,0.5,0.7)
Slightly low	SL	(0.15,0.3,0.5)
Low	L	(0,0.15,0.3)
Very Low	VL	(0,0,0.15)
Imposible	N	(0,0,0)

Total risk of each bridge for each criterion is calculated from additive weighting of six risk events as follows:

$$\tilde{a}_{11} = W_{11} * X_1 + W_{21} * X_2 + W_{31} * X_3 + W_{41} * X_4 + W_{51} * X_5 + W_{61} * X_6 \qquad (3-2)$$

Where $\tilde{a}_{11}$ is total risk of first bridge (A1) for first criterion (C1).

After calculating of total risk for all bridges and all criteria, decision matrix has been built as follows.

$$\tilde{D} = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \cdot \\ \cdot \\ \cdot \\ A_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & C_3 & C_4 \end{array} \\ \begin{bmatrix} \tilde{a}_{11} & \tilde{a}_{12} & \tilde{a}_{13} & \tilde{a}_{14} \\ \tilde{a}_{21} & \tilde{a}_{22} & \tilde{a}_{23} & \tilde{a}_{24} \\ \tilde{a}_{31} & \tilde{a}_{32} & \tilde{a}_{33} & \tilde{a}_{34} \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ \tilde{a}_{m1} & \tilde{a}_{m2} & \tilde{a}_{m3} & \tilde{a}_{m4} \end{bmatrix} \end{array} \qquad (3-3)$$

Bridge structures can be ranked for repair and maintenance projects on basis of decision matrix in (3-3) using fuzzy TOPSIS method in section 2.

Relative importance of criteria have been calculated by averaging of seven DMs assessment of consequences rating in table 3. They are indicated in table6.

Table 6. Fuzzy weights of criteria

criteria	Fuzzy weights
Safety	(0.63,0.79,0.97)
Functionality	(0.56,0.76,0.95)
Cost	(0.51,0.73,0.94)
Environment	(0.23,0.47,0.74)

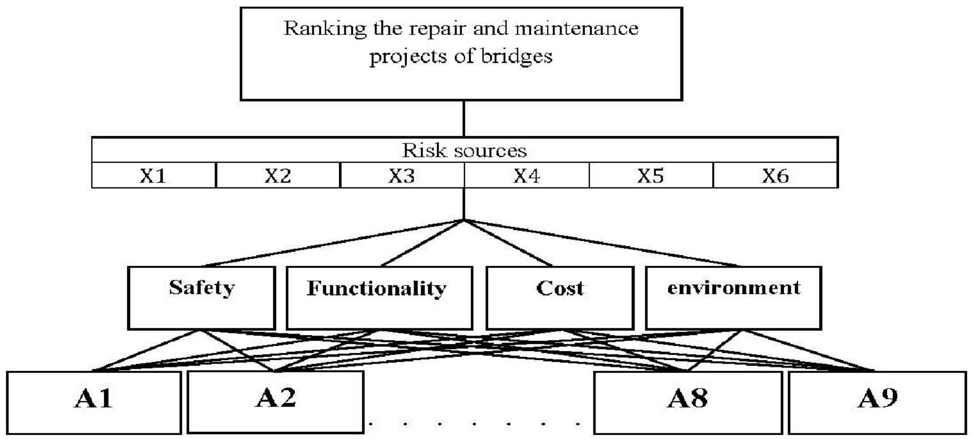

Figure 1.General model of problem

Table 7. Intensity of risk events for bridge A1

risks	$C1$	$C2$	$C3$	$C4$
$X1$	(0.15,0.425,0.7)	(0.15,0.425,0.7)	(0.045,0. 25,0.595)	(0.045,0. 25,0.595)
$X2$	(0.25,0.525,0.85)	(0.075,0.35,0.723)	(0.075,0.35,0.723)	(0,0.105,0.425)
$X3$	(0.15,0.425,0.7)	(0.15,0.425,0.7)	(0.15,0.425,0.7)	(0.045,0. 25,0.595)
$X4$	(0,0.075,0.35)	(0,0.075,0.35)	(0.045,0. 25,0.595)	(0,0.075,0.35)
$X5$	(0,0.023,0.15)	(0,0.075,0.255)	(0,0.075,0.255)	(0,0,0.045)
$X6$	(0,0.025,0.45)	(0.023,0.15,0.425)	(0,0.045,0.25)	(0,0,0.075)

4. Case study

There are more than fifty large bridges in Kurdestan province. We select nine bridges of two main routes as our case study. General model of problem has been indicated in figure 1. These bridges have been investigated by bridge experts. They determined the likelihood and consequences of each risk event according to each criteria. Intensity of risks has been calculated for all bridges and all criteria. Calculated risks for bridge structure A1 are indicated in table 7as an example.

Total risk for all bridges considering the criteria have been calculated to define decision matrix (3-3). For example, total risk for bridge A1 and criterion C1 ($\tilde{a}_{11}$) has been calculated using (3-2) as follows.

$\tilde{a}_{11}$ = (0.7,0.8,0.98)* (0.15,0.425,0.7)+ (0.7,0.85,1)* (0.25,0.525,0.85)+ (0.63,0.75,0.93)* (0.15,0.425,0.7)+ (0.55,0.8,0.98)* (0,0.075,0.35)+ (0.65,0.75,0.96)* (0,0.023,0.15)+ (0.55,0.8,0.98)* (0,0.025,0.45)= (0.374,1.218,2.916)

Other elements of decision matrix has been calculated like $\tilde{a}_{11}$. They are indicated in table 8.

The normalized fuzzy decision matrix has been calculated using (2-2), (2-3), (2-4), (2-5) as indicated in table 9.

The weighted fuzzy normalized decision matrix has been calculated by multiplication of weights of criteria in table 6 and normalized decision matrix in table 9 as described in (2-6). This matrix will be the basis of bridge ranking and it has been indicated in table 10.

Positive ideal solution and Negative ideal solution are determined by (2-7), (2-8) on the basis of weighted fuzzy normalized decision matrix in table 10 as follows:

A^+ = {(0.087,0.364,0.970),(0.056,0.325,0.951),(0.006,0.024,0.151),(0.005,0.115,0.744)}

A^- = {(0.003,0.075,0.430),(0.021,0.175,0.624),(0.011,0.058,0.936),(0.000,0.020,0.270)}

The distance from the positive ideal solution and the negative ideal solution for each alternative have been calculated from (2-9), (2-10), (2-11). They are indicated in table11.

Table 8. Fuzzy decision matrix

	C1	C2	C3	C4
A1	(0.374,1.218,2.916)	(0.222,1.146,3.006)	(0.172,1.045,2.94)	(0.027,0.363,1.63)
A2	(0.198,0.985,2.838)	(0.296,1.319,3.334)	(0.141,1.019,3.08)	(0.018,0.212,1.1)
A3	(0.486,1.623,3.526)	(0.372,1.604,3.741)	(0.245,1.193,3.143)	(0.027,0.282,1.289)
A4	(0.256,1.174,3.055)	(0.33,1.473,3.492)	(0.116,0.923,2.931)	(0.018,0.194,1.028)
A5	(0.229,1.244,3.356)	(0.256,1.36,3.445)	(0.165,0.96,2.852)	(0.037,0.421,1.74)
A6	(0.177,0.969,2.88)	(0.195,1.193,3.288)	(0.057,0.608,2.416)	(0.018,0.214,1.152)
A7	(0.016,.334,1.563)	(0.144,0.866,2.456)	(0.039,0.499,1.875)	(0,0.072,0.632)
A8	(0.046,0.489,2.144)	(0.139,0.896,2.546)	(0.074,0.556,2.005)	(0.009,0.137,0.863)
A9	(0.215,0.888,2.397)	(0.178,1.008,2.779)	(0.105,0.525,1.783)	(0.023,0.239,1.072)

Table 9. Fuzzy normalized decision matrix

	C1	C2	C3	C4
A1	(0.106,0.345,0.827)	(0.059,0.306,0.804)	(0.013,0.038,0.228)	(0.016,0.209,0.937)
A2	(0.056,0.279,0.805)	(0.079,0.353,0.891)	(0.013,0.039,0.279)	(0.011,0.122,0.632)
A3	(0.138,0.460,1.000)	(0.100,0.429,1.000)	(0.013,0.033,0.161)	(0.016,0.162,0.741)
A4	(0.073,0.333,0.866)	(0.088,0.394,0.933)	(0.013,0.043,0.340)	(0.010,0.112,0.591)
A5	(0.065,0.353,0.952)	(0.068,0.363,0.921)	(0.014,0.041,0.239)	(0.021,0.242,1.000)
A6	(0.050,0.275,0.817)	(0.052,0.319,0.879)	(0.016,0.065,0.686)	(0.01,0.123,0.662)
A7	(0.004,0.095,0.443)	(0.039,0.231,0.656)	(0.021,0.079,1.000)	(0.000,0.041,0.363)
A8	(0.013,0.139,0.608)	(0.037,0.239,0.681)	(0.020,0.071,0.530)	(0.005,0.079,0.496)
A9	(0.061,0.252,0.680)	(0.047,0.269,0.743)	(0.022,0.075,0.376)	(0.013,0.138,0.616)

Table 10. Weighted fuzzy normalized decision matrix

	C1	C2	C3	C4
A1	(0.67,0.283,0.802)	(0.033,0.232,0.764)	(0.007,0.028,0.214)	(0.004,0.099,0.697)
A2	(0.035,0.221,0.781)	(0.044,0.267,0.848)	(0.007,0.028,0.261)	(0.002,0.058,0.471)
A3	(0.087,0.364,0.97)	(0.056,0.325,0.951)	(0.006,0.024,0.151)	(0.004,0.077,0.551)
A4	(0.046,0.264,0.841)	(0.049,0.299,0.888)	(0.007,0.031,0.319)	(0.002,0.053,0.44)
A5	(0.041,0.279,0.923)	(0.038,0.276,0.876)	(0.007,0.030,0.224)	(0.005,0.115,0.744)
A6	(0.032,0.218,0.793)	(0.029,0.242,0.836)	(0.008,0.047,0.642)	(0.002,0.058,0.493)
A7	(0.003,0.075,0.43)	(0.022,0.175,0.624)	(0.011,0.058,0.936)	(0.000,0.020,0.27)
A8	(0.008,0.11,0.59)	(0.021,0.182,0.647)	(0.01,0.052,0.496)	(0.001,0.037,0.369)
A9	(0.038,0.199,0.659)	(0.027,0.204,0.706)	(0.011,0.055,0.352)	(0.003,0.065,0.458)

Table 11. The distance of alternatives from positive and negative ideal solution

Criteria	C1		C2		C3		C4		D	
Distance	d^+	d^-	d^+	d^-	d^+	d^-	d^+	d^-	D^+	D^-
A1	0.111	0.246	0.121	0.087	0.036	0.417	0.029	0.251	0.297	1.002
A2	0.140	0.220	0.069	0.140	0.064	0.390	0.161	0.118	0.434	0.868
A3	0.000	0.357	0.000	0.208	0.000	0.454	0.113	0.166	0.113	1.185
A4	0.098	0.262	0.040	0.169	0.097	0.357	0.179	0.100	0.414	0.887
A5	0.062	0.309	0.053	0.157	0.042	0.411	0.000	0.279	0.157	1.156
A6	0.137	0.226	0.084	0.128	0.284	0.170	0.149	0.130	0.653	0.654
A7	0.357	0.000	0.208	0.000	0.454	0.000	0.279	0.000	1.298	0.001
A8	0.268	0.094	0.195	0.014	0.200	0.254	0.221	0.058	0.884	0.420
A9	0.205	0.152	0.159	0.050	0.118	0.337	0.167	0.112	0.649	0.651

The closeness coefficient (CC) has been calculated from (2-12) and table 11 for each alternative and they are ranked in descending order as follows:

Table 12. Closeness Coefficient and bridge ranking

Bridges	CC	Ranking
A1	0.771	3
A2	0.667	5
A3	0.913	1
A4	0.682	4
A5	0.880	2
A6	0.500	7
A7	0.001	9
A8	0.322	8
A9	0.501	6

According to the ranking indicated in table 12, The bridge A3 is at the first in prioritization and the bridge A7 is the last one. The repair and maintenance projects should be plan considering this ranking, and it helps to do appropriate and opportune operations and prevents the destruction of bridges.

5. Conclusion

In this paper we have proposed a method to planning the bridges investigation and maintenance projects according to risks that influence the bridges. At first the main risks have been recognized and they have been classified in six groups. They are risks arising from Earthquake and their effect on the sphere, design and traffic insufficiency, flood, structural system, structural resistance against earthquake and different designing, building or maintenance problems.

These recognized risks have been assessed based on a multiple criteria decision making (MCDM) method known as TOPSIS in fuzzy environment. So the fuzzy weights of these risks have been determined according to four criteria: safety, functionality, cost and environment. Further in a case study, repair and maintenance projects of bridges have been prioritized using the proposed method. Analyzing the results presents that the proposed method is efficiently applicable for bridge prioritization and decision making about allocation of funds and performing maintenance projects. There is not limitation for number of bridges or risks in the proposed method and it can be applied in different conditions or regions.

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