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Enhancing Group Decision Making with Interval Valued Fuzzy Soft Max–min Method: An Examination in Manpower Recruitment

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ABSTRACT

Maji et al. expanded on soft set theory by introducing fuzzy soft set theory, offering a versatile approach for tackling problems marked by uncertainty and fuzziness, while effectively modelling and representing data. The authors developed a matrix representation within this fuzzy soft set framework and explored various properties of these matrices. Despite this, existing applications of interval-valued fuzzy soft matrices in group decision-making often assume equal importance for all criteria, which fails to capture the true preferences of decision-makers.

This study proposes a novel approach to group decision-making through the Interval Valued Fuzzy Soft Max-min Decision-Making Method (IVFSMmDM), which considers the varying importance of each criterion, followed by using the Fuzzy Soft Max-min decision-making technique to prioritize decisions. The integration of these methods provides a more accurate and practical decision-making framework.

The effectiveness of IVFSMmDM is illustrated through a detailed numerical example in the context of manpower recruitment, involving the selection of 7 programmers for a software development organization's team. The results indicate that Programmer 5 was chosen, achieving the highest-ranking value of (0.019, 0.021). This highlights the practical utility and effectiveness of the Interval Valued Fuzzy Soft Max-min Decision-Making Method in real-world decision-making scenarios.

1. INTRODUCTION

Numerous challenges encountered in fields such as engineering, management, social sciences, and medicine often involve data characterized by inherent uncertainties, rather than being precise or deterministic. To navigate these complexities, traditional concepts such as probability, fuzzy sets, intuitionistic fuzzy sets, interval mathematics, and rough sets have been employed. Nevertheless, these approaches present certain limitations. In response to these shortcomings, Molodtsov introduced soft set theory in 1999, which provides a framework that remains unaffected by the parameterization challenges faced by other methodologies. Since its introduction, soft set theory has gained traction and found extensive

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applications in diverse domains, including decision–making and data mining. Significant contributions have been made by researchers such as Maji et al. (2002), Kong et al. (2021), Qin et al. (2021), and Feng et al. (2016, 2020), who have applied the TOPSIS method for decision-making within the context of soft sets. Furthermore, studies by Zulqarnain (2020), Maharana (2021), and Tripathy et al. (2019) have concentrated on parameter reduction and the advancement of new mathematical tools pertinent to soft set theory. Additionally, Sai (2020) has offered a thorough overview of its applications in decision-making, highlighting the considerable importance of soft set theory in this area.

Regenerate response fuzzy soft sets extend soft sets by incorporating fuzzy numbers, a concept developed by Zadeh in 1965 to handle uncertainties in real-life situations. These sets are characterized by a membership function that assigns a grade of membership to each object. Liu and Kwon (2007) further expanded the concept by considering parameters as fuzzy hedges or fuzzy parameters and defining operations on fuzzy soft groups. Shagari and Azam (2020) proposed a novel algorithm for decision-making in a fuzzy soft set environment, enhancing object discrimination and inference. Qin et al. (2021) presented a new approach to decision-making using interval-valued fuzzy soft sets, incorporating a contrast table to address extreme values and outliers. In 2019 Khalil and Hassan, introduced the idea of inverse fuzzy soft sets and their application in decision-making, providing more mathematical insight for decision-makers. Das et al. (2022) defined various practical operations on fuzzy soft sets, including the algebraic sum, bounded sum, and Einstein product, and investigated the basic properties of these new operations. These studies collectively contribute to the development of decision-making techniques based on soft set theory.

Cagman and Enginoglu (2013) advanced the practical use of fuzzy soft sets by defining fuzzy soft matrices, particularly for decision-making under uncertainty. They redefined the four products in soft matrices as fuzzy soft matrix products and investigated their properties. Using the fuzzy soft max-min decision function and the "And" product of fuzzy soft matrices, they developed the Fuzzy Soft Max-min Decision-Making (FSMmDM) method tailored for scenarios with two decision makers. Subsequent studies by Khalil and Hassan (2019) and Razak et al. (2013) further explored the use of FSMmDM in different contexts. Razak et al. (2017) introduced a hierarchical approach to fuzzy soft matrices and group decision-making, while Khalil developed inverse fuzzy soft sets for decision-making applications. Enginoğlu and Memis (2020) refined the criteria weighted FSMmDM approach with two new algorithms that enhanced its complexity and efficiency. These contributions highlight the flexibility and effectiveness of FSMmDM in managing uncertainty and vagueness in decision-making.

The concept of Interval-Valued Fuzzy Soft Sets (IVFSS) has been explored for various applications. Shanthi and Gaynthri (2020) introduced the normalized Euclidean distance between IVFSS establishing it as a metric, while Lambodharan (2019) discussed IVFSS operations and their properties, including principal disjunctive and conjunctive normal forms. Zulqarnain (2017,2020) applied IVFSS in a medical context for patient identification. In 2021, Silambarasan introduced Hamacher operations, scalar multiplication, and exponentiation for interval valued fuzzy matrices, enhancing their algebraic properties. Interval-valued fuzzy soft sets (IVFSS) have become an effective tool for managing uncertainty in decision-making processes. This approach integrates interval-valued fuzzy sets with soft set theory, providing a more adaptable way to represent membership degrees (Abdul & Musheer, 2020). Interval-valued fuzzy soft sets (IVFSS) have been applied to various real-world evaluation systems, such as those for apartments, universities, and stock markets (Qin & Ma, 2018; Sooraj & Tripathy, 2017). Researchers have developed comprehensive models for these evaluation systems using IVFSS, incorporating steps like data collection, decision-making, parameter reduction, and data set integration (Qin & Ma, 2018). Further expansions, like interval-valued hesitant fuzzy soft sets, have been proposed to enhance the model's effectiveness (Sooraj & Tripathy, 2017). Recent progress includes the formulation of interval-valued fuzzy soft preorderings and equivalence relations, as well as the creation of scoring functions for multi-group decision-making challenges (Ali & Kılıçman, 2021).

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The previous research based on IVFSS already applied to decision-making problems, however, the combination of determination criteria weight by using proper the method with IVFSS remains relatively unexplored. To address this gap, this study proposes a novel method, the IVFSMmDM, which integrates the fuzzy AHP Lambda-max method for more objective criteria weighting and efficient resolution of decision-making problems. The fuzzy AHP method is straightforward to compute and provides a definite value directly from experts, but it doesn't fully capture the human thinking style. The findings of this study will significantly contribute to addressing group decision-making problems. We developed a graphical model for the IVFSMmDM method using the IVFSMmDM function incorporating with Fuzzy AHP Lambda-Max method.

1.1 Preliminaries

1.1.1. Fuzzy Soft Matrix

A fuzzy set represents a group of elements characterized by a membership grade ranging continuously from 0 to 1, inclusive. A triangular fuzzy number, represented by the 3–tuple (l, m, u), is a convex and normal fuzzy set with the highest membership grade of 1. It is characterized by the membership function defined as:

$$\mu(x) = \begin{cases} \dfrac{x-l}{m-l}, & l \le x \le m \\ \dfrac{u-x}{u-m}, & m \le x \le u \\ 0, & otherwise \end{cases}$$

Maji et al. (2022) defined fuzzy soft set theory as a generalization of standard soft sets in the following manner:

Definition 1: Let U be an initial universe set and E be a set of all parameters. Let $F(U)$ denote the set of all fuzzy sets in U. Then $(\widetilde{F}, A)$ is called a fuzzy soft set over U where $A \subseteq E$ and $\widetilde{F}$ is a mapping given by

$$\widetilde{F} : A \to F(U)$$

In general, for every $x \in A$, $\widetilde{F}[x]$ is a fuzzy set in U and it is called a fuzzy value set of parameter x. If every $x \in A, \widetilde{F}[x]$ is a crisp subset of U, then (F, A) is degenerated to be the standard soft set.

Cagman and Enginoglu (2012) developed a fuzzy soft decision-making method by the following definition.

Definition 2: Let $(\widetilde{F}, A)$ be a fuzzy soft set over U, where $U = \{u_1, u_2, \dots, u_m\}$ be an initial universe set, $E = \{e_1, e_2, \dots, e_n\}$ be a set of parameters, and $A \subseteq E$. For $\forall u_i \in U$ and $\forall e_j \in E$, there exists a membership degree $[a_{ij}] = f_{e_j}(u_i)$, then all the membership degrees will be presented as in Table 1:

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Table 1. Evaluation of membership degrees fuzzy soft matrices $(FSM_{m\times n})$

	e_1	e_2	$\cdots$	e_n
u_1	$XR_A(u_1,e_1)$	$XR_A(u_1,e_2)$	$\cdots$	$XR_A(u_1,e_n)$
u_2	$XR_A(u_2,e_1)$	$XR_A(u_2,e_2)$	$\cdots$	$XR_A(u_2,e_n)$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
u_m	$XR_A(u_m,e_1)$	$XR_A(u_m,e_2)$	$\cdots$	$XR_A(u_m,e_n)$

The matrix $A_{m\times n}=[a_{ij}]_{m\times n}=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}$ is called interval fuzzy soft matrix of $(\tilde{F},A)$ over U (Basu et al. 2014).

Definition 3: Let $[a_{ij}],[b_{ik}]\in FSM_{m\times n}$. The *And*-product $\wedge$ between $[a_{ij}]$ and $[b_{ik}]$ is defined by $\wedge: FSM_{m\times n}\times FSM_{m\times n}\to FSM_{m\times n^2}$, $[a_{ij}]\wedge[b_{ik}]=[t_{ip}]$, where $[c_{ip}]=\min\{a_{ij},b_{ik}\}$ such that $p=n(j-1)+k.$

1.1.2. Interval Valued Fuzzy Soft Matrix

Definition 4: Let $(\overline{F},A)$ be an interval valued fuzzy soft set over U . Then a subset of $U\times E$ is uniquely defined by

$$R_A=\{(u,e): e\in A, u\in \overline{F}_A(E)\}$$

which is called a relation form of $(\overline{F}_A,E)$. Now the relation R_A is characterized by the membership function $U\times E\to Int([0,1])$ such that

$$\mu_A=\begin{cases} [\mu^{-}_{\overline{F}_A(e)}(u),\mu^{+}_{\overline{F}_A(e)}(u)], & if\ e\in A \\ [0,0], & if\ \ e\notin A \end{cases}$$

where Int ([0,1]) stands for the set of all closed sub-intervals of [0,1] and $[\mu^{-}_{\overline{F}_A(e)}(u),\mu^{+}_{\overline{F}_A(e)}(u)]$ denotes the interval–valued fuzzy membership degree of the object u associated with the parameter e .

Now if the set of universes $U=\{u_1,u_2,\ldots,u_m\}$ be an initial universe set, $E=\{e_1,e_2,\ldots e_n\}$ be a set of parameters then R_A can be presented by a table in the following form

Table 2. Evaluation of membership degrees interval value fuzzy soft matrices $(IVFSM_{m\times n})$

	e_1	e_2	$\cdots$	e_n
u_1	$\mu_A(u_1,e_1)$	$\mu_A(u_1,e_2)$	$\cdots$	$\mu_A(u_1,e_n)$
u_2	$\mu_A(u_2,e_1)$	$\mu_A(u_2,e_2)$	$\cdots$	$\mu_A(u_2,e_n)$
$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$
u_m	$\mu_A(u_m,e_1)$	$\mu_A(u_m,e_2)$	$\cdots$	$\mu_A(u_m,e_n)$

where $\mu_A(u_m,e_n)=[\mu^{-}_{\overline{F}_A(e_n)}(u_m),\mu^{+}_{\overline{F}_A(e_n)}(u_m)]$. If $a_{ij}=[\mu^{-}_{\overline{F}_A(e_j)}(u_i),^{+}_{\overline{F}_A(e_j)}(u_i)]$, then from Table 2 we can define a matrix

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$$A_{m\times n} = [\overline{a}_{ij}]_{m\times n} = \begin{bmatrix} a_{11}^{-}, a_{11}^{+}) & (a_{12}^{-}, a_{12}^{+}) & \cdots & (a_{1n}^{-}, a_{1n}^{+}) \\ (a_{21}^{-}, a_{21}^{+}) & (a_{22}^{-}, a_{22}^{+}) & \cdots & (a_{2n}^{-}, a_{2n}^{+}) \\ \vdots & \vdots & \ddots & \vdots \\ (a_{m1}^{-}, a_{m1}^{+}) & (a_{m2}^{-}, a_{m2}^{+}) & \cdots & (a_{mn}^{-}, a_{mn}^{+}) \end{bmatrix}$$

which is called an interval fuzzy soft matrix or simply IVFS-matrix of order $m\times n$ corresponding to the interval-valued fuzzy soft set $(\overline{F}_A, E)$ over U. An interval-valued fuzzy soft set $(\overline{F}_A, E)$ is uniquely characterized by the matrix $(\overline{a}_{ij})_{m\times n}$

1.1.2. Fuzzy Soft Max–min Decision Making Method

Cagman and Enginoglu (2012) introduced a Fuzzy Soft Max–min Decision Making Method by using And–product and defined as follows:

Definition 5: Let $[b_{ip}] \in FSM_{m\times n^2}$, $I_k = \{ p : \exists i, b_{ip} \neq 0, (k-1)n, < p \leq kn\}$ for all $k \in I =$ $\{1,2,\ldots,n\}$. Then Max-min decision function, denoted *Mm*, is defined as follows:

$Mm : FSM_{m\times n^2} \to FSM_{m\times 1},\ Mm[b_{ip}] = [\max_{k\in I}\{t_k\}]$, where

$$t_k = \begin{cases} \min_{p\in I_k} \{b_{ip}\}, & if\, I_k \neq \phi, \\ 0, & if\, I_k = \phi \end{cases}$$

The one column soft matrix $Mm[b_{ip}]$ is called max-min decision fuzzy soft matrix.

Proposition 1: The operators for $\wedge$ and $\vee$ are defined as follows, for (x_1, y_1), $(x_2, y_2) \in \overline{a}_{ij}$ *and* $\overline{b}_{ij}$ **:**

$$(x_1, y_1) \wedge (x_2, y_2) = (\min(x_1, x_2), \max(y_1, y_2))$$
$$(x_1, y_1) \vee (x_2, y_2) = (\max(x_1, x_2), \min(y_1, y_2))$$

Definition 6: Let $[a_{ij}], [b_{ik}] \in IV - FSM_{m\times n}$. The *And*-product $\wedge$ between $[a_{ij}]$ and $[b_{ik}]$ is defined by $\wedge : IV - FSM_{m\times n} \times IV - FSM_{m\times n} \to IV - FSM_{m\times n^2}$, $[a_{ij}] \wedge [b_{ik}] = [(\min(x_1, x_2), \max(y_1, y_2))]$, where $[c_{ip}] = \min\{a_{ij}, b_{ik}\}$ such that $p = n(j-1) + k.$

2. METHODOLOGY

The Analytic Hierarchy Process (AHP), introduced by Saaty in 1980, is one of the most popular and widely used techniques for determining criteria weight. It is highly flexible and can accommodate various types of multi-criteria decision-making (MCDM) methods, making it useful as an input for ranking alternatives (Liu, Kwon & Kang, 2014). AHP combine the evaluation results and expert opinions with a sophisticated decision-making process to create a straightforward, elementary hierarchy. Moreover, AHP can effectively manage both qualitative and quantitative data and is easy to compute. It also provides a reliable method for checking the consistency of the evaluation criteria and the alternatives selected by the decision maker. Thus, it can reduce bias in decision making (Lixiong, Liang & Minzhong, 2010). All the evaluation methods among the criteria will be analysed through pairwise comparisons using the AHP. However, AHP's inability to adequately handle the evaluations uncertainty and imprecision in which the human judgement is represented in terms of fuzzy numbers (Cheng et al. 2009). Fuzzy sets can be aligned through pairwise

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comparisons as an extension of AHP to overcome this limitation. Han et al. (2020) applied AHP for road selection and obtained a result that preserved the original road network structure. To create a priority list of counties based on hazard and exposure vulnerability, Guo (2020) utilized AHP in earthquake risk assessment. França (2020) employed AHP to map environmental fragility mapping and provide a hierarchy of critical environment criteria.

The concept of Analytic Hierarchy Process (AHP) was initially extended to fuzzy AHP in 1983 by Van Laarhoven and Pedrycz. This approach effectively addresses uncertainty and vagueness inherent in subjective performance and decision makers' experiences in solving hierarchical problems. The Lambda-max method, a key component of fuzzy hierarchical analysis, was introduced by Csutora & Buckley (2001) as a technique for determining fuzzy weights. Razak et al. (2012,2013,2017) have utilized fuzzy AHP (Lambda–max Method) in determining the criteria weight for the main and sub criteria in solving the group decision making problem. The proposed method involves two procedures. The first procedure involves determining the criteria weight using Lambda-max method obtained from Razak et al. (2017). The second procedure addresses solving group decision making problems. This paper employs IVFSMmDM incorporating together with criteria weight. The details of both procedures are given below.

2.1 Criteria Weight Determination

The Lambda-max method (Csutora and Buckley, 2012) is used in determining criteria weight. The procedure of the Lambda-max method involves 4 steps as follows:

Step 1: Apply $\alpha - cut$. To obtain the positive matrix of decision maker, let $\alpha = 1$, $\tilde{T}_m^s = \left[\tilde{r}_{ij}\right]_m^s$, and let $\alpha = 0$ to obtain the lower bound and upper bound positive matrices of decision maker s, $\tilde{T}_l^s = \left[\tilde{r}_{ij}\right]_l^s$ and $\tilde{T}_u^s = \left[\tilde{r}_{ij}\right]_u^s$ .Calculate the weight vector based on the weight calculation procedure in AHP, $W_m^s = \left(w_i\right)_m^s$, $W_l^s = \left(w_i\right)_l^s$, *and* $W_u^s = \left(w_i\right)_u^s$, $i = 1,2,\ldots,n.$

Step 2: To minimize the fuzziness of the weight, choose two constants, M_l^s and M_u^s, as follows:

$$M_l^s = \min\left\{\frac{w_{im}^s}{w_{il}^s}\right\},\ 1 \le i \le n \quad M_u^s = \min\left\{\frac{w_{im}^s}{w_{iu}^s}\right\},\ 1 \le i \le n \tag{1}$$

and the upper bound and lower bound of the weight is defined as:

$$W_{il}^{*s} = M_l^s w_{il}^s \ ,\ W_{iu}^{*s} = M_u^s w_{iu}^s\ , \tag{2}$$

so the lower bound and upper bound weight vectors are $(w_i^*)_l^s$ and $(w_i^*)_u^s$, $i = 1,2,\ldots,n.$

Step 3: By combining the upper bound, the middle bound and lower bound weight vectors, the fuzzy weight matrix for decision maker *s* can be obtained and is defined as $\tilde{W}_i^s = (w_{il}^{*s}, w_{im}^{*s}, w_{iu}^{*s}),\quad i = 1,2,\ldots,n.$

Step 4: Calculate local fuzzy weights and global fuzzy weight with repetition from step 1 until step 3.

2.2 Interval Valued Fuzzy Soft Max-min Decision Making (IVFSMmDM) Method

Zulqarnain et al. (2020) introduced an IVFSMmDM by using *And*–product. They then defined max-min decision function as follows:

Definition 7: Let $[c_{ip}] \in IVFSM_{m\times n^2}, I_k = \{P : c_{ip} \ne 0, (k-1)n < p \le kn\}$ for all $k \in \{1,2,3,\ldots n)$ and IVFS max-min decision function defined as follows

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$Mm : IVFSM_{m\times n^2} \to IVFSM_{m\times 1}$

where $Mm[c_{ip}] = [d_{i1}] = [\max\{t_{ik}\}]$,

such that $t_{ik} = \begin{cases} \min_{p\in I_K}\{c_{ip}\} & If\ I_k \neq 0 \\ [0.0,0.0] & If\ I_k = 0 \end{cases}$

$c_{ip} = [\min(\mu^L_{A_J}, \mu^L_{B_J}), \min(\min(\mu^U_{A_J}, \mu^U_{B_J})] \forall i, j, k$ and $p = n(j-1)+k$ is known as IVFSMmDM function.

Definition 8: Let $U = \{u_1, u_2, u_3, \ldots, u_m\}$ be an initial universe and $Mm[c_{ip}] = [d_{i1}]$. Then a subset of U can be obtained by using $[d_{i1}]$ as in the following expression

$Opt[d_{i1}](U) = \{d_{il}/u_i : u_i \in U, d_{i1} \neq 0\}$, which is called an optimum set of U .

Now using definition 8 and 9, the IVFSMmDM method can be developed by the following algorithm:

Step 1: Choose the feasible subsets of the set of parameters.
Step 2: Use the matrix form to construct the *ivfs*–matrix for each set of parameters.
Step 3: Find the *And*–product for the *ivfs*–matrices.
Step 4: Find a max-min decision *ivfs*–matrix.
Step 5: Find an optimum set of U .

$$Opt_{Mm}(U) = [u_1 \quad u_2 \quad \cdots \quad u_n]^T .$$

2.3 Development of IVFSMmDM Method with Criteria Weight

Our proposed decision–making procedure, IVFSMmDM, is outlined as follows:

Step 1: Assess the membership value of each alternative concerning each criterion in the decision–making problem.

Step 2: Use the matrix form to create the interval value fuzzy soft matrices for each set of criteria.

$$\left[r^k_{ij}\right]_{m\times n} = \begin{bmatrix} (r^u_{11}, r^l_{11}) & (r^u_{12}, r^l_{12}) & \cdots & (r^u_{1n}, r^l_{1n}) \\ (r^u_{21}, r^l_{21}) & (r^u_{22}, r^l_{22}) & \cdots & (r^u_{2n}, r^l_{2n}) \\ \vdots & \vdots & \ddots & \vdots \\ (r^u_{m1}, r^l_{m1}) & (r^u_{m2}, r^l_{m2}) & \cdots & (r^u_{mn}, r^l_{mn}) \end{bmatrix}, \quad \textbf{(3)}$$

where $[r_{ij}]$ is an interval fuzzy soft matrix of decision maker *k, m* represents the number of alternatives involved and *n* refers to the parameters/criteria.

Step 3: Multiply the matrix from step 2 by the criteria weight w_a and compute the values for each alternative and then construct the resulting matrix.

$$A_{ij} = \left[r^k_{ij} \otimes \widetilde{W}_k\right]_{m\times n} = \begin{bmatrix} (r^u_{11}, r^l_{11})\otimes w_1 & (r^u_{12}, r^l_{12})\otimes w_2 & \cdots & (r^u_{1n}, r^l_{1n})\otimes w_n \\ (r^u_{21}, r^l_{21})\otimes w_1 & (r^u_{22}, r^l_{22})\otimes w_2 & \cdots & (r^u_{2n}, r^l_{2n})\otimes w_n \\ \vdots & \vdots & \ddots & \vdots \\ (r^u_{m1}, r^l_{m1})\otimes w_1 & (r^u_{m2}, r^l_{m2})\otimes w_2 & \cdots & (r^u_{mn}, r^l_{mn})\otimes w_n \end{bmatrix}, \quad \textbf{(4)}$$

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Step 4: Determine the *And*-product of interval fuzzy soft matrices $\left(\text{e.g.}\left(DM_{n-1} \wedge DM_n = A\right)\right)$.

$$[A_{ij}] \wedge [B_{ik}] = \begin{bmatrix} A_{11} & A_{12} & \cdots & A_{1n} \\ A_{21} & A_{22} & \cdots & A_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ A_{m1} & A_{m2} & \cdots & A_{mn} \end{bmatrix} \wedge \begin{bmatrix} B_{11} & B_{12} & \cdots & B_{1n} \\ B_{21} & B_{22} & \cdots & B_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ B_{m1} & B_{m2} & \cdots & B_{mn} \end{bmatrix} \quad \textbf{(5)}$$

The resulting fuzzy soft matrix will have a size $(m \times n^2)$, where there are n blocks of $(m \times n)$ elements in the matrix.

Step 5: Calculate $Mm([A_{ij}] \wedge [B_{ik}]) = d_{i1}$, where $i = 1,2,3,\ldots,n$

First, we find $d_{11} = \min\{t_{ik}\} = \min\{t_{11}, t_{12}, t_{13,\ldots,} t_{1n}\}$, to find

d_{11} we need to find t_{1k} for every $k = 1,2,3,\ldots,s$, If $k = 1$ and $i = n$, t_{11} is $I_1 = \{P : C_{ip} \neq 0, 0 < P \leq n\}$, then, to find

t_{12} for every $k = 1,2,3,\ldots,s$, If $k = 2$ and $i = n$, t_{12} is $I_2 = \{P : C_{ip} \neq 0, n < P \leq n + n = n_1\}$, then, to find

t_{13} for every $k = 1,2,3,\ldots,s$, If $k = 3$ and $i = n$, t_{13} is $I_3 = \{P : C_{ip} \neq 0, n_1 < P \leq n_1 + n = n_2\}$

Find the minimum of And – product between $[A_{ij}]$ and $[B_{ij}]$ for each n block on interval value of $[m \times n]$ elements above. $[t_{ir}] = \begin{bmatrix} t_{11} & t_{12} & \cdots & t_{1n} \\ t_{21} & t_{22} & \cdots & t_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ t_{m1} & t_{m2} & \cdots & t_{mn} \end{bmatrix}$, where the elements of $[t_{ir}] = \min\limits_{r=1,2,3\ldots} [A_{ij}] \wedge [B_{ik}]$ is in term of Interval numbers

Step 6: Find the max – min decision fuzzy soft matrix,

$$(Mm)([A_{ij}] \wedge [B_{ik}]) = [u_1 \quad u_2 \quad \cdots \quad u_n]^T. \quad \textbf{(6)}$$

Step 7: Find an optimum set of

$$opt_{Mm}([A_{ij}] \wedge [B_{ik}](T) = \{[a_1, a_2]/T_1, [b_1, b_2]/T_2, [c_1, c_2]/T_3, \ldots, [k_1, k_2]/T_n\}^T \quad \textbf{(7)}$$

Step 8: Find an optimum fuzzy set according to $Mm(([R_{ij}] \wedge [S_{ij}])$

3. NUMERICAL EXAMPLE: MANPOWER RECRUITMENT PROBLEM

As an illustration, we revisit numerical illustration of manpower recruitment by Chaudhuri et al (2013) as an example for this paper. In this research we use an interval – valued fuzzy numbers to describe the membership degree. Two staffs' members from the Human Resources Department, referred to as *A* and *B*, are involved as decision-makers. There are eight criteria considered as a parameter and seven programmers to be recruited by a Software Development Organization. The recruitment process for a Software Development Organization considers eight criteria as parameters and evaluates seven programmers. The criteria weights are calculated using the Lambda – max method, and the IVFSMmDM method is applied to prioritize the seven programmers in this decision – making problem.

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Let $U = \{m_1, m_2, m_3, m_4, m_5, m_6, m_7\}$ be a set of seven programmers to be recruited by a Software Development Organization by the Human Resources Manager as a possible alternative. The set of parameters $E = \{e_1, e_2, e_3, e_3, e_4, e_5, e_6, e_7, e_8\}$, where e_1, e_2, e_3, e_4, e_5, e_6, e_7, and e_8, represent the parameters “hardworking”, “disciplined”, “honest”, “obedient”, “intelligence”, “innovative”, “entrepreneurial attitude”, and “aspirant” respectively. Intelligence and innovation reflect the programmer's creative mindset, while hard work and discipline signify their punctuality. Honesty and obedience indicate the integrity in the programmer's behaviour, and an entrepreneurial attitude along with being aspirant highlight their exploratory nature.

3.1 Criteria weight for each decision maker

Table 3 showed the criteria weight by two decision makers calculate by using Lambda-max method from each decision makers. The criteria weight obtains from (Razak et al. 2017).

Table 3: Criteria weight by every decision maker

CRITERIA	DM 1 (W_A)	DM 2 (W_B)
C_1	0.024	0.025
C_2	0.031	0.208
C_3	0.220	0.175
C_4	0.057	0.036
C_5	0.061	0.122
C_6	0.109	0.082
C_7	0.177	0.053
C_8	0.322	0.299

3.2 IVFSMmDM Calculation

Step 1: Assessment of membership degrees by each decision maker

Step 2: Construct interval valued fuzzy soft evaluation in Step 1 into matrix form, where A and B refer to decision maker 1 and decision maker 2 respectively.

$$A_{ij} = \begin{bmatrix} [0.70,0.78] & [0.70,0.90] & [0.70,0.76] & [0.40,0.50] & [0.60,0.70] & [0.60,0.70] & [0.85,0.90] & [0.55,0.60] \\ [0.60,0.70] & [0.88,1.00] & [0.70,0.86] & [0.70,0.80] & [0.40,0.50] & [0.75,0.80] & [0.70,0.78] & [0.40,0.50] \\ [0.35,0.50] & [0.65,0.70] & [0.50,0.54] & [0.40,0.45] & [0.50,0.60] & [0.60,0.65] & [0.45,0.52] & [0.90,1.00] \\ [0.40,0.59] & [0.10,0.20] & [0.10,0.20] & [0.50,0.60] & [0.70,0.74] & [0.70,0.73] & [0.50,0.60] & [0.80,0.87] \\ [0.90,1.00] & [0.60,0.70] & [0.70,0.89] & [0.67,0.70] & [0.70,0.80] & [0.80,0.82] & [0.90,1.00] & [0.90,1.00] \\ [0.55,0.60] & [0.90,1.00] & [0.85,0.90] & [0.95,1.00] & [0.80,0.90] & [0.60,0.68] & [0.75,0.89] & [0.60,0.66] \\ [0.90,1.00] & [0.75,0.80] & [0.45,0.50] & [0.50,0.52] & [0.95,1.00] & [0.50,0.56] & [0.80,0.83] & [0.60,0.70] \end{bmatrix}$$

$$B_{ik} = \begin{bmatrix} [0.60,0.68] & [0.80,0.89] & [0.60,0.63] & [0.45,0.50] & [0.85,1.00] & [0.70,0.80] & [0.70,0.80] & [0.80,0.85] \\ [0.80,0.85] & [0.60,0.65] & [0.70,0.81] & [0.40,0.44] & [0.90,1.00] & [0.85,0.90] & [0.65,0.74] & [0.85,0.96] \\ [0.500.55] & [0.70,0.75] & [0.60,0.65] & [0.80,0.90] & [0.60,0.68] & [0.90,1.00] & [0.60,0.68] & [0.85,1.00] \\ [0.60,0.65] & [0.70,0.79] & [0.70,0.80] & [0.90,1.00] & [0.90,0.98] & [0.80,0.89] & [0.80,0.82] & [10.90,.00] \\ [0.80,0.82] & [0.80,0.89] & [0.70,0.80] & [0.70,0.75] & [0.86,1.00] & [0.90,0.98] & [0.80,0.90] & [0.80,0.89] \\ [0.85,0.95] & [0.90,1.00] & [0.80,0.90] & [0.60,0.65] & [0.60,0.69] & [0.86,1.00] & [0.90,1.00] & [0.60,0.68] \\ [0.48,0.56] & [0.85,1.00] & [0.60,0.75] & [0.57,0.63] & [0.80,0.86] & [0.70,0.76] & [0.50,0.57] & [0.90,1.00] \end{bmatrix}$$

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Step 3: Integrate the criteria weights for each decision maker into the fuzzy soft matrix. These yields:

The calculation for this step is: $a_{11=}[(0.70\times 0.024),(0.78\times 0.024)]=[0.017,0.019]$
$a_{12=}[(0.70\times 0.031),(0.90\times 0.031)]=[0.022,0.028]$

$[A_{ij}\times W_A]=[R_{ij}]=$

$$\begin{bmatrix} [0.017,0.019] & [0.022,0.028] & [0.154,0.167] & [0.023,0.029] & [0.037,0.043] & [0.065,0.076] & [0.150,0.159] & [0.177,0.193] \\ [0.014,0.017] & [0.027,0.031] & [0.154,0.189] & [0.040,0.046] & [0.024,0.031] & [0.082,0.087] & [0.142,0.138] & [0.129,0.161] \\ [0.008,0.012] & [0.020,0.022] & [0.110,0.119] & [0.023,0.026] & [0.034,0.037] & [0.065,0.071] & [0.080,0.092] & [0.290,0322] \\ [0.010,0.014] & [0.003,0.006] & [0.022,0.044] & [0.029,0.034] & [0.043,0.045] & [0.076,0.080] & [0.089,0.106] & [0.258,0.280] \\ [0.022,0.024] & [0.019,0.022] & [0.154,0.196] & [0.038,0.040] & [0.043,0.049] & [0.087,0.089] & [0.159,0.177] & [0.290,0.322] \\ [0.013,0.014] & [0.028,0.031] & [0..187,0.198] & [0.054,0.057] & [0.049,0.055] & [0.065,0.074] & [0.133,0.158] & [0.193,0.213] \\ [0.022,0.024] & [0.023,0.025] & [0.099,0.110] & [0.029,0.030] & [0.058,0.061] & [0.055,0.061] & [0.142,0.147] & [0.193,0.225] \end{bmatrix}$$

The calculation for this step is: $a_{11=}[(0.60\times 0.024),(0.68\times 0.024)]=[0.015,0.017]$
$a_{12=}[(0.80\times 0.031),(0.89\times 0.031)]=[0.166,0.185]$

$[B_{ij}\times W_B]=[S_{ij}]=$

$$\begin{bmatrix} [0.015,0.017] & [0.166,0.185] & [0.105,0.110] & [0.016,0.018] & [0.104,0.122] & [0.057,0.066] & [0.037,0.042] & [0.239,0.254] \\ [0.020,0.021] & [0.125,0.135] & [0.123,0.142] & [0.014,0.016] & [0.110,0.122] & [0.070,0.074] & [0.034,0.039] & [0.254,0.287] \\ [0.013,0.014] & [0.146,0.156] & [0.105,0.114] & [0.029,0.032] & [0.073,0.083] & [0.074,0.082] & [0.032,0.036] & [0.254,0.299] \\ [0.015,0.016] & [0.146,0.164] & [0.123,0.140] & [0.032,0.036] & [0.110,0.120] & [0.066,0.073] & [0.042,0.043] & [0.269,0.299] \\ [0.020,0.021] & [0.166,0.185] & [0.123,0.140] & [0.025,0.027] & [0.116,0.122] & [0.074,0.080] & [0.042,0.048] & [0.239,0.266] \\ [0.0210.024] & [0.187,0.208] & [0.140,0.158] & [0.022,0.023] & [0.073,0.084] & [0.071,0.082] & [0.048,0.053] & [0.179,0.203] \\ [0.012,0.014] & [0.177,0.208] & [0.105,0.131] & [0.021,0.023] & [0.098,0.105] & [0.057,0.062] & [0.027,0.030] & [0.269,0.299] \end{bmatrix}$$

Step 4: By applying the *And*-product, the product of interval valued fuzzy soft matrices between $[R_{ij}]$ and $[S_{ij}]$ is obtained as follows:

$$\begin{bmatrix} [0.015,0.017] & [0.022,0.028] & [0.154,0.167] & [0.023,0.029] & [0.037,0.043] & [0.017,0.019] & [0.017,0.019] & [0.017,0.019] \\ [0.014,0.017] & [0.027,0.031] & [0.154,0.189] & [0.040,0.046] & [0.024,0.031] & [0.014,0.017] & [0.014,0.017] & [0.014,0.019] \\ [0.008,0.012] & [0.020,0.022] & [0.110,0.119] & [0.023,0.026] & [0.034,0.037] & [0.008,0.012] & [0.008,0.012] & [0.008,0.012] \\ [0.010,0.014] & [0.003,0.006] & [0.022,0.044] & [0.029,0.034] & [0.043,0.045] & [0.010,0.014] & [0.010,0.014] & [0.010,0.014] \\ [0.020,0.013] & [0.166,0.024] & [0.154,0.196] & [0.038,0.040] & [0.043,0.049] & [0.022,0.024] & [0.022,0.024] & [0.022,0.024] \\ [0.014,0.021] & [0.187,0.014] & [0.187,0.198] & [0.054,0.057] & [0.049,0.055] & [0.013,0.014] & [0.013,0.014] & [0.013,0.014] \\ [0.012,0.014] & [0.177,0.024] & [0.099,0.110] & [0.0290.030] & [0.058,0.061] & [0.022,0.024] & [0.022,0.024] & [0.022,0.024] \end{bmatrix}$$

$$\begin{matrix} [0.015,0.017] & [0.022,0.028] & [0.022,0.028] & [0.016,0.018] & [0.022,0.028] & [0.022,0.028] & [0.022,0.028] & [0.022,0.028] \\ [0.020,0.021] & [0.027,0.031] & [0.027,0.031] & [0.014,0.016] & [0.027,0.031] & [0.027,0.031] & [0.022,0.031] & [0.027,0.031] \\ [0.013,0.014] & [0.020,0.022] & [0.020,0.022] & [0.0200.022] & [0.020,0.022] & [0.020,0.022] & [0.020,0.022] & [0.020,0.022] \\ [0.003,0.006] & [0.003,0.006] & [0.003,0.006] & [0.003,0.006] & [0.003,0.006] & [0.003,0.006] & [0.003,0.006] & [0.003,0.006] \\ [0.019,0.021] & [0.019,0.022] & [0.019,0.022] & [0.019,0.022] & [0.019,0.022] & [0.019,0.022] & [0.019,0.022] & [0.019,0.022] \\ [0.021,0.024] & [0.028,0.031] & [0.028,0.031] & [0.022,0.023] & [0.028,0.031] & [0.028,0.031] & [0.003,0.031] & [0.028,0.031] \\ [0.012,0.014] & [0.023,0.025] & [0.023,0.025] & [0.021,0.023] & [0.023,0.025] & [0.023,0.025] & [0.003,0.025] & [0.023,0.025] \end{matrix}$$

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[0.015,0.017]	[0.154,0.167]	[0.105,0.110]	[0.016,0.018]	[0.023,0.029]	[0.057,0.066]	[0.037,0.042]	[0.167,0.167]
[0.020,0.021]	[0.125,0.135]	[0.123,0.142]	[0.014,0.016]	[0.110,0.122]	[0.070,0.074]	[0.034,0.039]	[0.189,0.189]
[0.013,0.014]	[0.110,0.119]	[0.105,0.114]	[0.029,0.032]	[0.073,0.083]	[0.074,0.082]	[0.032,0.036]	[0.119,0.119]
[0.015,0.016]	[0.022,0.044]	[0.022,0.044]	[0.022,0.036]	[0.022,0.044]	[0.022,0.044]	[0.022,0.043]	[0.044,0.044]
[0.020,0.021]	[0.154,0.185]	[0.123,0.140]	[0.025,0.027]	[0.116,0.122]	[0.074,0.080]	[0.042,0.048]	[0.196,0.196]
[0.021,0.024]	[0.187,0.198]	[0.140,0.158]	[0.022,0.023]	[0.073,0.084]	[0.071,0.082]	[0.048,0.053]	[0.179,0.198]
[0.012,0.014]	[0.099,0.110]	[0.099,0.110]	[0.021,0.023]	[0.098,0.105]	[0.057,0.062]	[0.027,0.030]	[0.110,0.110]

[0.015,0.017]	[0.023,0.029]	[0.023,0.029]	[0.016,0.018]	[0.023,0.029]	[0.023,0.029]	[0.023,0.029]	[0.023,0.029]
[0.020,0.021]	[0.040,0.046]	[0.040,0.046]	[0.014,0.016]	[0.040,0.046]	[0.040,0.046]	[0.034,0.039]	[0.040,0.046]
[0.013,0.014]	[0.023,0.026]	[0.023,0.026]	[0.023,0.026]	[0.023,0.026]	[0.023,0.026]	[0.023,0.026]	[0.023,0.026]
[0.015,0.016]	[0.029,0.034]	[0.029,0.034]	[0.029,0.034]	[0.029,0.034]	[0.029,0.034]	[0.029,0.034]	[0.029,0.034]
[0.020,0.021]	[0.038,0.040]	[0.038,0.040]	[0.025,0.027]	[0.038,0.040]	[0.038,0.040]	[0.038,0.040]	[0.038,0.040]
[0.021,0.024]	[0.054,0.057]	[0.054,0.057]	[0.022,0.023]	[0.054,0.057]	[0.054,0.057]	[0.048,0.053]	[0.054,0.057]
[0.012,0.014]	[0.029,0.030]	[0.029,0.030]	[0.021,0.023]	[0.029,0.030]	[0.029,0.030]	[0.027,0.030]	[0.029,0.030]

[0.015,0.017]	[0.037,0.043]	[0.037,0.043]	[0.016,0.018]	[0.037,0.043]	[0.037,0.043]	[0.037,0.042]	[0.037,0.043]
[0.020,0.021]	[0.024,0.031]	[0.024,0.031]	[0.014,0.016]	[0.024,0.031]	[0.024,0.031]	[0.024,0.031]	[0.024,0.031]
[0.013,0.014]	[0.034,0.037]	[0.034,0.037]	[0.029,0.032]	[0.034,0.037]	[0.034,0.037]	[0.032,0.036]	[0.034,0.037]
[0.015,0.016]	[0.043,0.045]	[0.043,0.045]	[0.032,0.036]	[0.043,0.045]	[0.043,0.045]	[0.042,0.043]	[0.043,0.045]
[0.020,0.021]	[0.043,0.049]	[0.043,0.049]	[0.025,0.027]	[0.043,0.049]	[0.043,0.049]	[0.042,0.048]	[0.043,0.049]
[0.021,0.024]	[0.049,0.055]	[0.049,0.055]	[0.022,0.023]	[0.049,0.055]	[0.049,0.055]	[0.048,0.053]	[0.049,0.055]
[0.012,0.014]	[0.058,0.061]	[0.058,0.061]	[0.021,0.023]	[0.058,0.061]	[0.057,0.061]	[0.027,0.030]	[0.058,0.061]

[0.015,0.017]	[0.065,0.076]	[0.065,0.076]	[0.016,0.018]	[0.065,0.076]	[0.057,0.066]	[0.037,0.042]	[0.065,0.076]
[0.020,0.021]	[0.082,0.087]	[0.082,0.087]	[0.014,0.016]	[0.082,0.087]	[0.070,0.074]	[0.034,0.039]	[0.082,0.087]
[0.013,0.014]	[0.065,0.071]	[0.065,0.071]	[0.029,0.032]	[0.065,0.071]	[0.065,0.071]	[0.032,0.036]	[0.065,0.071]
[0.015,0.016]	[0.076,0.080]	[0.076,0.080]	[0.032,0.036]	[0.076,0.080]	[0.066,0.073]	[0.042,0.043]	[0.076,0.080]
[0.020,0.021]	[0.087,0.089]	[0.087,0.089]	[0.025,0.027]	[0.087,0.089]	[0.074,0.080]	[0.042,0.048]	[0.087,0.089]
[0.021,0.024]	[0.065,0.074]	[0.065,0.074]	[0.022,0.023]	[0.065,0.074]	[0.065,0.074]	[0.048,0.053]	[0.065,0.074]
[0.012,0.014]	[0.055,0.061]	[0.055,0.061]	[0.021,0.023]	[0.055,0.061]	[0.055,0.061]	[0.027,0.030]	[0.055,0.061]

[0.015,0.017]	[0.150,0.159]	[0.105,0.110]	[0.016,0.018]	[0.104,0.122]	[0.057,0.066]	[0.037,0.042]	[0.150,0.159]
[0.020,0.021]	[0.124,0.135]	[0.123,0.138]	[0.014,0.016]	[0.110,0.122]	[0.070,0.074]	[0.034,0.039]	[0.124,0.138]
[0.013,0.014]	[0.080,0.092]	[0.080,0.092]	[0.029,0.032]	[0.073,0.083]	[0.074,0.082]	[0.032,0.036]	[0.080,0.092]
[0.015,0.016]	[0.089,0.106]	[0.089,0.106]	[0.032,0.036]	[0.089,0.106]	[0.066,0.073]	[0.042,0.043]	[0.089,0.106]
[0.020,0.021]	[0.159,0.177]	[0.123,0.140]	[0.025,0.027]	[0.116,0.122]	[0.074,0.080]	[0.042,0.048]	[0.159,0.177]
[0.021,0.024]	[0.133,0.158]	[0.133,0.158]	[0.022,0.023]	[0.073,0.084]	[0.071,0.082]	[0.048,0.053]	[0.133,0.158]
[0.012,0.014]	[0.142,0.147]	[0.105,0.131]	[0.021,0.023]	[0.098,0.105]	[0.057,0.062]	[0.027,0.030]	[0.142,0.147]

In this step we obtained fuzzy soft matrix of size $(m \times n^2)$, consisting of *n* blocks of $(m \times n)$ elements each. The matrix size 7×8, transform into a matrix size 7×64.

Step 5: Calculate $Mm([A_{ij}] \wedge [B_{ik}]) = d_{i1}$, where $i = 1,2,3,\ldots,n$

First, we find $d_{11} = \max\{t_{ik}\} = \max\{t_{11}, t_{12}, t_{13}, t_{14}, t_{15}, t_{16}, t_{17}, t_{18}\}$, to find

d_{11} we need to find t_{1k} for every $k = 1,2,3,\ldots,8$, If $k = 1$ and $i = n$, t_{11} is $I_1 = \{P : C_{ip} \neq 0, 0 < P \leq 8\}$,

$t_{11} = \{[0.015,0.017]\ [0.166,0.019]\ [0.017,0.110]\ [0.016,0.018]\ [0.017,0.019]\ [0.017,0.019]\ [0.017,0.019]\ [0.017,0.019]\}$

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If $k = 2$ and $i = n$, t_{12} is $I_1 = \{P : C_{ip} \neq 0, 8 < P \leq 16\}$,

$$t_{12} = \{[0.015,0.017]\ [0.022,0.028]\ [0.22,0.028]\ [0.016,0.018]\ [0.022,0.028]\ [0.022,0.028]\ [0.022,0.028]\ [0.022,0.028]\}$$

$\vdots$

$$t_{16} = \{[0.015,0.017]\ [0.166,0.185]\ [0.105,0.110]\ [0.016,0.018]\ [0.104,0.122]\ [0.057,0.066]\ [0.037,0.042]\ 0.177,0.193\}$$

Step 6: Find the Max – min decision interval valued fuzzy soft matrix.

The calculation for this matrix come from step 5 as follows:

$$\min[(0.015,0.166,0.017,0.016,0.017,0.017,0.017,0.017),(0.017,0.019,0.110,0.018,0.019,0.019,0.019,0.019)] = [0.015,0.017]$$

$$\begin{bmatrix} [0.015,0.017] & [0.166,0.019] & [0.017,0.110] & [0.016,0,018] & [0.017,0.019] & [0.017,0.019] & [0.017,0.019] & [0.017,0.019] \\ [0.014,0.016] & [0.014,0.016] & [0.014,0.016] & [0.014,0.016] & [0.014,0.016] & [0.014,0.016] & [0.014,0.016] & [0.014,0.016] \\ [0.008,0.012] & [0.013,0.014] & [0.013,0.014] & [0.013,0.014] & [0.013,0.014] & [0.013,0.014] & [0.013,0.014] & [0.013,0.014] \\ [0.010,0.014] & [0.003,0.006] & [0.015,0.016] & [0.015,0.016] & [0.015,0.016] & [0.015,0.016] & [0.015,0.016] & [0.015,0.016] \\ [0.020,0.021] & [0.019,0.021] & [0.019,0.021] & [0.019,0.021] & [0.019,0.021] & [0.019,0.021] & [0.019,0.021] & [0.019,0.021] \\ [0.013,0.014] & [0.003,0.023] & [0.021,0.023] & [0.021,0.023] & [0.021,0.023] & [0.021,0.023] & [0.021,0.023] & [0.021,0.023] \\ [0.012,0.014] & [0.003,0.014] & [0.012,0.014] & [0.012,0.014] & [0.012,0.014] & [0.012,0.014] & [0.012,0.014] & [0.012,0.014] \end{bmatrix}$$

Step 7: Find the maximum set interval valued fuzzy soft matrix

The calculation for this step is come from matrix in Step 6 as follows:

$$\max[(0.015,0.015,0.015,0.015,0.015,0.015,0.015,0.015),(0.017,0.017,0.017,0.017,0.017,0.017,0.017,0.017)] = [0.015,0.017]$$

$$\begin{bmatrix} 0.015,0.017 \\ 0.014,0.016 \\ 0.008,0.012 \\ 0.003,0.006 \\ 0.019,0.021 \\ 0.003,0.014 \\ 0.003,0.014 \end{bmatrix}$$

Step 8: Finally, we find an optimum fuzzy set according to $Mm(([R_{ij}] \wedge [S_{ij}]))$ as:

$$Opt_{Mm(([R_{ij}] \wedge [S_{ij}]))}(U) = \{M5)$$

$$M_5 = [0.019,0.021]$$

It is clear that M_5 represent the best choice of programmer within the universal set. Consequently, the human resources department will choose programmer 5 to join the Software Development Organization's team.

4. CONCLUSION

This research introduced a novel decision–making approach called the IVFSMmDM. The method was designed to address the limitations of existing group decision–making techniques, particularly in contexts characterized by uncertainty and imprecise data. By integrating the Lambda–max method, IVFSMmDM enables more objective and precise determination of criteria weights, which are crucial for evaluating alternatives in decision-making processes. A key contribution of this research is the application of IVFSMmDM in a real-world scenario manpower recruitment for a software development organization. The

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method's efficacy was demonstrated through a detailed numerical example involving the selection of programmers. The results identified Programmer 5 as the optimal choice, with a maximum interval value of the overall priority vector calculated as (0.019, 0.021). This result highlights the method's robustness and practical utility in managing complex decision-making scenarios with multiple criteria and decision-makers. This outcome not only underscores the robustness of the IVFSMmDM but also supports previous studies, such as those by Maji et al. (2002) and Kong et al. (2021), which have shown the effectiveness of advanced decision-making frameworks within soft set theory contexts. The findings reinforce the method's practical utility for addressing complex decision–making challenges involving multiple criteria and decision makers, aligning with the conclusions of prior research that emphasized the necessity of innovative approaches in the field.

This study indicates that IVFSMmDM has potential applications across a range of decision-making context where data is uncertain or vague. Its adaptability and flexibility suggest opportunities for further development and refinement to extend its use. Future research could explore additional enhancements to the IVFSMmDM method, potentially by incorporating new factors or integrating it with other decision-making techniques to increase its precision and applicability. Advancing these research avenues could help IVFSMmDM evolve, offering even greater accuracy and versatility in decision-making processes characterized by uncertainty.

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6. CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare the absence of conflicting interests with the funders.

7. AUTHORS' CONTRIBUTION

Samsiah Abdul Razak: Conceptualisation, methodology, formal analysis, investigation and writing-original draft; **Ini Imaina Abdullah**: Conceptualisation, writing-review based on methodology, and formal analysis; **Nur Azila Yahya**: Conceptualisation, formating, writing- review,editing, and validation.

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