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An Integrated Group Decision Analysis Framework to Evaluate the 3P Projects in Intuitionistic Fuzzy Setting

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Abstract *– In today's world, one of the most efficient ways to build large projects and infrastructure is related to public-private partnership (3P) projects. This method is based on the partnership between the public and private sectors and exempts the government from providing financial, human and equipment resources along with taking risks in the construction of the project. In this method, after construction and operation, the project is handed over to governments and made available to the public. In this article, following the removal of obstacles to production and development projects, we used 3P approach in the face of intuitive fuzzy uncertainty to bring management decisions closer to the outside world. Meanwhile, an integrated group decision analysis based on intuitionistic fuzzy utility degree method and intuitionistic fuzzy preference evaluation technique is tailored to compute the experts' weights and criteria importance, respectively. Then, a novel ranking approach based on positive/negative ideal solutions and relative closeness coefficient under intuitionistic fuzzy set theory is proposed to solve the 3P urban development project selection problem. Finally, in order to evaluate the proposed method and determine its efficiency for use in large projects, a case study of urban development is used, and comparisons are made between previous methods and the proposed method.*

Keywords*–3P projects, Intuitionistic fuzzy sets, Group decision analysis, Ranking alternatives method*

I. INTRODUCTION

Today, the issue of economic development has become one of the most important issues in different countries in the world, which always has many challenges. This is different in each area. Economic development in a state requires enterprise in several sections and economic activities; To the operations that without investing in foundation projects, one cannot envisage the expansion of employment, production, and economic success (Abad-Segura and González-Zamar, 2021). Novel projects and their appropriate performance with time and cost estimates are known as the main index of a dynamic and successful economy (Ren et al., 2021). One of the most important areas in any government is related to the development and construction of infrastructure and construction projects (Hamzeh et al., 2020; Gitinavard et al., 2020). Construction projects have always been associated with the challenges of delayed delivery and estimated costs, which has led governments to stop participating directly in construction (Gitinavard, 2019; Davoudabadi et al., 2019). To this end, the use of the private sector alongside the public sector in infrastructure construction is recommended. Using the private

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sector along with the public sector can significantly help the public sector in providing financial and human resources for the construction, completion, and implementation of infrastructure projects (Gitinavard and Mousavi, 2015; Wen, 2021).

As mentioned earlier, one of the most important and effective areas in the field of construction has been related to the field of construction projects. Development projects are the largest part of the financial and economic cycle of the country and alone have a great impact on the financial and economic policies of different countries (Borujeni and Gitinavard, 2017). Therefore, time and cost control in these projects is very important (Ebrahimnejad et al., 2017; Zhang et al., 2021). Among these, one of the methods used in the field of manufacturing and production is related to the consultation of the private and public sectors simultaneously. The private sector acts as an investor and fully assumes all financial, human and equipment capital. Projects based on construction and participation in the public and private sectors are called public-private partnership (3P) projects (Tang et al., 2010).

In 3P projects, the main requirement to start working is to have common interests and resources between the public and private sectors, and this means creating a division of resources between the two sectors to complement each other and create the final product (Kryukov et al., 2016). The use of this technique allows the public sector, which is generally made up of governments, to look at large-scale infrastructure projects that it has not been able to implement before (Mousavi and Gitinavard, 2019). In this way, governments use private sector leverage as intermediaries and start building large projects (Cheng et al., 2021). Infrastructure and labor laws are among the main variables affecting the attraction of partnerships and private sector capital, and this can increase the level of participation of the private sector and investors and thus increase economic growth. The existence of an index related to labor laws can attract more investors (Kilinkarova et al., 2020).

In a general definition, public-private partnership refers to an investment project in which a government-owned company operates with one or more private companies to finance, build, and operate projects. In this type of approach, the profit from the partnership is divided among the existing sectors. Simply put, these projects are based on the public sector using the knowledge, experience and financial resources of the private sector (Khan et al., 2020). In the first step, specific contracts should be drawn up between the public and private sectors, in which the sharing of all benefits and risks is mentioned, and the synergy of resources and expertise is seen in it (Solgi et al., 2019). At this time, governments are changing their role from investor and executor to regulator and quality overseer (Zhang et al., 2019). Finally, construction projects based on 3P contracts are a kind of long-term project based on the participation of both public and private sectors and lead the project to common goals between the two sectors. In these projects, the infrastructure is provided by the private sector. One of the most important challenges in attracting investors is the proper way of financing by the private sector (Djabbari, 2021; Yurdakul and Kamasak, 2021).

Facing any of the challenges in the provision of resources for the private sector requires the use of appropriate management techniques to make the best decision in the shortest time. One of the major problems facing the private sector in terms of investment is the uncertainty in construction systems (Boniotti, 2021; Miasa and Apitsa, 2021). Various private companies are always faced with uncertainty, risks and challenges that can lead to project failure and complete loss of capital. The use of existing approaches in conditions of uncertainty can significantly help the management level to make appropriate management decisions (Vahdani, 2016). This paper to cope with this condition is used intuitionistic fuzzy (IF) approach. Afterward, the groups of the decision makers (DMs) and experts are used to analyze the project condition under fuzzy intuitionistic environment (Gitinavard et al., 2016). The IF technique consists of the membership function and non-membership function (Alcantud et al., 2020). This approach is related to the multi-criteria group decision making (MCGDM) that helps to make an appropriate management decision (Ebrahimnezhad, 2017; Gitinavard and Mousavi, 2015). Also, this paper is conducted based on the real case study of development urban project under 3P environment. After that, the criteria identify and implement the proposed method under intuitionistic fuzzy conditions. The proposed method consists of two main sectors that are included the computation weighting technique and the ranking alternatives method under intuitionistic fuzzy environment. For this reason, the case study of development urban construction project uses to validate the proposed soft computing method. In sum, the merits and advantages of the proposed approach are defined as follows:

- Extending the utility degree method under intuitionistic fuzzy approach (IF-UD) to determine the experts' weights;
- Computing the criteria weights by developing intuitionistic fuzzy preference evaluation (IF-PE) method;
- Proposing a novel ranking approach based on positive/negative ideal solutions and relative closeness coefficient under IFSs theory;
- Considering a real case study about the 3P urban development project selection problem.

The rest of the paper includes Sect. 2, preliminaries are developed about the IFs. In Sect. 3, the novel method is illustrated in detail. In Sect. 4, one application example is considered to determine the validation and ability and appropriateness of the generated method. Also, respective analysis has been considered to show the performance of the proposed approach. Eventually, the conclusion and future suggestions are described in Sect. 5.

II. PRELIMINARIES

This sector is developed the usage various operator of the IFS for the proposed method. Also, this point is described with basic definitions of the IF approach.

Definition 1. (Atanassov, 1986). Let Y be a universe discourse. The IFS R of Y is an object determine in Eq. (1).

$$R = \{\langle y, \mu_R(y), v_R(y), \pi_R(y)\rangle | y \in Y\} \tag{1}$$

where, the amount of the membership function $\mu_R: Y \to [0,1]$ and non-membership function $v_R: Y \to [0,1]$ that the membership function and non-membership function mean a rate of membership and a degree of non-membership of the element y in the set R. Hence, for each $y \in Y$ examined $0 \le \mu_R(y) + v_R(y) \le 1, \pi_R = 1 - \mu_R - v_R$.

Definition 2. (Atanassov, 1994; De et al., 2000, Xu and Yager, 2008). Let R and Q are two IFSs from set of Y; then, the relations are defined in Eqs. (2) -(8).

$$\mathrm{R}\oplus\mathrm{Q} = \left\{\langle y, \mu_R(y) + \mu_Q(y) - \mu_R(y).\mu_Q(y), v_R(y).v_Q(y), 1 - \mu_R(y) - \mu_Q(y) + \mu_R(y)\mu_Q(y) - v_R(y)v_Q(y)\rangle\right\} \tag{2}$$

$$R\otimes Q = \left\{\langle y, \mu_R(y).\mu_R(y), v_R(y) + v_Q(y) - v_R(y).v_Q(y), 1 - \mu_R(y)\mu_Q(y) - v_R(y) - \mu_Q(y) + v_R(y)v_Q(y)\rangle\right\} \tag{3}$$

$$R^\lambda = \left\{\langle y, \mu_R(y)^\lambda, 1 - (1 - v_R(y)^\lambda)| y \in R\rangle\right\}, \lambda > 0; \tag{4}$$

$$\lambda R = \left\{\langle y, 1 - (1 - \mu_R(y))^\lambda, v_R(y)| y \in R\rangle\right\}, \lambda > 0; \tag{5}$$

Definition 3. (Szmidt and Kacprzyk, 2000). The hamming and Euclidean distances of two IFSs for $Y = \{y_1, y_2, \dots, y_M\}$ is obtained with Eqs. (11) and (12).

$$d_H(R,Q) = \sum_{i=1}^{M} \frac{1}{2m}\left(\left|\mu_R(y_i) - \mu_Q(y_i)\right| + \left|v_R(y_i) - v_Q(y_i)\right| + \left|\pi_R(y_i) - \pi_Q(y_i)\right|\right) \tag{6}$$

$$d(R,Q) = \sqrt{\frac{1}{2m}\sum_{i=1}^{M}\left(\left(\mu_R(y_i) - \mu_Q(y_i)\right)^2 + \left(v_R(y_i) - v_Q(y_i)\right)^2 + \left(\pi_R(y_i) - \pi_Q(y_i)\right)^2\right)} \tag{7}$$

Definition 4. (Xu and Yager, 2008). The intuitionistic fuzzy weight averaging (IFWA) obtains with Eq. (13).

$$IFWA_w(R(y_1), R(y_2), \dots, R(y_i)) = [\prod_{i=1}^{M}(\mu_R(y_i))^{w_i}, -\prod_{i=1}^{M}(1 - v_R(y_i))^{w_i}, \prod_{i=1}^{M}(1 - v_R(y_i))^{w_i} - \prod_{i=1}^{M}(\mu_R(y_i))^{w_i}] \tag{8}$$

The weight vector $w_i = (w_1, w_2, \dots, w_N)^T$ generates in this equation.

Definition 5. (He et al., 2014) The intuitionistic fuzzy weighted geometric (IFWG) calculates from Eq. (14).

$$IFWG(R(y_1), R(y_2), \dots, R(y_i)) = \langle \frac{2\prod_{i=1}^{M}(\mu_R(y_i))^{w_i}}{\prod_{i=1}^{M}(2-\mu_R(y_i))^{w_i} + \prod_{i=1}^{M}(\mu_R(y_i))^{w_i}}, \frac{\prod_{i=1}^{M}(1+v_R(y_i))^{w_i} - (1-v_R(y_i))^{w_i}}{\prod_{i=1}^{M}(1+v_R(y_i))^{w_i} + (1-v_R(y_i))^{w_i}} \rangle \quad (9)$$

III. PROPOSED INTEGRATED GROUP DECISION-BASED SOFT COMPUTING METHOD

This section is proposed a novel soft computing method, which is consisted of the calculation of the criteria and DMs weights and rank of the main alternatives, respectively. For this reason, the generated method has used the groups of the DMs $(DM_k, k = 1,2,3, \dots, K)$, the various conflicting criteria $(C_j, j = 1,2,3, \dots, n)$, and the potential alternatives $(A_i, i = 1,2,3, \dots, m)$. The relation of the computation novel method is described as follows:

Step 1. The group decision matrix (A) generates in Eq. (16).

$$A = \begin{array}{c} \\ A_1 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & \dots & C_j \end{array} \\ \begin{bmatrix} \{[\mu_{11}^1, v_{11}^1], [\mu_{11}^2, v_{11}^2], \dots, [\mu_{11}^k, v_{11}^k]\} & \cdots & \{[\mu_{1n}^1, v_{1n}^1], [\mu_{1n}^2, v_{1n}^2], \dots, [\mu_{1n}^k, v_{1n}^k]\} \\ \vdots & \ddots & \vdots \\ \{[\mu_{m1}^1, v_{m1}^1], [\mu_{m1}^2, v_{m1}^2], \dots, [\mu_{m1}^k, v_{m1}^k]\} & \cdots & \{[\mu_{mn}^1, v_{mn}^1], [\mu_{mn}^2, v_{mn}^2], \dots, [\mu_{mn}^k, v_{mn}^k]\} \end{bmatrix}_{m\times n} \end{array} \quad \forall k \quad (10)$$

Step 2. The normalized decision matrix is constructed.

Step 3. The utility degree method under intuitionistic fuzzy approach (IF-UD) extends to obtain the experts weights. This method is illustrated the following steps:

Step 3.1. The normalized expert decision matrix (κ_k) is presented in Eq. (11).

$$\kappa_k = \begin{array}{c} \\ A_1 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{ccc} C_1 & \dots & C_j \end{array} \\ \begin{bmatrix} [\mu_{11}^k, v_{11}^k] & \cdots & [\mu_{1n}^k, v_{1n}^k] \\ \vdots & \ddots & \vdots \\ [\mu_{m1}^k, v_{m1}^k] & \cdots & [\mu_{mn}^k, v_{mn}^k] \end{bmatrix}_{m\times n} \end{array} \quad \forall k \quad (11)$$

Step 3.2. The positive ideal decision matrix (θ^+), left and right negative ideal decision matrix $(\theta^{-L}, \theta^{+L})$ are obtained from Eqs. (12) -(17), respectively.

$$\theta^+ = [A_{ij}^+]_{m\times n} \quad \forall k \quad (12)$$

$$A_{ij}^+ = \begin{cases} \{y_j, \max_k \langle P_{k(ij)} \rangle\} \\ \{y_j, \min_k \langle P_{k(ij)} \rangle\} \end{cases} \quad \forall J, \acute{J} \quad (13)$$

Eq. (19) determines the establishment based on μ_{ij}^+ and v_{ij}^+.

$$\theta^{-L} = \left[A_{ij}^{-L}\right]_{m\times n} \qquad \forall k \qquad (14)$$

$$A_{ij}^{-L} = \begin{cases} \left\{y_j, \min_k \langle \left[\mu_{ij}^k, v_{ij}^k\right] \in P_{k(ij)} \middle| \left[\mu_{ij}^k, v_{ij}^k\right] \le A_{ij}^+ \rangle \right\} \\ \left\{y_j, \max_k \langle \left[\mu_{ij}^k, v_{ij}^k\right] \in P_{k(ij)} \middle| \left[\mu_{ij}^k, v_{ij}^k\right] \le A_{ij}^+ \rangle \right\} \end{cases} \qquad \forall J, \acute{J} \qquad (15)$$

$$\theta^{-R} = \left[A_{ij}^{-R}\right]_{m\times n} \qquad \forall k \qquad (16)$$

$$A_{ij}^{-R} = \begin{cases} \left\{y_j, \max_k \langle \left[\mu_{ij}^k, v_{ij}^k\right] \in P_{k(ij)} \middle| \left[\mu_{ij}^k, v_{ij}^k\right] \ge A_{ij}^+ \rangle \right\} \\ \left\{y_j, \min_k \langle \left[\mu_{ij}^k, v_{ij}^k\right] \in P_{k(ij)} \middle| \left[\mu_{ij}^k, v_{ij}^k\right] \ge A_{ij}^+ \rangle \right\} \end{cases} \qquad \forall J, \acute{J} \qquad (17)$$

where A_{ij}^{-L} and A_{ij}^{-R} are computed from $\left[\mu_{ij}^{-L}, v_{ij}^{-L}\right]$ and $\left[\mu_{ij}^{-R}, v_{ij}^{-R}\right]$, and the set of J is a benefit of the criteria and $\acute{J}$ is the cost of them.

Step 3.3. The positive ideal decision matrix separation measure $(\delta_k^+) is$ computed from Eq. (18).

$$\delta_k^+ = \sqrt{\frac{1}{2n}\sum_{i=1}^m \sum_{j=1}^n \left(\left|\mu_{ij}^{k\iota} - \mu_{ij}^{+\iota}\right|^2 + \left|v_{ij}^{k\iota} - v_{ij}^{+\iota}\right|^2\right)} \qquad \forall k \qquad (18)$$

Step 3.4. The left and right negative ideal decision matrix $(\delta_k^{-L}, \delta_k^{-R})$ separation measures are calculated with Eqs. (19) and (20), respectively.

$$\delta_k^{-L} = \sqrt{\frac{1}{2n}\sum_{i=1}^m \sum_{j=1}^n \left(\left|\mu_{ij}^{k\iota} - \mu_{ij}^{-L\iota}\right|^2 + \left|v_{ij}^{k\iota} - v_{ij}^{-L\iota}\right|^2\right)} \qquad \forall k \qquad (19)$$

$$\delta_k^{-R} = \sqrt{\frac{1}{2n}\sum_{i=1}^m \sum_{j=1}^n \left(\left|\mu_{ij}^{k\iota} - \mu_{ij}^{-R\iota}\right|^2 + \left|v_{ij}^{k\iota} - v_{ij}^{-R\iota}\right|^2\right)} \qquad \forall k \qquad (20)$$

Step 3.5. The importance degree of each expert (ρ_k) is computed with Eq. (21).

$$\rho_k = \frac{\delta_k^{-L} + \delta_k^{-R}}{(\delta_k^{-L} + \delta_k^{-R} + \delta_k^+)\left(\sum_{k=1}^K \left(\frac{\delta_k^{-L} + \delta_k^{-R}}{\delta_k^{-L} + \delta_k^{-R} + \delta_k^+}\right)\right)} \qquad \forall k \qquad (21)$$

Step 4. The criteria weights obtained with the intuitionistic fuzzy preference evaluation (IF-PE) method:

Step 4.1. The normalized criteria intuitionistic fuzzy group decision matrix (E_j) is examined by Eq. (22).

$$E_j = \begin{array}{c} \\ A_1 \\ \vdots \\ A_m \end{array} \begin{array}{c} \begin{array}{ccc} DM_1 & \cdots & DM_k \end{array} \\ \begin{bmatrix} [\mu_{11}^1, v_{11}^1] & \cdots & [\mu_{1j}^k, v_{1j}^k] \\ \vdots & \ddots & \vdots \\ [\mu_{mj}^1, v_{mj}^1] & \cdots & [\mu_{mj}^k, v_{mj}^k] \end{bmatrix}_{m\times k} \end{array} \qquad \forall j \qquad (22)$$

Step 4.2. The IF-PE value $(\Delta_j) is$ obtained from Eq. (23).

$$\Delta_k = \sqrt{\frac{1}{2n}\sum_{k=1}^K \sum_{i=1}^m \left(\left|\mu_{ij}^{kP\iota} - \frac{1}{2Km}\sum_{k=1}^K \sum_{i=1}^m \mu_{ij}^{kP}\right|^2 + \left|v_{ij}^{kP\iota} - \frac{1y}{2Km}\sum_{k=1}^K \sum_{i=1}^m v_{ij}^{kP}\right|^2\right)} \qquad \forall j \qquad (23)$$

Step 4.3. The criteria's weight (η_j) is computed with IF-PE method from Eq. (24).

$$\eta_j = \frac{\left(\left|1-\left(\frac{1}{2}\sum_{k=1}^{K}\sum_{i=1}^{m}\left(\left|\mu_{ij}^{kP\iota}-\frac{1}{2Km}\sum_{k=1}^{K}\sum_{i=1}^{m}\mu_{ij}^{kP}\right|^2+\left|v_{ij}^{kP\iota}-\frac{1x}{2Km}\sum_{k=1}^{K}\sum_{i=1}^{m}v_{ij}^{kP}\right|^2\right)\right)^{\frac{1}{2}}\right|\right)}{\sum_{j=1}^{n}\left(\left|1-\left(\frac{1}{2}\sum_{k=1}^{K}\sum_{i=1}^{m}\left(\left|\mu_{ij}^{kP\iota}-\frac{1}{2Km}\sum_{k=1}^{K}\sum_{i=1}^{m}\mu_{ij}^{kP}\right|^2+\left|v_{ij}^{kP\iota}-\frac{1y}{2Km}\sum_{k=1}^{K}\sum_{i=1}^{m}v_{ij}^{kP}\right|^2\right)\right)^{\frac{1}{2}}\right|\right)} \qquad \forall j \qquad (24)$$

Step 4.4. The final weight criteria (W_j^f) is calculated with Eq. (25). The importance degree of the *jth* creation that takes from *kth* DM is w_j^k.

$$W_j^f = \frac{\eta_j\left(\prod_{k=1}^{K}\left(w_j^k\right)^{\rho_k}\right)}{\sum_{j=1}^{n}\left(\eta_j\left(\prod_{k=1}^{K}\left(w_j^k\right)^{\rho_k}\right)\right)} \qquad \forall j \qquad (25)$$

Step 5. The IF normalized decision matrix (G^k) computes from Eq. (26).

$$G^k = \begin{array}{c} \\ A_1 \\ \vdots \\ A_m \end{array}\begin{array}{c} \begin{array}{ccc} C_1 & \cdots & C_n \end{array} \\ \begin{bmatrix} W_1^f[\mu_{11}^k, v_{11}^k] & \cdots & W_n^f[\mu_{1n}^k, v_{1n}^k] \\ \vdots & \ddots & \vdots \\ W_1^f[\mu_{m1}^k, v_{m1}^k] & \cdots & W_n^f[\mu_{mn}^k, v_{mn}^k] \end{bmatrix}_{m\times n} \end{array} \qquad \forall k \qquad (26)$$

Step 6. The IF positive ideal solution (IF-PIS) and IF negative ideal solution (IF-NIS) are obtained from Eqs. (27) - (30).

$$A_j^+ = \{\theta_1^+, \dots, \theta_n^+\} \qquad \forall k \qquad (27)$$

$$\theta_j^+ = \begin{cases} \left\{y_j, \max_i \langle\theta_{ij}^{\sigma(\lambda)}\rangle\right\} \\ \left\{y_j, \min_i \langle\theta_{ij}^{\sigma(\lambda)}\rangle\right\} \end{cases} \qquad \forall J, \acute{J} \qquad (28)$$

$$A_j^- = \{\theta_1^-, \dots, \theta_n^-\} \qquad \forall k \qquad (29)$$

$$\theta_j^- = \begin{cases} \left\{y_j, \min_i \langle\theta_{ij}^{\sigma(\lambda)}\rangle\right\} \\ \left\{y_j, \max_i \langle\theta_{ij}^{\sigma(\lambda)}\rangle\right\} \end{cases} \qquad \forall J, \acute{J} \qquad (30)$$

Step 7. The distance value between the IF-decision matrix, IF-PIS and IF-NIS are computed from Eqs. (31) and (32).

$$\zeta_i^+ = \sum_{j=1}^{n}\sqrt{\frac{1}{2n}\sum_{\lambda=1}^{n}\left(\left|G_{ij}^{k\sigma(\lambda)}-\mu_{ij}^{+\sigma(\lambda)}\right|^2+\left|G_{ij}^{k\sigma(\lambda)}-v_{ij}^{+\sigma(\lambda)}\right|^2\right)} \qquad \forall i \qquad (31)$$

$$\zeta_i^- = \sum_{j=1}^{n}\sqrt{\frac{1}{2n}\sum_{\lambda=1}^{n}\left(\left|G_{ij}^{k\sigma(\lambda)}-\mu_{ij}^{-\sigma(\lambda)}\right|^2+\left|G_{ij}^{k\sigma(\lambda)}-v_{ij}^{-\sigma(\lambda)}\right|^2\right)} \qquad \forall i \qquad (32)$$

Step 8. The hamming distance compute the relative closeness coefficient (C_i) with Eq. (33). In this equation $\overline{D}^+$ and $\overline{D}^-$ are the average degrees of $D_1^+, \dots D_m^+$ and $D_1^-, \dots D_m^-$, respectively.

$$C_i = \frac{\left(\frac{1}{l\zeta_i^-}\sum_{j=1}^{l}\left|D_i^{-\sigma(j)} - \bar{D}^-\right|\right)^2 + \left(\frac{1}{l\zeta_i^+}\sum_{j=1}^{l}\left|D_i^{+\sigma(j)} - \bar{D}^+\right|\right)^2}{\frac{1}{l\zeta_i^-}\sum_{j=1}^{l}\left|D_i^{-\sigma(j)} - \bar{D}^-\right| + \frac{1}{l\zeta_i^+}\sum_{j=1}^{l}\left|D_i^{+\sigma(j)} - \bar{D}^+\right|} \tag{33}$$

Step 9. The rank of the alternatives occurs with decreasing sorting of C_i degree.

IV. COMPUTATIONAL RESULTS AND ANALYSIS

A. Problem description and proposed method implementation

This section is generated a real case study of urban development projects based on 3P fundamental and validates the proposed novel method. Hence, four DMs DM_1, DM_2, DM_3, DM_4) use to obtain the weights of 10 various criteria based on financing nature $(C_1, C_2, \ldots, C_{10})$. These are developed in Table 1 for 3 types of the 3P problems (P_1, P_2, P_3). Also, these are collected from the real information of the same company. Furthermore, the main alternatives determine in Table 2, and the judgment of the experts implement based on linguistic terms that are existed in Tables 3 and 4 for criteria and alternatives. Eventually, the experts' judgment change to the IF value.

Table I. The description of the criteria

Criteria	*Description*
C_1	Payment oscillations
C_2	Fixed changes in public laws
C_3	Government patronage for the private section
C_4	Inflation efficacy on construction and operation
C_5	Computing a bank loan
C_6	Defeat to paying bills on time by the government
C_7	How to accumulate the issue of the project
C_8	Adequate familiarity with international law
C_9	Lockout
C_{10}	Appropriate election of partners (second-hand contractors)

Table II. The definition of the alternatives

Alternatives	*Description*
P_1	the bridge construction
P_2	the highway construction
P_3	the metro development

Table III. The linguistic terms to evaluate the importance of the criteria

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 IV. The linguistic terms to rate the alternatives

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)

In addition, the judgment of the experts generates in Tables 5 and 6 with linguistic variables. Afterward, these values are changed to the IF degree with Tables 3 and 4, and we compute the weights and ranks of the alternatives with the proposed approach. These linguistic judgments show in Tables 5 and 6.

Table V. The linguistic value of the criteria

Criteria	*Decision-makers*		
	DM_1	DM_2	DM_3
C_1	H	H	VH
C_2	VH	VH	H
C_3	L	VL	L
C_4	VH	VH	VH
C_5	H	M	VL
C_6	VH	VH	VH
C_7	M	L	M
C_8	VL	VL	VL
C_9	VH	VH	VH
C_{10}	M	L	L

Table VI. The linguistic variables of alternatives

Alternatives	*DMs*	*Criteria*									
		C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
P_1	DM_1	VH	AH	VL	VVH	ML	AH	M	L	VVH	ML
	DM_2	VVH	VVH	L	AH	L	AH	H	L	VVH	L
	DM_3	VVH	VH	VL	VVH	VL	VVH	MH	ML	VVH	ML
P_2	DM_1	VH	H	L	VH	M	ML	VH	H	MH	H
	DM_2	AH	M	H	VVH	MH	VH	VH	MH	VH	H
	DM_3	M	H	AH	MH	MH	VVH	L	M	H	ML
P_3	DM_1	H	H	H	VH	MH	H	MH	H	M	MH
	DM_2	M	VH	M	ML	VH	L	ML	L	ML	L
	DM_3	H	VVH	VH	VH	VVH	VVH	L	VH	VVH	ML

At first, the DMs weights compute based on IF-UD approach to decrease the computational errors. This aim is needed to obtain the positive ideal decision matrix, negative left, and right of them. After that, the aforementioned ideal matrix calculates, and the final results are shown in Table 7.

Table VII. The DM weights obtain based on IF-UD approach

Decision-makers	ϑ_k^{+}	ϑ_k^{-L}	ϑ_k^{-R}	φ_k
DM_1	0.83490	0.56254	0.37423	0.30614
DM_2	0.66910	0.42603	0.50922	0.33752
DM_3	0.60564	0.56356	0.40571	0.35634

Also, the criteria' weights calculate with IF-preference evaluation approach, which results are determined in Table 8.

Table VIII. Criteria' weights calculate with IF-preference evaluation approach

Criteria	Θ_k	χ_j	ϖ_j^f
C_1	0.84404	0.07372	0.07421
C_2	0.85413	0.08806	0.08864
C_3	0.80825	0.11154	0.11228
C_4	0.85806	0.13048	0.13135
C_5	0.70232	0.25597	0.25767
C_6	0.85110	0.10022	0.10088
C_7	0.74494	0.08460	0.08516
C_8	0.71240	0.01244	0.01252
C_9	0.83539	0.08638	0.08695
C_{10}	0.67619	0.05001	0.05034

The selection and the rank of the alternatives relevant to the urban development 3P project uses the proposed method. These results are shown in Table 8.

Table IX. The results of the separation measures

Alternatives	ζ_i^{+}	ζ_i^{-}	C_i	*Final rank*
P_1	0.01303	0.01283	0.00415	2
P_2	0.01310	0.01280	0.00406	3
P_3	0.01271	0.00017	0.00821	1

This table is determined that the third alternative has a high priority than the others. This point is related to the development of the metro in the cities, which has an important position in the life of the people in the urban. After that, the bridge construction project has a more important role in the communication of the people in the cities.

B. Discussion

Eventually, the proposed method should be compared to other methods until to determine the powerful point of it with previous approaches. To this case, the SAW method uses to rank the alternatives. The final results of the comparison are shown in Fig. 1. The ranking of the alternatives is similar between two various methods, but their values of them are different between them.

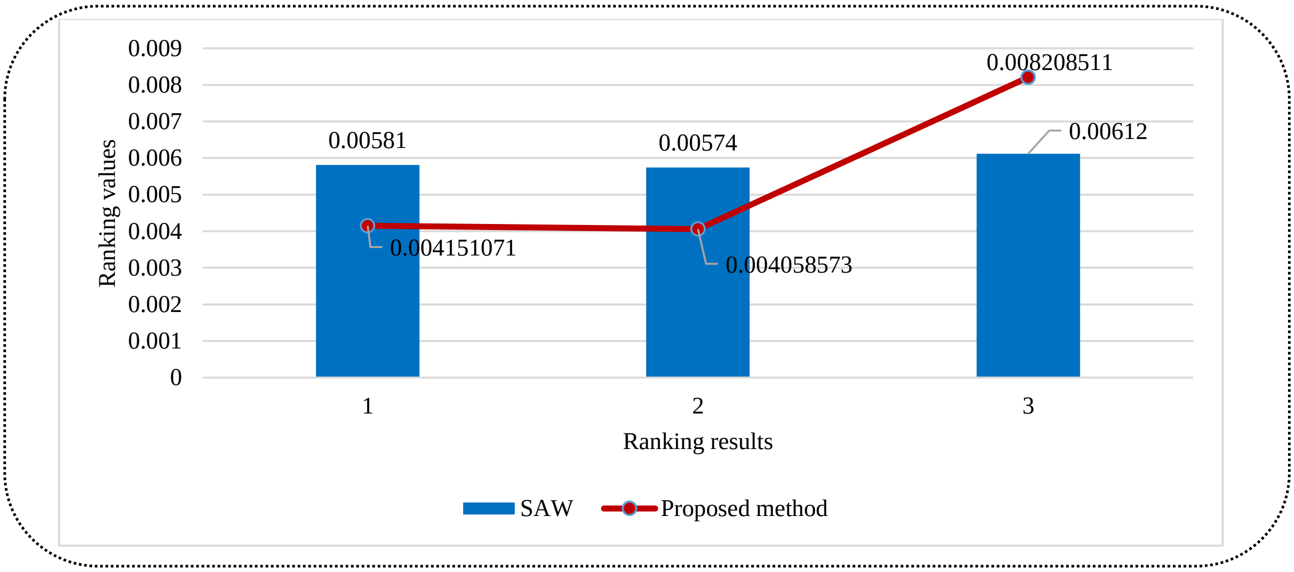

Fig 1. The comparison between ranking methods

Although both aforementioned approaches have reached to same ranking results, the proposed approach has some main features that could assist the users to reach precise solutions. Therefore, some comparison parameters including uncertainty modeling, attributes importance, decision makers' weights, group decision analysis, and time complexity are considered to compare the merits of each method. In the following, the comparison parameters analysis is explained in detail.

- **Modeling of uncertainty:** The proposed approach in comparison with the SAW technique is developed based on intuitionistic fuzzy information that helps experts to explain their opinions based on linguistic terms. Consequently, the proposed approach of this article could appropriately manipulate the subjectivity and uncertainty of the 3p project selection problem.

- **Attribute importance:** Attribute importance is known as a weight factor in decision making analysis which could affect the results of final ranking. However, the attribute importance in this study is computed based on intuitionistic fuzzy preference evaluation. But, the SAW method can be considered the experts' judgments about the attributes importance.

- **Decision makers' weights:** Determining the decision makers' expertise is much suitable for solving the 3P urban development project selection problem. Meanwhile, the proposed approach computed the decision makers' weights based on the proposed intuitionistic fuzzy utility degree method to reduce the judgments' errors. Therefore, the proposed methodology versus SAW method could obtain a precise solution.

- **Group decision analysis:** Today, establishing a group decision making analysis in process of decision-making tool extensions is more popular. Meanwhile, group decision analysis could provide the experts' knowledge and their expertise in decision making process. In this comparison parameter, both methodologies are adequate by providing a group of decision makers to assess the candidates based on conflicted attributes.

- **Time complexity:** This comparison parameter is more related to the size of methodology computations. Meanwhile, the SAW technique could perform better than the developed methodology. As a result, tailoring the experts' weights computations, attributes weights calculations, and covering the imprecise information led to a big computational size.

However, the discussion based on five comparison parameters represents that the developed approach regarding the SAW methodology has three advantages consisting of uncertainty covering, attributes importance computation, and experts' weights determination. On the other hand, the time complexity of the SAW methodology is much lower than the presented approach and also both techniques are adequate for group decision analysis comparison parameters. Finally, although each technique has unique merits, the discussion reported that the presented methodology in this study can perform more precisely and effectively based on the aforementioned comparison parameters.

V. CONCLUSIONS AND FUTURE RESEARCH

One of the most important economic and social measures in the world today is related to the construction of large infrastructure projects. In such projects, the end product is a structure or a basic facility that significantly helps to improve the quality of life of people. Most of these projects are in practice related to governments, and their implementation requires a financial and human investment of the government for the construction and operation of the project. Large projects have high financial risks and in case of failure or delay in delivery time can cause harmful losses to the manufacturer and builder. To this end, the use of a participatory system based on the interaction between the public and private sectors can pave the way for construction and development. In such projects, the government acts as an overseer, and the private sector company, as a contractor, begins to raise resources, including financial, human, and equipment, and after construction, begins construction. In these projects, all the risks of the project are borne by the construction sector, and governments receive less damage in case of project failure. In this study, we investigated a construction project based on the 3P method and examined this issue under intuitive fuzzy uncertainty. The proposed method was for calculating the weights of indicators and options in the problem, and a new method was presented for ranking. In addition, five comparison parameters are considered to compare the proposed approach regarding the SAW method. The results show that the developed approach has three advantages including uncertainty covering, attributes importance computation, and experts' weights determination. On the other hand, the time complexity is a limitation of this study that the SAW method can perform in less time. Finally, in order to determine the efficiency of the proposed method, a case study for urban development was used, and its final results were compared with a traditional method. The results show the strength of the proposed method and consider this method suitable for large decisions. Finally, metro construction has a high priority than other alternatives to develop urban and cities.

In order to make future suggestions, other fuzzy approaches can be used alongside the proposed method, and the results can be compared with this method. In addition, developing a decision support system based on the proposed approach and last aggregation is the main issue to enhance the presented fuzzy group decision technique.

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