8th INTERNATIONAL CONFERENCE ON INDUSTRIAL ENGINEERING

PROCEEDINGS

INNOVATION CENTER
FACULTY OF MECHANICAL ENGINEERING
UNIVERSITY OF BELGRADE
&
INDUSTRIAL ENGINEERING DEPARTMENT
FACULTY OF MECHANICAL ENGINEERING
UNIVERSITY OF BELGRADE

SIE 2022

Editors: **Vesna Spasojević-Brkić**
Mirjana Misita
Uglješa Bugarić

29th-30th September, 2022
Belgrade, Serbia

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PREFACE

Since the first event in Belgrade, Serbia more than 25 years ago, in 1996, International Conference on Industrial Engineering - SIE has been held regularly every 3 years. This time we are one year late due to pandemic conditions. It represents an opportunity for researchers in the Industrial Engineering community to review and evaluate their scientific achievements over the period since the previous SIE, share their most recent results and ideas, and discuss possibilities for new directions in research, joint experiments and observing campaigns.

The first aim of the 8th International Conference on Industrial Engineering – SIE 2022 is to celebrate 70 years from founding of our department by prof. dr Vukan Dešić! We are proud of professor Dešić who, as stated in one of the archive documents was “a man of excellent professional abilities and one of the best experts” and thank him for all his immeasurable contributions! The second aim of SIE 2022 is to contribute to a better comprehension of the role and importance of Industrial Engineering and to point out to the future trends in the field of Industrial Engineering. The conference is also expected to foster networking, collaboration and joint effort among the conference participants to advance the theory and practice as well as to identify major trends in Industrial Engineering today. According to these goals the conference addresses itself to all experts in all fields of Industrial Engineering to make their contribution to success and show capabilities achieved in the work that has been done are very welcomed. SIE 2022 traditionally provides an international forum for the dissemination and exchange of scientific information in industrial engineering fields through the large number of multidisciplinary topics and continues tradition established by prof. Dešić to gather and bring together experts in the field.

The book brought together almost 200 authors from 20 countries, namely from Canada, Croatia, Finland, Germany, Iran, Italy, Libya, Montenegro, Netherlands, North Macedonia, Poland, Portugal, Russia, Bosnia & Herzegovina, Singapore, Slovakia, Switzerland, Turkey and USA and Serbia. The 84 submitted full length manuscripts were peer-reviewed, and 81 of them were selected for publication by experts in their respective fields. The authors ranged from senior and renowned scientists to young researchers. Only unpublished papers were accepted and the first author is responsible for the originality of the paper. All papers are classified into five chapters, including plenary lectures and numerous results of national and EU projects are there presented (financed by MESTD, PSHESR ARV, SF RS, EC, EF RD, TUKE, INAIL etc.).

We expect that papers and discussions will contribute to better comprehension the role and importance of Industrial Engineering in this and other countries, both in domain of scientific work and everyday practice.

Our efforts in organizing would not succeed without the considerable help of the members of Scientific Program and the financial help of Ministry of Education, Science and Technological Development was greatly supportive for the success of the entire project.

At the end, the editors hope, and would like, that this book to be useful, meeting the expectation of the authors and wider readership and to incentive further scientific development and creation of new papers in the field of Industrial Engineering.

Welcome to the 8th International Conference on Industrial Engineering – SIE 2022! We wish to all participants a pleasant stay in Belgrade and are looking forward to seeing you all together at the 9th Conference on Industrial Engineering – SIE 2025.

Belgrade, September 2022

EDITORS

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SESSION 3 - CHAIRPERSONS: Ivan Mihajlović, Mirjana Misita, Zoran Anišić, Maria Francesca Milazzo

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COMBINING MOORA AND DELPHI UNDER INTUITIVE ENVIRONMENT

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Abstract. *A new model is developed that combines Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) and Delphi technique that are extended with intuitive fuzzy sets. Determining the weight of the criteria is set as fuzzy group decision making problem. Weights vector of criteria is set by proposed Delphi technique under the intuitionistic environment. Estimated value of criteria is given according to the assessment of decision makers. They use pre-defined linguistic expressions which are modelled by intuitionistic fuzzy numbers. The difference between the weighted normalized value of each alternative and reference point is determined by using Hamming distance. The rank of the alternative is based on the obtained values which are sorted in descending order. The proposed method is tested in real life data originating from a state service enterprise.*

Key words: *Intuitionistic fuzzy sets, MOORA, Delphi technique, selection of offer.*

1.INTRODUCTION

In the literature, many MADM methods have been developed and classified into different groups[13]. Utility-based methods are classic representatives of the American school. What this group of MADM methods is based on is the ability to "communicate" between alternatives. In fact, the main limitation of this group of methods is their application only when the criteria are observed independently [4]. Methods within the same group are based on a similar mathematical and logical basis. In this paper, MOORA is considered as a distance - based technique.

It can be considered closer to human nature that DMs express their estimates better when using linguistics than precise numbers. The development of various areas of mathematics such as intuitionistic fuzzy sets theory [1] has enabled linguistic expressions to be quantified in a sufficiently good way. In this research, uncertainties into the relative importance of criteria and its values are modelled by the interval valued intuitionistic fuzzy sets (IVIFNs).

For this reason, various authors expended their techniques based on distances with intuitive fuzzy sets theory [2,9].

In this research, the weights vector is calculated by using Delphi technique which is widened with IVIFNs (IF-Delphi technique). The rank of alternatives is given by using the proposed Multi-Objective Optimization on the basis of Ratio Analysis (MOORA) with IVIF (IF-MOORA).

1.1. Fuzzy Delphi technique

In general, the relative importance of criteria can be assessed by using qualitative methods [12]. One of the most widely used methods is the Delphi technique which is used in different domains, such as: economic development planning [11], risk assessment of project success [5], etc. The Delphi technique has the four features: anonymity, iteration, controlled feedback, and statistical "group response" [6]. There are no rules about the number of DMs involved in the decision making process. In practice, the number of DMs is determined according to the size of the decision making problem. The obtained result can be presented as ultimately group consensus.

There is no consensus, the DMs will be provided with the calculated mean as a controlled feedback together with questionnaire. After several rounds, when the consensus was achieved, based on the average of the final round, the items are screened. In the literature, various studies can be found in which different methods for determining consensus are proposed. In practice, it is considered that the obtained solution in the second round can be considered as the optimal solution.Also, there is a significant amount of papers where Delphi technique is extended with fuzzy sets [8,10].

1.2. The proposed MOORA

Brauers&Zavadskas [3] have developed MOORA to satisfy the seven conditions. They have said that MOORA is composed of ratio analysis and reference point theory.

According to the papers that can be found in the literature, certain differences between them can be indicated: (1) choosing criteria is based on the recommendations from practice; (2) rating of the relative importance of criteria and their values is based on using the pre-defined linguistic expressions which are modelled by IVIFNs; (3) the aggregation of DM opinions is obtained by using an intuitionistic fuzzy weighted Averaging (IFWA) operator in almost all analyzed papers; in this research, the authors propose an intuitionistic fuzzy weighted geometric (IVIFWG) operator; (4) the normalized Euclidian distance between two IVIFNs have been used in many papers [2,7], as in this research; (5) the fuzzy decision matrix is based on the consensus of DMs in [2] as in this research; (6) the normalization procedure [14]was applied in this research; (7) The reference point is determined according to [7]; (8) the rank of alternative is obtained by analogy conventional MOORA.

2. THE PROPOSED METHODOLOGY

In order to facilitate the understanding of the proposed methodology, the following notation is given:

- I The total number of alternatives
- i Index of alternative $i = 1, \ldots, I$
- K The total number of observed criteria
- k Index of criterion $k = 1, \ldots, K$
- E The total number of DMs
- e Index of DM $e = 1, \ldots, E$

2.1. Modelling of uncertainties

The uncertain relative importance criteria and their values are assessed in a direct way by DMs. It is assumed that they use 7 linguistic expressions which are modelled by IVIFNs:

very low value (VLV)-([0.05,0.15], [0.65,0.85])
low value (LV)-([0.10,0.2], [0.7,0.8])
fairly low values (FLV)-([0.2,0.35], [0.5,0.65])
medium value (MV)-([0.45,0.55], [0.4,0.45])
fairly high values (FHV)-([0.65,0.8], [0.15,0.2])
high value (HV)-([0.7,0.8], [0.1,0.2])
very high value (VHV)-([0.85,0.95], [0.05, 0.05])

2.2. The Delphi technique with IVIFNs

Step 1. Fuzzy rating of the relative importance of criterion k, k=1,..,K is performed by each DM $e, e = 1, \ldots, E$. They use pre-defined linguistic expressions which are modelled by IVIFNs:
$\tilde{\omega}_k^{Ie} = ([a_{1k}^{Ie}, a_{2k}^{Ie}], [a_{3k}^{e}, a_{4k}^{Ie}])$

Step 2. The aggregation of criteria weights in the first round are calculated by using IVIFWG:

$$\tilde{\omega}_k^{I} = \left(\begin{array}{c} \left[\prod_{e=1,\ldots,E} (a_{1k}^{Ie})^{w_e}, \prod_{e=1,\ldots,E} (a_{2k}^{Ie})^{w_e} \right], \\ \left[\left(1 - \prod_{k=1,\ldots,K} (1 - a_{3k}^{Ie})^{w_e}\right), \left(1 - \prod_{k=1,\ldots,K} (1 - a_{4k}^{Ie})^{w_e}\right) \right] \end{array} \right)$$

Step 3. The calculated distances IVIF $\tilde{\omega}_k^{I}$ from IVIFNs are corresponding to pre-defined linguistic expressions, $\Delta_{kj}, j = 1, \ldots, 5$. To each criterion $k, k = 1, \ldots, K$ associated are pre-defined linguistic expressions $j, j = 1, \ldots, 5$ according to expression: $\min_{j=1,\ldots,5} \Delta_{kj}$.

Step 4. Fuzzy rating of the relative importance of criterion k, k=1,..,K in the second round, $\tilde{\omega}_k^{IIe}$ is performed by each DM $e, e = 1, \ldots, E$ by respecting the obtained results of the first round.

Step 5. The aggregated weights of criteria in the second round are determined by using IVIFWG. This value can be accepted as final value, $\tilde{\omega}_k$ and

$$\tilde{\omega}_k = ([a_{1k}, a_{2k}], [a_{3k}, a_{4k}])$$

2.3. The extended MOORA

Step 1. Constructed the fuzzy decision matrix: $[\tilde{x}_{ik}]_{IxK}$

Where $\tilde{x}_{ik} = ([a_{1ik}, a_{2ik}], [a_{3ik}, a_{4ik}])$ is IVIFN which describes the value criterion k, k=1,..,K for failure I, i=1,..,I.

Step 2.The normalized fuzzy decision matrix is constructed: $[\tilde{r}_{ik}]_{IxK}$

Where:

a) benefit type:

$$r_{1ik} = \frac{a_{1ik}}{\sqrt{\sum_i (2 - a_{3ik} - a_{4ik})^2}} \quad r_{2ik} = \frac{a_{2ik}}{\sqrt{\sum_i (2 - a_{3ik} - a_{4ik})^2}}$$

$$r_{3ik} = 1 - \frac{1 - a_{3ik}}{\sqrt{\sum_i (a_{1ik} + a_{2ik})^2}} \quad r_{4ik} = 1 - \frac{1 - a_{4ik}}{\sqrt{\sum_i (a_{1ik} + a_{2ik})^2}}$$

b) cost type:

$$r_{1ik} = \frac{(1 - a_{3ik})^{-1}}{\sqrt{\sum_i ((a_{1ik})^{-1} + (a_{2ik})^{-1})^2}} \quad r_{2ik} = \frac{(1 - a_{4ik})^{-1}}{\sqrt{\sum_i ((a_{1ik})^{-1} + (a_{2ik})^{-1})^2}}$$

$$r_{3ik} = 1 - \frac{(a_{1ik})^{-1}}{\sqrt{\sum_i ((1 - a_{3ik})^{-1} + (1 - a_{4ik}}} \quad r_{4ik} = 1 - \frac{(a_{2ik})^{-1}}{\sqrt{\sum_i ((1 - a_{3ik})^{-1} + (1 - a_{4ik}}}$$

Step 3. The weighted fuzzy decision matrix is constructed: $[\tilde{z}_{ik}]_{IxK}$

Where:

$$\tilde{z}_{ik} = \widetilde{\omega}_k \cdot \tilde{r}_{ik} = ([\alpha_{ik}, \beta_{ik}], [\gamma_{ik}, \delta_{ik}])$$

*Step 4.*The reference point is calculated:

$$\tilde{f}_k = \left(\left[\max_i \alpha_{ik}, \max_i \beta_{ik}\right], \left[\min_i \gamma_{ik}, \min_i \delta_{ik}\right]\right)$$

Step 5. The distances between weighted normalized values alternatives at the level of each criterion from the reference point are calculated:

$$d_{ik} = \frac{1}{K} \cdot d(\tilde{z}_{ik}, \tilde{f}_k)$$

Step 6. The values, d_i that is associated with each alternative are calculated according to the expression:

$$d_i \max_{k=1,\ldots,K} d_{ik}$$

Step 7. The values d_i are sorted in descending order.

3. ILLUSTRATIVE EXAMPLE

In this section, the proposed methodology was tested on the example of the selection of offers for on-going maintenance services and troubleshooting of vehicles in the public procurement procedure in the Revenue Administration. Criteria according to which offers are evaluated are: unit price of service (k=1), grouped services in one service center (k=2), distance of service units (k=3), unit price of technical inspection service (k=4), vehicle transport price (k=5), deadline for complaints about completed services (k=6) and price ratio of spare parts (k=7). DMs that assess the relative importance of the criteria as well as their values.

3.1. An application of the proposed Delphi with IVIFNs

The assessments of the relative importance of the criteria are:

k=1: *HV, FHV, VHV, FHV, HV*

k=2: *LV,FLV,FLV,VLV,MV*

k=3: *MV,MV,FHV,FHV,VHV*

k=4: *FHV,FHV,MV,FHV,HV*

k=5: *MV,LV,FLV,VHV,LV*

k=6: *FLV,VHV,MV,MV,VLV*

k=7: *LV,FLV,FLV,LV,LV*

The proposed methodology is illustrated for criterion (k=1). The DMs importance are considered as: 0.4, 0.2, 0.15, 0.1 and 0.05

The aggregated relative importance of criterion (k=1) is $\widetilde{\omega}_1^I = ([0.70, 0.82], [0.11, 0.18])$.

The distance between the $\widetilde{\omega}_1^I$ and pre-defined linguistic expressions (j=1) is $d(\widetilde{\omega}_1^I, VLV) = \frac{1}{4} \cdot \{|0.70 - 0.05| + |0.82 - 0.15| + |0.11 - 0.65| + |0.18 - 0.85|\} = 0.642$

The linguistic statement that joins the criterion (k=1) is determined by the expression:

$$\min_{j=1,\ldots,5}(0.64, 0.62, 0.46, 0.28, 0.04, 0.02, 0.11) = 0.04$$

Based on the obtained result, it follows that the criterion (k = 1) can be described by the linguistic statement FHV.

In the second round of the extended Delphi technique, estimates of the relative importance of the criterion (k = 1) are:

FHV, FHV, HV, FHV, FHV

Weights of the considered criteria are:

$$\widetilde{\omega}_1 = \begin{pmatrix}[0.66, 0.80],\\ [0.14, 0.20]\end{pmatrix} \quad \widetilde{\omega}_5 = \begin{pmatrix}[0.23, 0.38],\\ [0.47, 0.62]\end{pmatrix}$$

$$\widetilde{\omega}_2 = \begin{pmatrix}[0.10, 0.21],\\ [0.69, 0.79]\end{pmatrix} \quad \widetilde{\omega}_6 = \begin{pmatrix}[0.47, 0.57],\\ [0.36, 0.43]\end{pmatrix}$$

$$\widetilde{\omega}_3 = \begin{pmatrix}[0.46, 0.56],\\ [0.39, 0.44]\end{pmatrix} \quad \widetilde{\omega}_7 = \begin{pmatrix}[0.10, 0.20],\\ [0.70, 0.80]\end{pmatrix}$$

$$\widetilde{\omega}_4 = \begin{pmatrix}[0.65, 0.80],\\ [0.15, 0.20]\end{pmatrix}$$

3.2. An application of the proposed MOORA with IVIFNs

The fuzzy decision matrix is presented in Table 3 and the weighted normalized fuzzy decision matrix as well as the reference point is presented in Table 4.

Table 3. The fuzzy decision matrix

	$k=1$	$k=2$	$k=3$	$k=4$	$k=5$	$k=6$	$k=7$
$i=1$	*FHV*	*HV*	*VLV*	*MV*	*FHV*	*MV*	*FLV*
$i=2$	*HV*	*FLV*	*FLV*	*LV*	*MV*	*FHV*	*MV*
$i=3$	*MV*	*VLV*	*MV*	*FLV*	*LV*	*VHV*	*FHV*

Table 4. The weighted normalized fuzzy decision matrix and the reference point

	$k=1$	$k=2$	$k=3$	$k=4$	k = 5	k = 6	k = 7
$i=1$	([0.08,0.18], [0.72,0.79])	([0.04,0.09], [0.83,0.89])	([0.05,0.13], [0.39,0.67])	([0.07,0.09], [0.81,0.86])	([0.02,0.03], [0.92,0.95])	([0.15,0.19], [0.96,0.97])	([0.01,0.03], [0.92,0.96])
$i=2$	([0.13,0.18], [0.75,0.79])	([0.01,0.04], [0.90,0.95])	([0.03,0.06], [0.73,0.86])	([0.12,0.23], [0.17,0.61])	([0.03,0.05], [0.87,0.93])	([0.10,0.13], [0.97,0.98])	([0.02,0.05], [0.90,0.94])
$i=3$	([0.20,0.26], [0.60,0.70])	([0,0.02] , [0.93,0.98])	([0.03,0.04], [0.88,0.91])	([0.07,0.13], [0.58,0.78])	([0.05,0.12], [0.47,0.80])	([0.09,0.11], [0.98,0.98])	([0.03,0.07], [0.86,0.91])
$\tilde{f}_k$	([0.20,0.26], [0.60,0.70])	([0.04,0.09], [0.83,0.89])	([0.05,0.13], [0.39,0.67])	([0.12,0.23], [0.17,0.61])	([0.05,0.12], [0.47,0.80])	([0.15,0.19], [0.96,0.97])	([0.03,0.07], [0.86,0.91])

Distance between the weighted normalized values of alternatives and reference points are presented in Table 5.

Table 5. The matrix of distance values at the level of each criterion

	k = 1	k = 2	k = 3	k = 4	k = 5	k = 6	k = 7
i= 1	0.0150	0	0	0.0386	0.0257	0	0.0061
i= 2	0.0139	0.0075	0.0221	0	0.0221	0.0046	0.0036
i= 3	0	0.0107	0.0300	0.0260	0	0.0046	0

Respecting the proposed Algorithm, each alternative is joined to the greatest value of distance with respects to all considered criteria. The obtained results are presented in Table 6.

Table 6. Rank of alternatives

	d_i	Rank
i = 1	0.0386	1
i = 2	0.0221	3
i = 3	0.0300	2

According to the obtained results, it follows that the closest offer (i = 3) respects all the criteria as well as their weights.

3. CONCLUSIONS

In this paper, the new model, which combines the IF-Delphi technique and IF-MOORA for measuring and ranking the alternatives with respects to numerous criteria, was developed.

The relative importance of criteria are assessed by DMs and depends on their knowledge, current information and experiences. In order to reduce subjectivity, in this research, determination of criteria weights is based on application of IF-Delphi technique.

The elements of fuzzy decision matrix are given according to the assessments of DMs and modelled by IVIFNs. As the criteria used to measure the alternative benefit and cost type, authors constructed the normalized fuzzy decision matrix. By applying fuzzy algebra rules, the weighted normalized fuzzy decision matrix is stated. The distance between the elements of the weighted normalized fuzzy decision matrix and reference point are calculated by using the Hamming distance. The rank alternatives are obtained by analogy conventional MOORA.

The future research should be oriented to the improvement of the IF-Delphi technique by introducing criteria for achieving consistency in the assessment of DMs.

The main advantages of the presented fuzzy model are: (1) using IVFNs, the linguistic pre-defined linguistics are quantitatively described in a manner that is good enough, (2) The proposed model can be quickly and easily adjusted to changes in the number of criteria, the relative importance of criteria as well as their values.

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