Journal of Quality Engineering and Production Optimization

Vol. 6, No. 2, Summer & Autumn 2021

http://jqepo.shahed.ac.ir

Research Paper

DOI: 10.22070/JQEPO.2021.14852.1199

A new hierarchical evaluation approach for risk response strategy selection in BOT projects under uncertainty

Mohsen Nezami [1], Mohammad Reza Adlparvar [1,2*], Mahtiam Shahbazi [3]

[1] *Department of Civil Engineering, Qeshm Branch, Islamic Azad University, Qeshm, Iran*

[2] *Associate professor, Technical and Engineering Faculty, University of Qom, Qom, Iran*

[3] *Assistant professor, Department of Architecture, Science and research Branch, Islamic Azad University, Tehran, Iran*

**** Corresponding Author:*** *Mohammad Reza Adlparvar (Email: adlparvar@qom.ac.ir)*

Abstract *– One of the topics in the world today is related to the production and development of infrastructure projects under the supervision and control of governments, in which the government has no operational role and acts as an observer. This type of production is called BOT, which brings both the risk and the project's profit to the private sector company. In such projects, before concluding a contract, the government gives a concession to a private company for a certain period to deliver the completed project, and on the other hand, it assigns the risks in the project to the investing company in full. In this research, the risks in BOT projects are investigated and using a proposed approach under the conditions of intuitive fuzzy uncertainty and multi-period systems, the weights of these indicators are calculated, and the strategies in this research are ranked. Finally, a case study is presented to construct a highway project, and the efficiency of the proposed method compared to a traditional method is measured. Meanwhile, the performance of the proposed approach is analyzed by eliminating contributions such as the last aggregation concept, criteria weights determination, experts' weights computations. Moreover, a sensitivity analysis is provided to represent the robustness and sensitiveness of the main parameters.*

Keywords– *BOT project, Intuitionistic fuzzy set, Risk management, Ranking strategies, Hierarchical structure.*

I. INTRODUCTION

In today's world, one of the most important measures at the national and international level is related to the construction and construction of infrastructure projects. This phenomenon is more common in developing countries than the others. Infrastructure projects include the construction of roads and constructions on a large scale, which requires a large budget from the government. Also, infrastructure projects have risky structures, and governments may face serious risks during the construction and implementation of these projects. These risks allow the government to incur heavy losses and pay exorbitant costs (Hamzeh et al., 2020; Mousavi et al., 2014; Mousavi & Gitinavard, 2019).

In the meantime, one of the efficient and practical methods has been related to using the private sector for build, operation, and transfer (BOT). The private sector starts the initial design with the initial investment in the large infrastructure project and starts construction after the design. After the construction and reaching the operation stage,

Manuscript Received:28- August- 2021 & Revised: 7- Nov -2021 & Accepted: 6 - December -2021
ISSN: 2423-3781

the project will be handed over to the public sector. Continued economic growth in developing countries has led governments to turn to the private sector due to bottlenecks such as lack of funding and lack of modern technology in the country (Chen et al., 2021; Solgi et al., 2019). The BOT method has been proposed as a reliable method of attracting private capital that gives the strategic government control over facilities. In this type of construction method, which consists of two general parts of the public and private sectors, the tasks of the private sector are design, construction, operation, and financing, respectively, and the tasks of the public sector are: scoring the private sector for performance. The project provides loans and receives interest on the final construction (Gitinavard et al., 2020).

The government, as a key part of building an infrastructure project, initially uses the private sector to avoid potential project risks. The private sector considers concessions in the contract with the government. These concessions can be, for example, the use of highway tolls after the delivery of the project for a limited and specific period. Once the expectations of the parties are determined, the initial design and funding of materials, human resources, and resources by the private sector will begin. In the meantime, the government acts as a watchdog over the activities of the private sector and monitors its activities on an ongoing basis (Gitinavard and Mousavi, 2015). Also, if the private sector is more willing to provide financial resources, the government can provide loans to the sector. After the construction and implementation of the project under the supervision of the government, the private sector obtains its privilege and, after obtaining the specified privilege, transfers the project to the government for national and public benefit (Borujeni and Gitinavard, 2017; Zhao et al., 2013).

This process can lead to many risks in the middle of the road that with the transfer of the project from the government to the private sector, all these risks are borne by the private sector, and there is no national risk to the country and the government. In addition, in case of any non-commitment and delays by the private sector, the government can demand a fine from the private sector. These risks can greatly harm the private sector, and therefore the management of these risks during construction is considered necessary and vital (Fahad Al-Azimi et al., 2014).

The stated risks can include investment risks, project technical risks, project implementation risks, and general project risks. There are also other categories of project risks that can affect the project and not hurt the private investor (Muriana and Vizzini, 2017; Mousavi and Gitinavard, 2019). In much more sensitive and acute cases, the private sector faces severe risks during the construction of the project, and it is possible that there will be delays in the delivery of the project or even the cancellation of cooperation for the construction of the project. In such circumstances, the government, as a controlling agent, also suffers losses such as lack of access and final operation of the project on time, and in return for this issue, the private company seeks to delay and fines (Bagui, 2011).

By recognizing BOT projects and the impact of project risks on the construction and final transfer of the project and the amount of damage caused, managing project risks before their occurrence is considered important and necessary (Okudan et al., 2021). Private investor companies with proper knowledge of the project and the risks involved in it can prevent the occurrence of these risks and with a proper view of the project situation to invest financial and human resources to build, implement and deliver the project (Gitinavard, 2019). One of the efficient methods in the field of recognizing project risks and evaluating their position in the project and their effectiveness is related to risk identification methods as the main criteria and using the opinions of a group of experts in multi-criteria group decision making (MCGDM) approach (Akram et al., 2020; Ebrahimnejad et al., 2017).

Another problem with the risks of BOT projects is their uncertain nature. To predict project risks and take action to eliminate and manage them, managers need to recognize the existing uncertainties and ways to deal with them (Chiara and Garvin, 2008; Ebrahimnejad et al., 2017). One of the appropriate approaches to deal with such uncertain parameters is the use of fuzzy methods (Mousavi et al., 2014). Managers, to make key decisions in consultation with a group of experts and specialists, need to know the proper ways to deal with the uncertainties in the project to make appropriate decisions (Gitinavard et al., 2016; Vahdani, 2016; Gitinavard and Zarandi, 2016). In this research, in order to deal with the uncertainty in the problem, the intuitionistic fuzzy (IF) approach is used. This method is based on membership and non-membership functions. In this paper, in order to solve the problem of multi-period problems and the possibility of changes in the nature of the project in different time periods, the dynamic intuitionistic fuzzy (DIF) method is used.

In this article, in order to obtain the local weight of the criteria's risk based on IF, the subject of highway construction has been used a standard deviation approach. Also, in order to obtain the weights of hierarchical structure with interdependencies criteria, the decision-making trial and evaluation laboratory (DEMATEL) approach is used under the IF situation. Also, a novel DIF-utility grade method is proposed to calculate the weight of every expert. Then, weights of experts or decision-makers (DM) are taken into account in the determining multi-phase weighting method. Furthermore, the DIF-MPW-CI–DEMATEL methodologies are introduced via the last association approach to keep around from the data loss. Eventually, the IF-overall evaluation score (IF-OES) is used to compute each alternative score. The main contributions of the paper are defined as:

- Expanding the necessary risk of the construction highway BOT project.
- Tailoring the multiphase weighting method and the DEMATEL method with DIF condition.
- Developing the new equations on the DIF method. The equations of the weight factors obtained and the standard deviation with the DIF condition did not exist in the literature. Furthermore, the equations DIF-DEMATEL and DIF-utility are completely new.
- Using the judgment of the expert to obtain DIF weight to decrease the computation local weight error.
- Expanding multi-phase novel weighting approach to decrease the data lost.
- Developing the DIF utility novel method to show experts' weight.
- Extending the hierarchical structure to evaluate the risk of the BOT project.
- Extending the IF-OES to compute the score of each alternative.

In the rest of the paper in section 2, the proposed methodology collective criteria multi-phase weighting approach and DEMATEL method under DIF environment are proposed to select the BOT project critical risk. Section 3 is related to the validity of the proposed approach with generating the real case study and providing a comparative analysis. Meanwhile, the sensitivity analysis is represented in section 4. Finally, some conclusions and future suggestions are defined in section 5.

II. PROPOSED METHOD

This section introduces the framework of the proposed method that is included the weighting and scoring approaches. The weighting methods are consist of the collective method and DEMATEL technique. The proposed method is considered under dynamic conditions and is used the DIF principle in the calculation. The three stages of the method are related to DIF collective criteria stage, the DIF DEMATEL stage, and the integrated stage. The proposed method is used the SOE method to score the alternatives and is used the DIF-utility to decrease the error of the expert judgment. This method used the groups of DMs $(DM_S;\ DM_1, \dots DM_S)$, some of the alternatives $\left(A_j;\ A_1, \dots n\right)$ of criteria $(C_i;\ C_1, \dots C_m)$ and sub-criteria $\left(SC_g;\ SC_1, \dots SC_G\right)$ under multi-period $\left(T_f;\ T_1, \dots T_f\right)$.

Stage 1. This stage starts with controlling the local weight of criteria using the collective index method and standard deviation approach.

Step 1.1. The normalized DIF matrix (ξ_s^f) is determined.

Step 1.2. The normalized DIF decision matrix $\left(\Gamma_s^{wf}\right)$ calculates from Eq. (1), and the Sub-criteria weight normalized obtained based on the DMs opinions from criteria $\left(\eta_{si}^f\right)$ and sub-criteria $\left(\eta_{sg}^f\right)$.

$$\xi_s^{wf} = \begin{array}{c} \\ A_1 \\ \vdots \\ A_j \end{array} \begin{array}{c} \begin{array}{ccc} SC_1 & \dots & SC_G \end{array} \\ \begin{bmatrix} \Delta_{1s}^f\left[\mu_{11}^{sf}, v_{11}^{sf}\right] & \cdots & \Delta_{Gs}^f\left[\mu_{1G}^{sf}, v_{1G}^{sf}\right] \\ \vdots & \ddots & \vdots \\ \Delta_{1s}^f\left[\mu_{n1}^{sf}, v_{n1}^{sf}\right] & \cdots & \Delta_{Gs}^f\left[\mu_{nG}^{sf}, v_{nG}^{sf}\right] \end{bmatrix} \end{array} \qquad \forall f, s \tag{1}$$

The final weights of sub-criteria $\left(\Delta_{Gs}^{f}\right)$ are obtained from Eq. (2).

$$\Delta_{Gs}^{f} = \frac{\eta_{si}^{f}\eta_{sg}^{f}}{\sum_{g=1}^{G}\eta_{si}^{f}\eta_{sg}^{f}} \qquad \forall g \subseteq i \tag{2}$$

Step 1.3. The DIF overall evaluation score function (DIF-OES) (λ_{js}^{f}) determines in Eq. (3).

$$\lambda_{js}^{f} = \left[\prod_{g=1}^{G}\left(1-\mu_{(jg)s}^{w}\right), \prod_{g=1}^{G}\left(1-v_{(jg)s}^{w}\right)\right] \qquad \forall j, f, s \tag{3}$$

Step 1.4. It is essential to remove the sub-creation SC_r from the set of criteria to develop the impact of it on the decision-making process. The score function without ($\lambda_{j\acute{g}s}^{f}$) calculates with Eq. (4).

$$\lambda_{j\acute{g}s}^{f} = \left[\prod_{g=1,g\neq\acute{g}}^{G}\left(1-\mu_{(jg)s}^{w}\right), \prod_{g=1,g\neq\acute{g}}^{G}\left(1-v_{(jg)s}^{w}\right)\right] \qquad \forall j, \acute{g}, f, s \tag{4}$$

Step 1.5. The correlation between the DIF-OES and sub-criteria (φ_{gs}^{f}) obtains in Eq. (5).

$$\varphi_{gs}^{f} = \frac{1-\prod_{j=1}^{n}\left(1-\left(\varrho_{jgs}^{f}\times\varepsilon_{jgs}^{f}\right)\right)}{\sqrt{\left(1-\prod_{j=1}^{n}\left(1-{\varrho_{jgs}^{f}}^{2}\right)\right).\left(1-\prod_{j=1}^{n}\left(1-{\varepsilon_{jgs}^{f}}^{2}\right)\right)}} \qquad \forall g, f, s \tag{5}$$

where ϱ_{jgs}^{f} and ε_{jgs}^{f} obtain from Eqs. (6) and (7), respectively.

$$\varrho_{jgs}^{f} = \left(\frac{1}{E}\sum_{e=1}^{E}\left(\frac{1}{l}\sum_{P=1}^{l}\left[\frac{\prod_{g=1}^{G}\left(1-v_{(jg)s}^{\sigma(P)w}\right)+\prod_{g=1}^{G}\left(1-\mu_{(jg)s}^{\sigma(P)w}\right)}{2}\right]\right) + \left(\prod_{j=1}^{n}\xi_{(jg)s}^{wf}\right)^{\frac{1}{n}} - 1\right) \qquad \forall j, g, f, s \tag{6}$$

$$\varepsilon_{jgs}^{f} = \left(\frac{1}{E}\sum_{e=1}^{E}\left(\frac{1}{l}\sum_{P=1}^{l}\left[\frac{v_{(jg)s}^{\sigma(P)w}+\mu_{(jg)s}^{\sigma(P)w}}{2}\right]\right) + \left(\prod_{j=1}^{n}\lambda_{(jg)s}^{wf}\right)^{\frac{1}{n}} - 1\right) \qquad \forall j, g, f, s \tag{7}$$

Step 1.6. The local weight of sub-criteria obtains with Eq. (8).

$$\psi_{\acute{g}s}^{f} = \frac{1-\left(1-\sqrt{1-\varphi_{\acute{g}s}^{f}}\right)^{\sigma_{\acute{g}s}^{f}}}{\left[\sum_{g=1}^{G}\left(\frac{1-\left(1-\sqrt{1-\varphi_{\acute{g}s}^{f}}\right)^{\sigma_{\acute{g}s}^{f}}}{1-\prod_{g=1,g\neq\acute{g}}^{G}\left(1-\left(1-\sqrt{1-\varphi_{\acute{g}s}^{f}}\right)^{\sigma_{\acute{g}s}^{f}}\right)}\right)\right]\left(1-\prod_{g=1,g\neq\acute{g}}^{G}\left(1-\left(1-\sqrt{1-\varphi_{\acute{g}s}^{f}}\right)^{\sigma_{\acute{g}s}^{f}}\right)\right)} \quad \forall \acute{r}, p, k \tag{8}$$

Afterward, the value of the IF standard deviation $\left(\sigma_{\acute{g}s}^{f}\right)$ computes with Eq. (9).

$$\sigma_{\acute{g}s}^{f} = \sqrt[2G]{\left(1-\prod_{j=1}^{n}\left(1-\left(\frac{1}{E}\sum_{e=1}^{E}\left(\frac{1}{l}\sum_{\lambda=1}^{l}\left[\xi_{(j\acute{g})s}^{\sigma(P)f}\right]\right)-\varrho_{j\acute{g}s}^{f}\right)^{2}\right)\right)} \quad \forall \acute{g}, f, s \tag{9}$$

Stage 2. In this stage, the weight of each DM computes with the DIF-utility degree technique.

Step 2.1. The normalized DIF decision matrix (ξ_{s}^{f}) computes from step 1.1.

Step 2.2. The Eqs. (10) and (11) show the DIF positive ideal solution (PIS) (χ^{+f}) and the negative ideal solution (NIS) (χ^{-f}).

$$\chi^{+f} = \left(\left[\mu_{jg}^{+f}, v_{jg}^{+f}\right]\right)_{n\times G} = \begin{cases} \mu_{jg}^{+f} = 1-\sqrt[s]{\prod_{s=1}^{S}\left(1-\mu_{jg}^{+sf}\right)} \\ v_{jg}^{+f} = 1-\sqrt[s]{\prod_{s=1}^{S}\left(1-v_{jg}^{+sf}\right)} \end{cases} \tag{10}$$

$$\chi^{-f} = \left(\left[\mu_{ir}^{-f}, v_{ir}^{-f}\right]\right)_{n\times G} = \min_{s}\left\{\left[v_{(jg)s}^{f}\right]_{n\times G}\right\} \tag{11}$$

Step 2.3. The PIS and NIS separation scale under DIF condition $\left(\rho_{s}^{+f}, \rho_{s}^{-f}\right)$ calculate with Eqs. (12) and (13).

$$\rho_{s}^{+f} = \frac{\left(\sum_{j=1}^{n}\sum_{g=1}^{G}\sum_{P=1}^{l}\left(\left|\vartheta_{(jg)s}^{\sigma(P)f} - \varepsilon_{jgs}^{+\sigma(P)f}\right|^{2}\right)\right)^{\frac{1}{2}}}{\sqrt{2l}} \quad \forall\, s, f \tag{12}$$

$$\rho_{s}^{-f} = \frac{\left(\sum_{j=1}^{n}\sum_{g=1}^{G}\sum_{P=1}^{l}\left(\left|\vartheta_{(jg)s}^{\sigma(P)f} - \varepsilon_{jgs}^{-\sigma(P)f}\right|^{2}\right)\right)^{\frac{1}{2}}}{\sqrt{2l}} \quad \forall\, s, f \tag{13}$$

Step 2.4. The DIF relative coefficient of every expert in each time period (θ_s^f) obtains in Eq. (14), and the experts' weights in the planning horizon (θ_s) computes with Eq. (15).

$$\theta_s^f = \frac{\eta_k^{-p}\left(\sum_{s=1}^{S}\frac{\rho_s^{-f}}{\rho_s^{-f}+\rho_s^{+f}}\right)^{-1}}{\eta_k^{-p}+\rho_s^{+f}} \qquad \forall\, s,f \qquad (14)$$

$$\theta_s = \frac{\bigoplus_{s=1}^{S}\left(\theta_s^f\right)^{\frac{1}{f}}}{\sum_{s=1}^{S}\left(\bigoplus_{f=1}^{F}\left(\theta_s^f\right)^{\frac{1}{f}}\right)} = \frac{\prod_{s=1}^{S}\left(\theta_s^f\right)^{\frac{1}{f}}}{\sum_{s=1}^{S}\left(\bigoplus_{f=1}^{F}\left(\theta_s^f\right)^{\frac{1}{f}}\right)} \qquad \forall\, s \qquad (15)$$

Stage 3. The final aggregation hierarchical decision level global weights (W_j) computes from Eq. (16).

$$W_j = \frac{w_{(1i)} \times w_{(1\acute{\iota})}}{\sum_{i=1}^{m}\left(w_{(1i)} \times w_{(1\acute{\iota})}\right)} \qquad \forall \jmath \in \acute{\jmath} \qquad (16)$$

where $w_{(1i)}$ is the ith sub-criteria dependent to $\acute{\iota}\ th$ criterion ($w_{(1\acute{\iota})}$).

Step 4. The normalized IF weights decision matrix based on the experts' opinions $\left(S_{ij}^{kf} = \left[\mu_{ij}^{sf}, v_{ij}^{sf}\right]_{n\times m}\right)$ in Eq. (17).

$$S^{sf} = \begin{array}{c} \\ A_1 \\ \vdots \\ A_n \end{array}\begin{array}{c} \begin{array}{ccc} C_1 & \cdots & C_m \end{array} \\ \begin{bmatrix} W_1\left[\mu_{11}^{sf}, v_{11}^{sf}\right] & \cdots & W_m\left[\mu_{1m}^{sf}, v_{1m}^{sf}\right] \\ \vdots & \ddots & \vdots \\ W_1\left[\mu_{n1}^{sf}, v_{n1}^{sf}\right] & \cdots & W_m\left[\mu_{nm}^{sf}, v_{nm}^{sf}\right] \end{bmatrix}_{n\times m} \end{array} \qquad \forall s \qquad (17)$$

Step 5. compute the IF normalized weight of positive, left, and suitable negative ideal decision matrix for each expert (S^{sf}).

Step 6. The distance between the positive ideal value (ζ^{+}) and the IF normalized weighted decision matrix for each expert (S^{s}) obtain with Eq. (18).

$$\zeta_i^{+sf} = \sum_{j=1}^{n}\sqrt{\frac{1}{2n}\left(\left|S_{ij}^{sf} - \mu_{ij}^{+\epsilon f}\right|^2 + \left|S_{ij}^{sf} - v_{ij}^{+\epsilon f}\right|^2\right)} \qquad \forall i,s,f \qquad (18)$$

Step 7. The distance between the left and right negative ideal decision matrix (ζ^{-L},ζ^{-R}) and the IF normalized weighted decision matrix for each expert compute with Eqs. (19) and (20), respectively.

$$\zeta_i^{-sLf} = \sum_{j=1}^{n}\sqrt{\frac{1}{2n}\left(\left|S_{ij}^{sf} - \mu_{ij}^{-L\epsilon f}\right|^2 + \left|S_{ij}^{sf} - v_{ij}^{-L\epsilon f}\right|^2\right)} \qquad \forall i,s,f \qquad (19)$$

$$\zeta_i^{-sRf} = \sum_{j=1}^{n} \sqrt{\frac{1}{2n}\left(\left|S_{ij}^{sf} - \mu_{ij}^{-R\epsilon f}\right|^2 + \left|S_{ij}^{sf} - \nu_{ij}^{-R\epsilon f}\right|^2\right)} \qquad \forall i, s, f \tag{20}$$

Step 8. The importance degree of the candidate obtains from the aggregation collection approach (ψ_i) with Eq. (21).

$$\psi_i = \frac{\prod_{s=1}^{S}\left(\zeta_i^{-sLf}\right)^{\varphi_s} + \prod_{s=1}^{S}\left(\zeta_i^{-sRf}\right)^{\varphi_s}}{\prod_{s=1}^{S}\left(\zeta_i^{-sLf}\right)^{\varphi_s} + \prod_{s=1}^{S}\left(\zeta_i^{-sRf}\right)^{\varphi_s} + \prod_{s=1}^{S}\left(\zeta_i^{+sf}\right)^{\varphi_s}} \qquad \forall i, s, f \tag{21}$$

Step 9. The candidates rank with the aggregation collection set by incrementing sorting method.

III. CASE STUDY AND COMPARATIVE ANALYSIS

A. Problem description and proposed method implementation

This section is created based on the highway construction BOT project. This section is implemented based on various strategies and is proposed the computational results to validate the generated approach. Hence, the 3 DMs (DM_1, DM_2, DM_3) use to compute the three various strategies. These are used this approach with eight sub-criteria $(SC_1, SC_2, \dots, SC_8)$ under two time periods (t_1, t_2). This section is made based on four essential criteria (C_1, C_2, C_3, C_4). These are included, infrastructure and resources criteria, design and implementation criteria, financial criteria, and environmental criteria. This paper is developed the proposed approach in the two time periods. The first period is relevant to the normal condition, and the second period is relevant to the various economic disruption scenarios. In this issue, the DMs considered their dynamic evaluations in the first and third phases of the project life cycle as two essential factors that their risks can be affected the project deliverables. Also, the main three strategies that DMs are used to take the appropriate decision are generated as follow:

- S_1: Tender winner performance strategy;
- S_2: Outsourcing strategy;
- S_3: Joint venture strategy.

Hence, Table I generates the linguistic variables to evaluate the criteria with DMs opinions, and Table II shows how to evaluate the sub-criteria. Also, the pairwise comparison matrix develops for criteria and sub-criteria in Table III. Furthermore, the estimation of criteria, sub-criteria, and candidate strategies generate in Tables VI, V, and VI, respectively.

Table I. The linguistic variables to evaluate the importance of the attributes

Linguistic variables	IFVs
Very low (VL)	(0.1,0.1)
Low (L)	(0.2,0.3)
Medium (M)	(0.3,0.5)
High (H)	(0.4,0.6)
Very high (VH)	(0.45,0.55)

Table II. The linguistic variables to evaluate the potential strategies

Linguistic variable	IFVs
Absolutely high (AH)	(0.49,0.5)
Very very high (VVH)	(0.47,0.49)
Very high (VH)	(0.45,0.47)
High (H)	(0.43,0.45)
Medium high (MH)	(0.4,0.43)
Medium (M)	(0.35,0.4)
Medium low (ML)	(0.3,0.35)
Low (L)	(0.2,0.25)
Very low (VL)	(0.15,0.2)
Very very low (VVL)	(0.1,0.1)

Table III. Pairwise comparison matrix to determine linguistic value of criteria weights

Criteria	***Infrastructure and resources criteria***	***Design and implementation criteria***	***Financial criteria***	***Environmental criteria***
$\boldsymbol{DM_1}$				
Infrastructure and resources criteria (C_1)	0	M	L	M
Design and implementation criteria (C_2)	M	0	VH	M
Financial criteria (C_3)	L	VH	0	M
Environmental criteria (C_4)	M	M	M	0
$\boldsymbol{DM_2}$				
Infrastructure and resources criteria (C_1)	0	H	M	M
Design and implementation criteria (C_2)	H	0	VH	H
Financial criteria (C_3)	M	VH	0	M
Environmental criteria (C_4)	M	H	M	0
$\boldsymbol{DM_3}$				
Infrastructure and resources criteria (C_1)	0	M	L	L
Design and implementation criteria (C_2)	M	0	H	M
Financial criteria (C_3)	L	H	0	VL
Environmental criteria (C_4)	L	M	VL	0

Table VI. Evaluating the candidate strategies under the criteria via linguistic variables

Sub-criteria	DM_1						DM_2						DM_3					
	T_1			T_2			T_1			T_2			T_1			T_2		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
Technological Capability (SC_{11})	M	H	AH	MH	MH	VVH	L	M	H	ML	MH	VH	M	M	VVH	M	H	H
Employment (SC_{12})	AH	M	H	VVH	MH	VH	VH	MH	VH	H	M	H	AH	H	H	VH	H	VH
Run time (SC_{21})	M	H	M	M	MH	M	L	M	ML	L	M	ML	M	M	M	VL	VH	ML
Resilience (SC_{22})	M	H	M	MH	MH	ML	VVH	VH	VVH	VH	VVH	AH	M	VH	M	VH	H	VH
Profitability (SC_{31})	H	MH	H	ML	H	H	MH	VH	H	M	VH	H	H	M	MH	L	VH	H
Return on Investment Rate (SC_{32})	VVH	VH	VH	VH	VVH	MH	VH	H	VH	M	VH	VH	AH	HH	VVH	ML	VH	MH
Environmental Damage Risk (SC_{41})	VVL	AH	VH	VVL	AH	VVH	VL	H	MH	VVL	H	MH	L	H	H	VL	VH	H
Risk of contingencies (corona, earthquake, etc.) (SC_{42})	H	VH	H	H	AH	VH	M	MH	ML	M	VVH	VH	ML	MH	MH	ML	H	H

Table V. Linguistic terms of the local weights of criteria

Criteria	DM_1		DM_2		DM_3	
	T_1	T_2	T_1	T_2	T_1	T_2
C_1	H	M	M	M	VH	H
C_2	VH	H	VH	H	H	VH
C_3	H	M	H	VH	M	H
C_4	L	M	M	M	M	H

Table VI. Linguistic terms of the local weights of sub-criteria

Criteria	***Sub-criteria***	DM_1		DM_2		DM_3	
		T_1	T_2	T_1	T_2	T_1	T_2
C_1	SC_{11}	H	VH	M	H	VH	H
	SC_{12}	H	M	VH	H	VH	VH
C_2	SC_{21}	H	M	M	H	VH	H
	SC_{22}	M	H	VH	H	H	M
C_3	SC_{31}	H	M	M	M	VH	VH
	SC_{32}	VH	H	M	H	VH	VH
C_4	SC_{41}	M	M	VH	H	L	M
	SC_{42}	M	M	H	M	VL	VL

Afterward, the combination DIF-collective index method to obtain the local weights of attributes consist of the DIF-correlation and standard deviation method. The final local weights of sub-criteria are generated in Table VII.

Table VII. The final local weights of the sub-criteria

Criteria	*Sub-criteria*	DM_1		DM_2		DM_3	
		T_1	T_2	T_1	T_2	T_1	T_2
C_1	SC11	0.75005	0.651809	0.79062	0.613496	0.91675	0.72889
	SC12	0.61065	0.66207	0.66692	0.63661	0.68502	0.64649
C_2	SC21	0.79143	0.85543	0.90565	0.87426	0.97775	0.92070
	SC22	0.70936	0.73724	0.68810	0.65687	0.67377	0.64032
C_3	SC31	0.72549	0.78456	0.84595	0.69096	0.73638	0.72962
	SC32	0.61065	0.67569	0.74176	0.67950	0.69792	0.69862
C_4	SC41	0.80359	0.71073	0.82864	0.71399	0.92362	0.81145
	SC42	0.72993	0.69421	0.72488	0.65050	0.73592	0.79388

Table VIII generates the experts' weights that are obtained from DIF-utility proposed method, NIS and PIS degree computation comes from Eqs. (12)-(13).

Table VIII. The weights of the experts

DM	η_k^{+p}		η_k^{-p}		θ_k^p		θ_k
	T_1	T_2	T_1	T_2	T_1	T_2	
DM_1	0.1632	0.112	9.91942	10.18268	1.487791	0.007312	0.440353
DM_2	0.0568	0.069	10.45339	10.26686	0.809535	0.008246	0.245063
DM_3	0.0755	0.0839	10.11056	10.12261	0.901688	0.009117	0.314584

Afterward, the aggregation of separation measures is generated in Table IX. Table X introduces the final rank of the strategies with the proposed method.

Table IX. The aggregation of separation measures and last aggregation index

Alternatives	ζ_i^{+k}	ζ_i^{-kL}	ζ_i^{-kR}	ψ_i
S_1	0.01926	0.00041	0.02010	0.51565
S_2	0.05691	0.00430	0.05502	0.51040
S_3	0	0.00107	0	1

Table X. The ranking of the strategies

Alternatives	*The rank of the proposed method*
S_1	2
S_2	3
S_3	1

Table 9 shows that the third strategy has a high rank among other them and the first and the second strategies place in the next properties, respectively. Eventually, the proposed method and the SAW method were compared with them to determine the efficiency of the proposed approach. The final results of the SAW ranks show in Table X, and the comparison of the aggregation values is generated in Fig. 1.

Table XI. The Final ranking among strategies with two approaches

Proposed method rank	*SAW method rank*	*Aggregation values*
2	2	0.48613
3	3	0.25459
1	1	0.86413

B. Comparative analysis

As it is represented in Table 10, the proposed approach of this study is compared with a popular method that is called the SAW methodology. Both approaches reach the same ranking result, but comparing the obtained results in detail can help users consider the contributions of this study as they want a precise solution. Therefore, the normalized standard deviation factor is considered to show the performance of the proposed method regarding the SAW methodology by considering the contributions of this study individually. The standard deviation factor is computed for ranking results that represent the distance between ranking values. When this factor is high, the candidates could take it apart from together, and users could select the best one easily. Meanwhile, the proposed approach and the SAW methodology are implemented in case of considering the last aggregation concept, criteria weights determination,

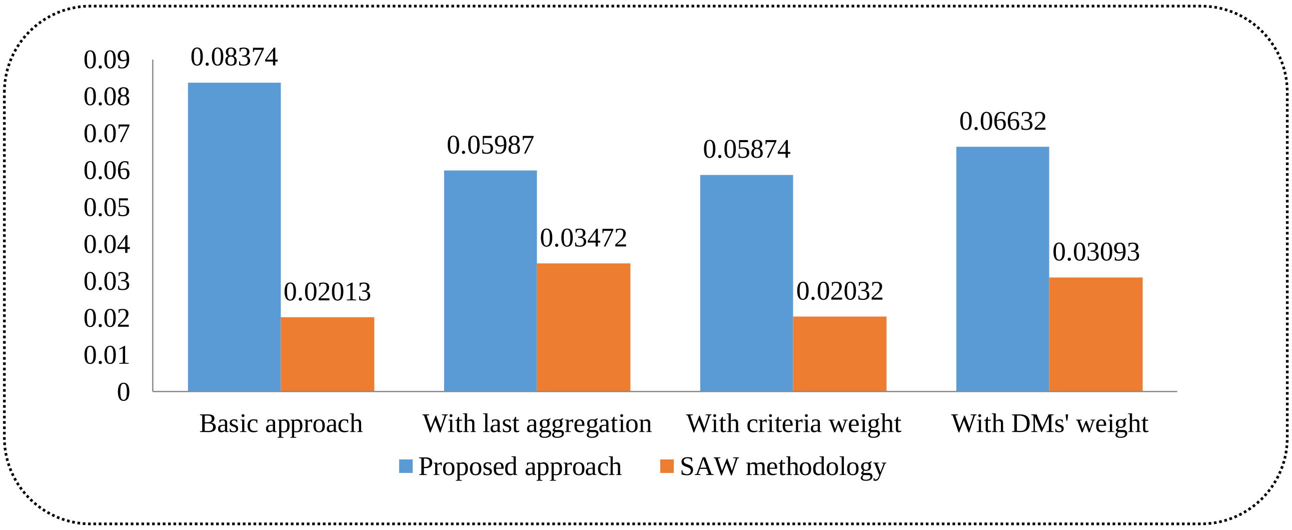

Figure 1. The standard deviation values for considering contributions of the proposed approach and SAW methodology

experts' weights computations, and basic approaches. As represented in Figure 1, the proposed approach regarding the SAW methodology has a better performance based on all considered contributions. In addition, the results represented that the SAW methodology with considering the last aggregation concept or experts' weights computations could increase the standard deviation factor.

As depicted in Figure 1, eliminating each contribution of the proposed approach could reduce their efficiency. Meanwhile, the proposed approach regarding its contributions could be appropriate versus the SAW methodology. To address the issue, the dispersion of standard deviation values regarding the contributions of the proposed approach and SAW methodology is depicted in Figure 2.

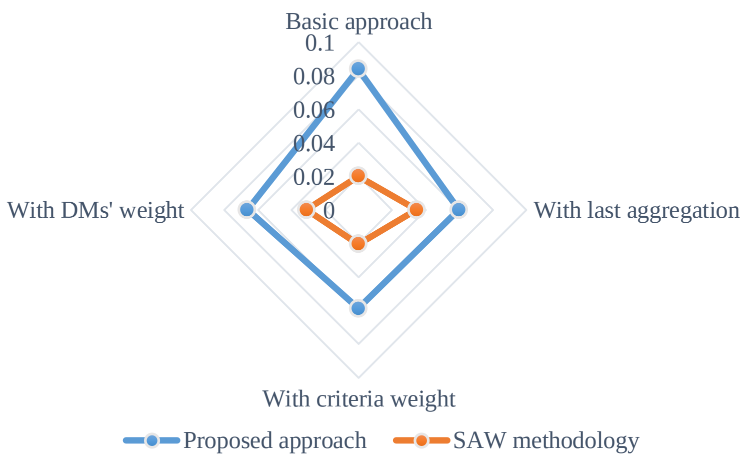

Figure 2. The dispersion of standard deviation values for the proposed approach based on four points of view

IV. SENSITIVITY ANALYSIS

Criteria weights computations are one of the main factors not to affect standard deviation values. Therefore, in this section, a sensitivity analysis is provided to represent the effect of criteria weights changing on candidate ranking results. Thus, the criteria weights are increased by adding the τ values to them, and then the criteria weights are normalized and considered in the process of the proposed approach to show its effects on the candidate ranking results. Meanwhile, the sensitivity analysis indicates that the obtained candidates ranking results is sensitive to criteria weights for $\tau < 0.5$. The aforementioned results are reported in Table XII.

Table XII. The sensitivity analysis based on attributes weights

τ values	*Attributes*	*Weights*	*Ranking results*
$\tau = 0.10$	C_1	0.308213	$A_2 > A_3 > A_2$
	C_2	0.269701	
	C_3	0.213469	
	C_4	0.208617	
$\tau = 0.30$	C_1	0.286021	$A_2 > A_3 > A_2$
	C_2	0.262191	
	C_3	0.227395	
	C_4	0.224393	

Continue Table XII. The sensitivity analysis based on attributes weights

τ values	*Attributes*	*Weights*	*Ranking results*
$\tau = 0.50$	C_1	0.276079	$A_3 > A_1 > A_2$
	C_2	0.258826	
	C_3	0.233634	
	C_4	0.231461	
$\tau = 0.70$	C_1	0.270438	$A_3 > A_1 > A_2$
	C_2	0.256917	
	C_3	0.237174	
	C_4	0.235471	
$\tau = 0.90$	C_1	0.266803	$A_3 > A_1 > A_2$
	C_2	0.255687	
	C_3	0.239455	
	C_4	0.238054	

Moreover, the trends of criteria weights represent that changing the criteria weights led to different ranking results. It shows that by increasing the τ values, the criteria weights are closer to each other, and the best candidate from A_2 leads to A_3.

V. CONCLUSIONS AND FUTURE SUGGESTIONS

Today, one of the problems and concerns of governments and countries in the construction and equipment of infrastructure and structure projects is related to the provision of financial and operational resources along with the risks in the project. Large and structural projects in practice can face large and small risks, which require sufficient knowledge of the type of risks and environmental conditions of the project along with the science of risk management. In order to prevent damage to countries due to project risks, one of the solutions has been to build projects with the BOT approach. In this study, in order to use this method, first, the project risks were identified and using the proposed approach based on standard deviation, utility method, and the proposed ranking approach under the conditions of intuitionistic fuzzy uncertainty—afterward, the proposed method used to solve and rank the existing strategies in the project. Furthermore, the real case study of highway construction was generated to validate the proposed method and measure its efficiency of it to compute and rank the various types of problems. The results of the real case study show that the third option, which is related to joint ventures, is more important than other cases. The notable point of the paper is related to the multi-period decision-making process that is caused to change IF environment to DIF environment. It is worthwhile to note that the main limitation of this study is computational complexity that led to spending more time on large-scale decision-making problems. Finally, for future research, a search engine can be used in the fuzzy mechanism of the problem.

REFERENCES

Akram, M., Ilyas, F., & Garg, H. (2020). Multi-criteria group decision making based on ELECTRE I method in Pythagorean fuzzy information. *Soft Computing*, *24*(5), 3425-3453.

Bagui, S. K. (2011). Risk analysis for a BOT project. *Jordan journal of Civil engineering*, *159*(2985), 1-13.

Borujeni, M. P., & Gitinavard, H. (2017). Evaluating the sustainable mining contractor selection problems: An imprecise last aggregation preference selection index method. *Journal of Sustainable Mining*, 16(4), 207-218.

Chen, Z., Ye, H., Liu, B., & Xue, W. (2021). Analysis of road capacity and franchise price decision delegation in toll road BOT project. *Transportation Research Part E: Logistics and Transportation Review*, *146*, 102213.

Chiara, N., & Garvin, M. J. (2008). Variance models for project financial risk analysis with applications to greenfield BOT highway projects. *Construction management and economics*, *26*(9), 925-939.

Ebrahimnezhad, S., Gitinavard, H., & Sohrabvandi, S. (2017). A new extended analytical hierarchy process technique with incomplete interval-valued information for risk assessment in IT outsourcing. *International Journal of Engineering*, 30(5), 739-748.

Ebrahimnejad, S., Naeini, M. A., Gitinavard, H., & Mousavi, S. M. (2017). Selection of IT outsourcing services' activities considering services cost and risks by designing an interval-valued hesitant fuzzy-decision approach. *Journal of Intelligent & Fuzzy Systems*, 32(6), 4081-4093.

Fahad Al-Azemi, K., Bhamra, R., & Salman, A. F. (2014). Risk management framework for build, operate and transfer (BOT) projects in Kuwait. *Journal of civil engineering and management*, *20*(3), 415-433.

Hamzeh, A. M., Mousavi, S. M., & Gitinavard, H. (2020). Imprecise earned duration model for time evaluation of construction projects with risk considerations. *Automation in Construction*, 111, 102993.

Gitinavard, H., Mousavi, S. M., Vahdani, B., & Siadat, A. (2020). Project safety evaluation by a new soft computing approach-based last aggregation hesitant fuzzy complex proportional assessment in construction industry. *Scientia Iranica*, 27(2), 983-1000.

Gitinavard, H., & Mousavi, S. M. (2015). Evaluating construction projects by a new group decision-making model based on intuitionistic fuzzy logic concepts. *International Journal of Engineering*, 28(9), 1312-1319.

Gitinavard, H. (2019). Strategic Evaluation of Sustainable Projects based on Hybrid Group Decision Analysis with Incomplete Information. *Journal of Quality Engineering and Production Optimization*, 4(2), 17-30.

Gitinavard, H., & Zarandi, M. H. F. (2016). A mixed expert evaluation system and dynamic interval-valued hesitant fuzzy selection approach. *International Journal of Mathematical and Computational Sciences*, 10(7), 341-349.

Gitinavard, H., Makui, A., & Jabbarzadeh, A. (2016). Interval-valued hesitant fuzzy method based on group decision analysis for estimating weights of decision makers. *Journal of Industrial and Systems Engineering*, 9(3), 96-110.

Mousavi, S. M., & Gitinavard, H. (2019). An extended multi-attribute group decision approach for selection of outsourcing services activities for information technology under risks. *International Journal of Applied Decision Sciences*, 12(3), 227-241.

Mousavi, S. M., Gitinavard, H., & Siadat, A. (2014, December). A new hesitant fuzzy analytical hierarchy process method for decision-making problems under uncertainty. In 2014 IEEE International Conference on Industrial Engineering and Engineering Management (pp. 622-626). IEEE.

Muriana, C., & Vizzini, G. (2017). Project risk management: A deterministic quantitative technique for assessment and mitigation. *International Journal of Project Management*, *35*(3), 320-340.

Okudan, O., Budayan, C., & Dikmen, I. (2021). A knowledge-based risk management tool for construction projects using case-based reasoning. *Expert Systems with Applications*, *173*, 114776.

Solgi, E., Husseini, S. M. M., Ahmadi, A., & Gitinavard, H. (2019). A hybrid hierarchical soft computing approach for the technology selection problem in brick industry considering environmental competencies: A case study. *Journal of environmental management*, 248, 109219.

Vahdani, B. (2016). Solving robot selection problem by a new interval-valued hesitant fuzzy multi-attributes group decision method. *International Journal of Industrial Mathematics*, 8(3), 231-240.

Zhao, Z. Y., Zuo, J., & Zillante, G. (2013). Factors influencing the success of BOT power plant projects in China: A review. *Renewable and Sustainable Energy Reviews*, *22*, 446-453.