MULTI-CRITERIA GROUP DECISION MAKING IN INTUITIONISTIC FUZZY ENVIRONMENT BASED ON GREY RELATIONAL ANALYSIS FOR WEAVER SELECTION IN KHADI INSTITUTION[1]

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Abstract

The objective of this paper is to present multi-criteria group decision making in intuitionistic fuzzy environment based on grey relational analysis for weaver selection in Khadi institution. Weaver selection is a group decision making process involving qualitative and quantitative criteria. Intuitionistic trapezoidal fuzzy weighted arithmetic average operator and intuitionistic trapezoidal fuzzy weighted geometric average operator are employed to aggregate individual opinions of Khadi experts into a group opinion. In the selection process, criteria and weights of the criteria are obtained from Khadi domain experts. The importance of the Khadi experts is presented by linguistic variables that can be expressed by intuitionistic trapezoidal fuzzy numbers. Normalized weights of Khadi experts are determined by expected weight value. The rating of an alternative with respect to certain criteria considered by Khadi experts is characterized by linguistic variable that can be represented by intuitionistic trapezoidal fuzzy number. Finally, grey relational analysis is applied for ranking and selection of alternatives to constitute a panel of selected weavers. The effectiveness of the proposed approach is illustrated through a numerical example for weaver selection.

Key words: grey relational analysis, grey relational coefficient, intuitionistic trapezoidal fuzzy number, multi-criteria group decision-making, weaver selection

1. Introduction

Khadi refers a handspun or woven material made up from cotton, silk and woolen yarn, which is a mixture of any two or all such yarns [1]. The Khadi industry occupies a significant role in ensuring employment opportunities and economic growth in India. It is important to note that it generates production at low capital cost, promotes the use of local materials, uses local skills and prevents the migration of labour force to the other districts or States. Khadi products are made by the weavers under institutions registered under Societies/ Charitable Trust/ Co-operatives Act or Khadi institutions under the Khadi Mahajan (Owner of Khadi institution). A Khadi institution needs sufficient number of efficient weavers for continuous production for smooth running of the organization. Selecting suitable weavers is a very challenging task.

Atanassov [2] introduced the concept of intuitionistic fuzzy sets which is a generalization of fuzzy sets [3], proposed by Zadeh in 1965. Deng [4] originally developed grey relational analysis (GRA) method for group decision analysis in 1989. GRA has been widely applied to multi-criteria group decision making (MCGDM) problems, where the data set are discrete in nature and information regarding attribute values is incomplete or sometimes unknown. Zhang and Liu [5] developed a GRA based intuitionistic fuzzy MCGDM method for personnel selection. Pramanik and Mukhopadhyaya [6] presented GRA based intuitionistic fuzzy MCGDM approach for teacher selection in higher education. Recently, Baskaran et al. [7] discussed the application of the grey approach for Indian textile suppliers' sustainability evaluation based on the selected sustainable criteria.

In the present study, we have presented an intuitionistic trapezoidal fuzzy MCGDM model with GRA for weaver selection in Khadi institution.

Rest of the paper is organized as follows. In Section 2, we present preliminaries of intuitionistic trapezoidal fuzzy numbers (ITFNs) and transformation between linguistic variables and ITFNs. Section 3 presents operational definition regarding weaver selection. Section 4 describes GRA. Section 5 is devoted to present intuitionistic trapezoidal fuzzy MCGDM based on GRA. Section 6 provides relevant example for illustrating the proposed approach. Finally, Section 7 concludes the paper.

2. Preliminaries

In the following, we first provide some basic concepts related to ITFNs.

Definition 1 [8-11] Let $\tilde{a}$ be an ITFN, its membership function $t_{\tilde{a}}(x)$ and non-membership function $f_{\tilde{a}}(x)$ can be defined as follows:

$$t_{\tilde{a}}(x)=\begin{cases}\dfrac{x-a}{b-a}t_{\tilde{a}}, & a\le x<b\\ t_{\tilde{a}}, & b\le x\le c\\ \dfrac{x-d}{c-d}t_{\tilde{a}}, & c<x\le d\\ 0, & \text{otherwise}\end{cases} \quad \text{and} \quad f_{\tilde{a}}(x)=\begin{cases}\dfrac{b-x+f_{\tilde{a}}(x-a_1)}{b-a_1}, & a_1\le x<b\\ f_{\tilde{a}}, & b\le x\le c\\ \dfrac{x-c+f_{\tilde{a}}(d_1-x)}{d_1-c}, & c<x\le d_1\\ 0, & \text{otherwise}\end{cases}$$

where $0\leq t_{\tilde{a}}(x)\leq 1$; $0\leq f_{\tilde{a}}(x)\leq 1$ and $0\leq t_{\tilde{a}}(x)+f_{\tilde{a}}(x)\leq 1$; $a, a_1, b, c, d, d_1 \in \Re$. $\tilde{a}$ = {([a, b, c, d]; $t_{\tilde{a}}$), ([a_1, b, c, d_1]; $f_{\tilde{a}}$)} is called ITFN. For convenience, let $\tilde{a}$ = ([a, b, c, d]; $t_{\tilde{a}}, f_{\tilde{a}}$).

Definition 2 [8-11] Let $\tilde{a}_1$ = ([a_1, b_1, c_1, d_1]; $t_{\tilde{a}_1}, f_{\tilde{a}_1}$) and $\tilde{a}_2$ = ([a_2, b_2, c_2, d_2]; $t_{\tilde{a}_2}$, $f_{\tilde{a}_2}$) be two ITFNs and $\alpha\geq 0$, then

(i) $\tilde{a}_1+\tilde{a}_2 = ([a_1+a_2, b_1+b_2, c_1+c_2, d_1+d_2]; t_{\tilde{a}_1}+t_{\tilde{a}_2}-t_{\tilde{a}_1}t_{\tilde{a}_2}, f_{\tilde{a}_1}f_{\tilde{a}_2})$

(ii) $\tilde{a}_1.\tilde{a}_2 = ([a_1 a_2, b_1 b_2, c_1 c_2, d_1 d_2]; t_{\tilde{a}_1}t_{\tilde{a}_2}, f_{\tilde{a}_1}+f_{\tilde{a}_2}-f_{\tilde{a}_1}f_{\tilde{a}_2})$

(iii) $\alpha\tilde{a}_1 = ([\alpha a_1, \alpha b_1, \alpha c_1, \alpha d_1]; 1-(1-t_{\tilde{a}_1})^{\alpha}, f_{\tilde{a}_1}^{\alpha})$

(iv) $\tilde{a}_1^{\alpha} = ([a_1^{\alpha}, b_1^{\alpha}, c_1^{\alpha}, d_1^{\alpha}]; t_{\tilde{a}_1}^{\alpha}, 1-(1-f_{\tilde{a}_1})^{\alpha})$

Definition 3 [10] Let $\tilde{a}_1$ = ([a_1, b_1, c_1, d_1]; $t_{\tilde{a}_1}, f_{\tilde{a}_1}$) and $\tilde{a}_2$ = ([a_2, b_2, c_2, d_2]; $t_{\tilde{a}_2}, f_{\tilde{a}_2}$) be two ITFNs, then the normalized Hamming distance between $\tilde{a}_1$ and $\tilde{a}_2$ is defined as follows:

$$H(\tilde{a}_1,\tilde{a}_2) = \frac{1}{8}\Big(\left|(1+t_{\tilde{a}_1}-f_{\tilde{a}_1})a_1-(1+t_{\tilde{a}_2}-f_{\tilde{a}_2})a_2\right| + \left|(1+t_{\tilde{a}_1}-f_{\tilde{a}_1})b_1-(1+t_{\tilde{a}_2}-f_{\tilde{a}_2})b_2\right| + \left|(1+t_{\tilde{a}_1}-f_{\tilde{a}_1})c_1-(1+t_{\tilde{a}_2}-f_{\tilde{a}_2})c_2\right| + \left|(1+t_{\tilde{a}_1}-f_{\tilde{a}_1})d_1-(1+t_{\tilde{a}_2}-f_{\tilde{a}_2})d_2\right|\Big)$$

Definition 4 [12] Let $\tilde{a}$ = ([a, b, c, d]; $t_{\tilde{a}}, f_{\tilde{a}}$) be an ITFN in the set of real numbers $\Re$. Then its expected value is defined as follows:

$$EV(\tilde{a}) = \frac{1}{4}(a+b+c+d)$$

Definition 5 [13] For a normalized intuitionistic trapezoidal fuzzy decision making matrix $\tilde{A}=(\tilde{a}_{ij})_{m\times n}$ = ([a_{ij}, b_{ij}, c_{ij}, d_{ij}]; t_{ij}, f_{ij}) where $0\leq a_{ij}\leq b_{ij}\leq c_{ij}\leq d_{ij}\leq 1$, $0\leq t_{ij}+f_{ij}\leq 1$. The intuitionistic trapezoidal fuzzy positive ideal solution (PIS) and intuitionistic trapezoidal fuzzy negative ideal solution (NIS) are formulated as follows:

$$\tilde{a}^{+} = ([a^+, b^+, c^+, d^+]; t^+, f^+) = ([1, 1, 1, 1]; 1, 0)$$

$$\tilde{a}^{-} = ([a^-, b^-, c^-, d^-]; t^-, f^-) = ([0, 0, 0, 0]; 0, 1).$$

2.1 Transformation between linguistic variables and ITFNs

A linguistic variable is referred as a variable whose values are words or sentences in a natural language. For example, the rating of alternative with respect to certain criteria could be expressed in terms of linguistic variables such as extreme good, very good, good, etc. Linguistic variables can be transformed into ITFNs (see Table1).

Table1. Transformation between the linguistic variables and the ITFNs

Linguistic variables	ITFNs
Extreme good (EG)	([0.80, 0.85, 0.90, 0.95]; 0.95, 0.05)
Very good (VG)	([0.70, 0.75, 0.80, 0.90]; 0.85, 0.10)
Good (G)	([0.60, 0.70, 0.75, 0.80]; 0.80, 0.10)
Medium good (MG)	([0.55, 0.60, 0.65, 0.70]; 0.70, 0.15)
Medium (M)	([0.45, 0.50, 0.55, 0.60]; 0.60, 0.20)
Medium low (ML)	([0.40, 0.45, 0.50, 0.55]; 0.50, 0.25)
Low (L)	([0.30, 0.40, 0.45, 0.50]; 0.45, 0.30)
Very low (VL)	([0.25, 0.30, 0.35, 0.40]; 0.35, 0.40)
Extreme low (EL)	([0.20, 0.25, 0.30, 0.35]; 0.40, 0.50)

3. Operational definition of the terms related to weaver selection problem

(i) **Skill**: Performing the weaving without damaging the Khadi outcome.

(ii) **Previous experience**: Weaving experience expressed in years.

(iii) **Honesty:** Honesty refers truthfulness along with the absence of lying, cheating, or theft of weaving raw materials.

(iv) **Physical fitness:** Physical fitness refers the ability to perform weaving related activities eight hours per day.

(v) **Locality of the weaver**: Reachable distance (0-6 kilo-meter) of weaver's residence from Khadi institution.

(vi) **Personality**: Personality refers the five factors of personality traits of five factor model of McCrae & Costa [14].

(vii) **Economic condition**: The ability of purchasing Khadi raw materials for amount rupees ten thousand.

4. Grey relational analysis

Let $\Re$ be a factor set of grey relation, $\Re = \{\Re_0, \Re_1, \ldots, \Re_p\}$, where $\Re_0 \in \Re$ denotes the referential sequence and $\Re_i \in \Re$, i = 1, 2, ..., p represents the comparative sequence. $\Re_0$ and $\Re_i$ comprise of q elements and can be presented as: $\Re_0$ = ($z_0(1)$, $z_0(2)$, ..., $z_0(k)$, ..., $x_0(q)$) , $\Re_i$ = ($z_i(1)$, $z_i(2)$, ..., $z_i(k)$, ..., $z_i(q)$), where i = 1, ..., p; k = 1, ..., q; $q \in N$, and $z_0(k)$ and $z_i(k)$ are the numbers of referential sequences and comparative sequences at point k, respectively. The grey relational coefficient of the referential sequences and comparative sequences at point k is $\Delta(z_0(k), z_i(k))$, then the grey relational grade for $\Re_0$ and $\Re_i$ will be $\Delta(\Re_0, \Re_i)$ subject to the four conditions:

1. **Normal interval:**

$0 < \Delta(\Re_0, \Re_i) \le 1$,

$\Delta(\Re_0, \Re_i) = 1 \Leftrightarrow \Re_0 = \Re_i$,

$\Delta(\Re_0, \Re_i) = 0 \Leftrightarrow \Re_0, \Re_i \in \Theta$, where Θ represents the empty set.

2. **Dual symmetry:**

$\Re_0, \Re_i \in \Re$

$\Delta(\Re_0, \Re_i) = \Delta(\Re_i, \Re_0) \Leftrightarrow \Re = \{\Re_0, \Re_i\}$.

3. **Wholeness:**

$\Delta(\Re_0, \Re_i) \overset{often}{\neq} \Delta(\Re_i, \Re_0)$

4. **Approachability:**

If $|z_0(k) - z_i(k)|$ getting larger, $\Delta(z_0(k), z_i(k))$ becomes smaller. The grey relational coefficient of the referential sequences and comparative sequences at point k can be expressed as follows:

$$\Delta(z_0(k), z_i(k)) = \frac{\min_i \min_k |z_0(k), z_i(k)| + \zeta \max_i \max_k |z_0(k), z_i(k)|}{|z_0(k), z_i(k)| + \zeta \max_i \max_k |z_0(k), z_i(k)|} \quad (1)$$

The symbol ζ denotes the "environmental coefficient" or the "distinguishing coefficient".

$\zeta \in [0, 1]$ is a free parameter. In general, ζ is considered as 0.5.

5. Intuitionistic trapezoidal fuzzy MCGDM based on GRA

For a MCGDM problem, let $\alpha = \{\alpha_1, \alpha_2, ..., \alpha_p\}$ $(p \geq 2)$ be a finite set of alternatives, $\varepsilon = \{\varepsilon_1, \varepsilon_2, ..., \varepsilon_q\}$ $(q \geq 2)$ be a finite set of Khadi decision makers (DMs) and $\beta = \{\beta_1, \beta_2, ..., \beta_r\}$ $(r \geq 2)$ be the set of criteria. Also let, $W = \{w_1, w_2, ..., w_r\}$ be the weighting vector of the criteria β_j (j = 1, 2, ..., r). The weights of the attribute criteria is provided by the Khadi domain experts in linguistic terms, which can be expressed by ITFNs such that $\sum_{j=1}^{r} w_j = 1$, where $w_i \in [0, 1]$.

We now describe the procedure for intuitionistic trapezoidal fuzzy MCGDM using GRA method by the following steps.

Step 1. Construct an intuitionistic trapezoidal fuzzy decision matrix $\tilde{P}$ of the DMs. Suppose that the rating of alternative α_i (i = 1, 2, ..., p) with respect to the attribute criteria β_j (j = 1, 2, ..., r), provided by the Khadi DMs, can be represented by the linguistic variable ε_{ij}^k (i = 1, 2, ..., p; j = 1, 2, ..., r; k = 1, 2, ..., q) that can be presented in terms of ITFNs $\tilde{p}_{ij}^k$ = $([a_{ij}^{1k}, a_{ij}^{2k}, a_{ij}^{3k}, a_{ij}^{4k}]; t_{ij}^k, f_{ij}^k)$, i = 1, 2, ..., p; j = 1, 2, ..., r; k = 1, 2, ..., q . Therefore, the decision matrix can be explicitly formulated as follows:

$$\widetilde{P} = (\widetilde{p}_{ij}^{k})_{p\times r} = \begin{bmatrix} \widetilde{p}_{11}^{k} & \widetilde{p}_{12}^{k} & \cdots & \widetilde{p}_{1r}^{k} \\ \widetilde{p}_{21}^{k} & \widetilde{p}_{22}^{k} & \cdots & \widetilde{p}_{2r}^{k} \\ . & . & \cdots & . \\ . & . & \cdots & . \\ \widetilde{p}_{p1}^{k} & \widetilde{p}_{p2}^{k} & \cdots & \widetilde{p}_{pr}^{k} \end{bmatrix} \quad (2)$$

Step 2. To eliminate the effect from different physical dimensions to decision results, the decision making matrix should be standardized [15] at first. Suppose that the standardized decision matrix is $\widetilde{D} = (\widetilde{d}_{ij}^{k})_{p\times r}$, $\widetilde{d}_{ij}^{k} = ([d_{ij}^{1k}, d_{ij}^{2k}, d_{ij}^{3k}, d_{ij}^{4k}]; t_{ij}^{k}, f_{ij}^{k})$. For two common types of criteria, namely, benefit type and cost type, the standardized methods are shown as follows:

i) For cost type of criteria: $d_{ij}^{mk} = \dfrac{\max\limits_{j} a_{ij}^{4k} - a_{ij}^{mk}}{\max\limits_{j} a_{ij}^{4k} - \min\limits_{j} a_{ij}^{1k}}$, m =1, 2, 3, 4; k = 1, 2, ..., q (3)

ii) For benefit type of criteria: $d_{ij}^{mk} = \dfrac{a_{ij}^{mk} - \min\limits_{j} a_{ij}^{1k}}{\max\limits_{j} a_{ij}^{4k} - \min\limits_{j} a_{ij}^{1k}}$, m =1, 2, 3, 4; k = 1, 2, ..., q (4)

Step 3. Suppose the decision making group comprises of q Khadi DMs. In the selection process, the importance of the DMs may not be equal. The importance of the Khadi DMs is provided by Khadi domain experts. Also, the importance of the Khadi DMs is presented by linguistic variables that can be expressed by ITFNs (see Table 2).

Table 2

Transformation between linguistic variables and the ITFNs for the importance of the DMs

linguistic variables	ITFNs
very important	([0.85, 0.90, 0.95, 1.00]; 0.95, 0.05)
Important	([0.75, 0.85, 0.90, 0.95]; 0.90, 0.05)
Medium	([0.70, 0.75, 0.80, 0.90]; 0.85, 0.05)
Unimportant	([0.60, 0.65, 0.75, 0.80]; 0.75, 0.10)
Very unimportant	([0.50, 0.55, 0.60, 0.65]; 0.65, 0.15)

The expected weight λ_k (k = 1, 2, ..., q) for an intuitionistic trapezoidal fuzzy weight is determined by definition (4). Then we normalize the expected weight value λ_k (k = 1, 2, ..., q) by the following formula [12]:

$$\lambda_k = \frac{Ev(\lambda_k)}{\sum_{k=1}^{q} Ev(\lambda_k)} \quad (5)$$

Step 4. Formulate the aggregated trapezoidal fuzzy decision matrix based on the opinion of the Khadi DMs. Let $\widetilde{P} = (\widetilde{p}_{ij}^{k})_{p\times r}$ be an trapezoidal fuzzy decision matrix of the k-th Khadi DM and $\lambda = (\lambda_1, \lambda_2, \ldots, \lambda_q)$ be the weight set of Khadi DMs such that $\sum_{k=1}^{q} \lambda_k = 1$. Now all individual decisions need to be fused into group opinion to formulate an aggregated trapezoidal fuzzy decision matrix. In order to do this, we use intuitionistic trapezoidal fuzzy weighted arithmetic average (ITFWAA) operator of Jianquian and Zhang [11] as follows:

Let $\tilde{d}_k$ = ([d_{1k}, d_{2k}, d_{3k}, d_{4k}; $t_{\tilde{d}_k}$, $f_{\tilde{d}_k}$]) (k = 1, 2, ..., q) be a set of standardized ITFNs, then

ITFWAA ($\tilde{d}_1, \tilde{d}_2, \ldots, \tilde{d}_q$) =

$$([\sum_{k=1}^{q}\lambda_k d_{1k}, \sum_{k=1}^{q}\lambda_k d_{2k}, \sum_{k=1}^{q}\lambda_k d_{3k}, \sum_{k=1}^{q}\lambda_k d_{4k}];\ 1-\prod_{k=1}^{q}(1-t_{\tilde{d}_k})^{\lambda_k},\ \prod_{j=1}^{q}(f_{\tilde{d}_k})^{\lambda_k}) \quad (6)$$

Here $\tilde{\lambda} = (\lambda_1, \lambda_2, \ldots, \lambda_q)^T$ is the weight vector of $\tilde{d}_k$ (k = 1, 2, ..., q) and $\lambda_k \in [0, 1]$, $\sum_{k=1}^{q}\lambda_k = 1$.

Also we can use intuitionistic trapezoidal fuzzy weighted geometric average (ITFWGA) operator of Jianquian and Zhang [11] as follows:

Let $\tilde{d}_k$ = ([d_{1k}, d_{2k}, d_{3k}, d_{4k}; $t_{\tilde{d}_k}$, $f_{\tilde{d}_k}$]) (k = 1, 2, ..., q) be a set of standardized ITFNs, then

ITFWGA ($\tilde{d}_1, \tilde{d}_2, \ldots, \tilde{d}_q$) =

$$([\prod_{k=1}^{q}\lambda_k d_{1k}, \prod_{k=1}^{q}\lambda_k d_{2k}, \prod_{k=1}^{q}\lambda_k d_{3k}, \prod_{k=1}^{q}\lambda_k d_{4k}];\ \prod_{j=1}^{q}(t_{\tilde{d}_k})^{\lambda_k},\ 1-\prod_{k=1}^{q}(1-f_{\tilde{d}_k})^{\lambda_k}) \quad (7)$$

Here $\tilde{\lambda} = (\lambda_1, \lambda_2, \ldots, \lambda_q)^T$ is the weight vector of $\tilde{d}_k$ (k = 1, 2, ..., q) and $\lambda_k \in$ [0, 1], $\sum_{k=1}^{q}\lambda_k = 1$.

But, Zhang et al. [15] found some errors in ITFWGA operator of Jianquian and Zhang [11] and they [15] modified the ITFWGA operator.

The modified form of ITFWGA operator [15] is presented as follows:

ITFWGA ($\tilde{d}_1, \tilde{d}_2, \ldots, \tilde{d}_q$) =

$$([\prod_{k=1}^{q}(d_{1k})^{\lambda_k}, \prod_{k=1}^{q}(d_{2k})^{\lambda_k}, \prod_{k=1}^{q}(d_{3k})^{\lambda_k}, \prod_{k=1}^{q}(d_{4k})^{\lambda_k}];\ \prod_{j=1}^{q}(t_{\tilde{d}_k})^{\lambda_k},\ 1-\prod_{k=1}^{q}(1-f_{\tilde{d}_k})^{\lambda_k}) \quad (8)$$

Here $\tilde{\lambda} = (\lambda_1, \lambda_2, \ldots, \lambda_q)^T$ is the weight vector of $\tilde{d}_k$ (k = 1, 2, ..., q) and $\lambda_k \in [0, 1]$, $\sum_{k=1}^{q}\lambda_k = 1$.

Step 5. Determine the reference sequence based on ITFNs. In intuitionistic fuzzy environment, $\tilde{p}^+$ = ([p^+, q^+, r^+, s^+]; μ^+, ν^+) = ([1, 1, 1, 1]; 1, 0) is used as the reference value. So the reference sequence $\tilde{p}_0$ is presented as follows:

$$\tilde{p}_0 = (\tilde{p}_{0j})_{1\times r} \quad (9)$$

Step 6. Determine the grey relational coefficient (χ_{ij}) using the following formula:

$$\chi_{ij} = \frac{\min\limits_{1\le i\le p}\min\limits_{1\le j\le r} d(\tilde{d}_{ij}, \tilde{p}_{0j}) + \zeta \max\limits_{1\le i\le p}\max\limits_{1\le j\le r} d(\tilde{d}_{ij}, \tilde{p}_{0j})}{d(\tilde{d}_{ij}, \tilde{p}_{0j}) + \zeta \max\limits_{1\le i\le p}\max\limits_{1\le j\le r} d(\tilde{d}_{ij}, \tilde{p}_{0j})} \quad (10)$$

Here $\zeta \in [0,1]$, however, in general, ζ is considered as 0.5.

Step 7. Calculate of the degree or grade of grey relational coefficient (κ_i) using the following equation:

$$\kappa_i = \sum_{j=1}^{r} w_j \chi_{ij}, \ i = 1, 2, ..., p \qquad (11)$$

Here w_j (j = 1, 2, …, r) is the weight of the j-th criterion.

Step 8. Rank the alternatives α_1, α_2, ..., α_p based on the degree or grade of grey relational coefficient κ_i. The alternative corresponding to the highest value of κ_i denotes the most desirable alternative.

6. Relevant example for weaver selection problem

Let us suppose that in a Khadi institution, a Khadi Mahajan wants to recruit three weavers from a list of four weavers. During the weavers' selection process, a committee of three Khadi DMs (the experts) has been formed to select two most appropriate weavers based on selected seven criteria namely skill (β_1), previous experience (β_2), honesty (β_3), physical fitness (β_4), locality of the weaver (β_5), personality (β_6), economic condition (β_7). The criteria are selected based on opinions of Khadi domain experts (Khadi Mahajans from Chak, a Gram Panchayet area of Murshidabad, West Bengal, India). In the selection process, the Khadi DMs consider the above mentioned seven selection criteria. The three Khadi DMs ε_j (j = 1, 2, 3) use the linguistic variables to represent the rating of the alternatives (weavers) α_i (i = 1, 2, ..., 4) with respect to the criteria β_j (j = 1, 2, ..., 7) as shown in the Table 3, Table 4, Table 5.

Table 3. Decision matrix for DM_1

Criterion / Alternative	β_1	β_2	β_3	β_4	β_5	β_6	β_7
α_1	VG	VG	MG	MG	M	MG	G
α_2	G	MG	MG	G	M	ML	M
α_3	MG	G	M	M	VG	M	M
α_4	G	G	MG	G	ML	M	G

Table 4. Decision matrix for DM_2

Criterion / Alternative	β_1	β_2	β_3	β_4	β_5	β_6	β_7
α_1	G	VG	G	MG	G	MG	G
α_2	MG	ML	MG	VG	G	M	M
α_3	M	MG	MG	M	M	MG	ML
α_4	MG	MG	M	G	M	ML	G

Table 5. Decision matrix $Z^{(3)}$ for DM_3

Criterion / Alternative	β_1	β_2	β_3	β_4	β_5	β_6	β_7
α_1	G	G	MG	M	M	MG	VG
α_2	EG	G	G	VG	M	ML	M
α_3	G	VG	G	MG	VG	G	M
α_4	G	G	M	MG	ML	MG	VG

We now present the procedure for intuitionistic trapezoidal fuzzy MCGDM using GRA method for weaver selection in Khadi institution by the following steps:

Step 1. Formulate the intuitionistic trapezoidal fuzzy decision matrix of each Khadi DM_i (i = 1, 2, 3). We convert the linguistic variables into ITFNs by using Table 1. The intuitionistic trapezoidal fuzzy decision matrices $\tilde{P}^k = (\tilde{p}_{ij}^k)_{p\times r}$ (k = 1, 2, 3) are formulated as in Table 6, Table 7, Table 8.

Table 6. The intuitionistic trapezoidal fuzzy decision matrix $(\tilde{p}_{ij}^1)_{4\times 7}$

([0.70,0.75,0.80,0.90];0.85,0.10)	([0.70,0.75,0.80,0.90];0.85,0.10)	([0.55,0.60,0.65,0.70];0.70,0.15])	([0.55,0.60,0.65,0.70];0.70,0.15)	([0.45,0.50,0.55,0.60];0.60,0.20)	([0.55,0.60,0.65,0.70];0.70,0.15)	([0.60,0.70,0.75,0.80];0.80,0.10)
([0.60,0.70,0.75,0.80];0.80,0.10)	([0.55,0.60,0.65,0.70];0.70,0.15)	([0.55,0.60,0.65,0.70];0.70,0.15)	([0.60,0.70,0.75,0.80];0.80,0.10)	([0.45,0.50,0.55,0.60];0.60,0.20)	([0.40,0.45,0.50,0.55];0.50,0.25)	([0.45,0.50,0.55,0.60]; 0.60,0.20)
([0.55,0.60,0.65,0.70];0.70,0.15)	([0.60,0.70,0.75,0.80];0.80,0.10)	([0.45,0.50,0.55,0.60];0.60,0.20)	([0.45,0.50,0.55,0.60];0.60,0.20)	([0.70,0.75,0.80,0.90];0.85,0.10)	([0.45,0.50,0.55,0.60];0.60,0.20)	([0.45,0.50,0.55,0.60]; 0.60,0.20)
([0.60,0.70,0.75,0.80];0.80,0.10)	([0.60,0.65,0.70,0.80];0.80,0.10)	([0.55,0.60,0.65,0.70];0.70,0.15)	([0.60,0.70,0.75,0.80];0.80,0.10)	([0.40,0.45,0.50,0.55];0.50,0.25)	([0.45,0.50,0.55,0.60];0.60,0.20)	([0.60,0.70,0.75,0.80]; 0.80,0.10)

Table 7. The intuitionistic trapezoidal fuzzy decision matrix $(\tilde{p}_{ij}^2)_{4\times 7}$

([0.60,0.70,0.75,0.80];0.80,0.10)	([0.70,0.75,0.80,0.90];0.85,0.10)	([0.60,0.70,0.75,0.80];0.80,0.10])	([0.55,0.60,0.65,0.70];0.80,0.10)	([0.60,0.70,0.75,0.80];0.80,0.10)	([0.55,0.60,0.65,0.70];0.70,0.15)	([0.60,0.70,0.75,0.80];0.80,0.10)
([0.55,0.60,0.65,0.70];0.70,0.15)	([0.40,0.45,0.50,0.55];0.50,0.25)	([0.55,0.60,0.65,0.70];0.70,0.15)	([0.70,0.75,0.80,0.90];0.80,0.10)	([0.60,0.70,0.75,0.80];0.80,0.10)	([0.45,0.50,0.55,0.60];0.60,0.20)	([0.45,0.50,0.55,0.60];0.60,0.20)
([0.45,0.50,0.55,0.60];0.60,0.20)	([0.55,0.60,0.65,0.70];0.70,0.15)	([0.55,0.60,0.65,0.70];0.70,0.15)	([0.45,0.50,0.55,0.60];0.60,0.20)	([0.45,0.50,0.55,0.60];0.60,0.20)	([0.55,0.60,0.65,0.70];0.70,0.15)	([0.40,0.45,0.50,0.55];0.50,0.25)
([0.55,0.60,0.65,0.70];0.70,0.15)	([0.55,0.60,0.65,0.70];0.70,0.15)	([0.45,0.50,0.55,0.60];0.60,0.20)	([0.60,0.70,0.75,0.80];0.70,0.15)	([0.45,0.50,0.55,0.60];0.60,0.20)	([0.40,0.45,0.50,0.55];0.50,0.25)	([0.60,0.70,0.75,0.80];0.80,0.10)

Table 8. The intuitionistic trapezoidal fuzzy decision matrix $(\tilde{p}_{ij}^3)_{4\times 7}$

([0.60,0.70,0.75,0.80];0.80,0.10)	([0.60,0.70,0.75,0.80];0.80,0.10)	([0.55,0.60,0.65,0.70];0.70,0.15])	([0.45,0.50,0.55,0.60];0.60,0.20)	([0.45,0.50,0.55,0.60];0.60,0.20)	([0.55,0.60,0.65,0.70];0.70,0.15)	([0.70,0.75,0.80,0.90];0.85,0.10)
([0.80,0.85,0.90,0.95];0.95,0.05)	([0.60,0.70,0.75,0.80];0.80,0.10)	([0.60,0.70,0.75,0.80];0.80,0.10)	([0.70,0.75,0.80,0.90];0.85,0.10)	([0.45,0.50,0.55,0.60];0.60,0.20)	([0.40,0.45,0.50,0.55];0.50,0.25)	([0.45,0.50,0.55,0.60];0.60,0.20)
([0.60,0.70,0.75,0.80];0.80,0.10)	([0.70,0.75,0.80,0.90];0.85,0.10)	([0.60,0.70,0.75,0.80];0.80,0.10)	([0.55,0.60,0.65,0.70];0.70,0.15)	([0.70,0.75,0.80,0.90];0.85,0.10)	([0.60,0.70,0.75,0.80];0.80,0.10)	([0.45,0.50,0.55,0.60];0.60,0.20)
([0.60,0.70,0.75,0.80];0.80,0.10)	([0.60,0.70,0.75,0.80];0.80,0.10)	([0.45,0.50,0.55,0.60];0.60,0.20)	([0.55,0.60,0.65,0.70];0.70,0.15)	([0.40,0.45,0.50,0.55];0.50,0.25)	([0.55,0.60,0.65,0.70];0.70,0.15)	([0.70,0.75,0.80,0.90];0.85,0.10)

Step 2. Construct the standardized decision matrix $\tilde{D}$ using benefit type of criteria by using equation (4) [See Table 9, Table 10, Table 11].

Table 9. The normalized intuitionistic trapezoidal fuzzy decision matrix $(\tilde{d}_{ij}^1)_{4\times 7}$

([0.43,0.57, 0.71,1.00];0.85,0.10)	([0.43,0.57, 0.71,1.00];0.85,0.10)	([0.40,0.60,0.80,1.00];0.70,0.15])	([0.28,0.43,0.57,0.71];0.70,0.15)	([0.10,0.20,0.30,0.40];0.60,0.20)	([0.50,0.67,0.83,1.00];0.70,0.15)	([0.43,0.71, 0.86,1.00];0.80,0.10)
([0.14,0.43,0.57,0.71];0.80,0.10)	([0.00,0.14,0.28,0.43];0.70,0.15)	([0.40,0.60,0.80,1.00];0.70,0.15)	([0.43,0.71, 0.86,1.00]];0.80,0.10)	([0.10,0.20,0.30,0.40];0.60,0.20)	([0.00,0.17,0.33,0.50];0.50,0.25)	([0.00,0.14,0.28,0.43];0.60,0.20)
([0.00,0.14,0.28,0.43];0.70,0.15)	([0.14,0.43,0.57,0.71];0.80,0.10)	([0.00,0.20,0.40,0.60];0.60,0.20)	([0.00,0.14,0.28,0.43];0.60,0.20)	([0.60,0.70,0.80,1.00];0.85,0.10)	([0.17,0.33,0.50,0.67];0.60,0.20)	([0.00,0.14,0.28,0.43];0.60,0.20)
([0.14,0.43,0.57,0.71];0.80,0.10)	(0.14,0.43,0.57,0.71];0.80,0.10)	([0.40,0.60,0.80,1.00];0.70,0.15)	([0.43,0.71, 0.86,1.00];0.80,0.10)	([0.00,0.10,0.20,0.30];0.50,0.25)	([0.17,0.33,0.50,0.67];0.60,0.20)	([0.43,0.71, 0.86,1.00];0.80,0.10)

Table 10. The normalized intuitionistic trapezoidal fuzzy decision matrix $(\tilde{d}_{ij}^{2})_{4\times 7}$

([0.43,0.71,0.86,1.00];0.80,0.10)	([0.60,0.70,0.80,1.00];0.85,0.10)	([0.43,0.71,0.86,1.00];0.80,0.10])	([0.22,0.33,0.44,0.56];0.80,0.10)	([0.43,0.71,0.86,1.00];0.80,0.10)	([0.50,0.67,0.83,1.00];0.70,0.15)	([0.50,0.75,0.88,1.00];0.80,0.10)
([0.28,0.43,0.57,0.71];0.70,0.15)	([0.00,0.10,0.20,0.30];0.50,0.25)	([0.28,0.43,0.57,0.71];0.70,0.15)	([0.56,0.67,0.78,1.00];0.80,0.10)	([0.43,0.71,0.86,1.00];0.80,0.10)	([0.17,0.33,0.50,0.67];0.60,0.20)	([0.12,0.25,0.38,0.50];0.60,0.20)
([0.00,0.14,0.28,0.43];0.60,0.20)	([0.30,0.40,0.50,0.60];0.70,0.15)	([0.28,0.43,0.57,0.71];0.70,0.15)	([0.00,0.11,0.22,0.33];0.60,0.20)	([0.00,0.14,0.28,0.43];0.60,0.20)	([0.50,0.67,0.83,1.00];0.70,0.15)	([0.00,0.12,0.25,0.38];0.50,0.25)
([0.28,0.43,0.57,0.71];0.70,0.15)	([0.30,0.40,0.50,0.60];0.70,0.15)	([0.00,0.14,0.28,0.43];0.60,0.20)	([0.33,0.56,0.67,0.78];0.70,0.15)	([0.00,0.14,0.28,0.43];0.60,0.20)	([0.00,0.17,0.33,0.50];0.50,0.25)	([0.50,0.75,0.88,1.00];0.80,0.10)

Table 11. The normalized intuitionistic trapezoidal fuzzy decision matrix $(\tilde{d}_{ij}^{3})_{4\times 7}$

([0.00,0.28,0.43,0.57];0.80,0.10)	([0.00,0.33,0.50,0.67];0.80,0.10)	([0.28,0.43,0.57,0.71];0.70,0.15])	([0.00,0.11,0.22,0.33];0.60,0.20)	([0.10,0.20,0.30,0.40];0.60,0.20)	([0.38,0.50,0.62,0.75];0.70,0.15)	([0.56,0.67,0.78,1.00];0.85,0.10)
([0.57,0.71,0.86,1.00];0.95,0.05)	([0.00,0.33,0.50,0.67];0.80,0.10)	([0.43, 0.71, 0.86,1.00];0.80,0.10)	([0.56,0.67,0.78,1.00];0.85,0.10)	([0.10,0.20,0.30,0.40];0.60,0.20)	([0.00,0.12,0.25,0.38];0.50,0.25)	([0.00,0.11,0.22,0.33];0.60,0.20)
([0.00,0.28,0.43,0.57];0.80,0.10)	([0.33,0.50,0.67,1.00];0.85,0.10)	([0.43, 0.71, 0.86,1.00];0.80,0.10)	([0.22,0.33,0.44,0.56];0.70,0.15)	([0.60,0.70,0.80,1.00];0.85,0.10)	([0.50,0.75,0.88,1.00];0.80,0.10)	([0.00,0.11,0.22,0.33];0.60,0.20)
([0.00,0.28,0.43,0.57];0.80,0.10)	([0.00,0.33,0.50,0.67];0.80,0.10)	([0.00,0.14,0.28,0.43];0.60,0.20)	([0.22,0.33,0.44,0.56];0.70,0.15)	([0.00,0.10,0.20,0.30];0.50,0.25)	([0.38,0.50,0.62,0.75];0.70,0.15)	([0.56,0.67,0.78,1.00];0.85,0.10)

Step 3. Determine the weights of the Khadi DMs. The expected weight value λ_k (k = 1, 2, 3) for an intuitionistic trapezoidal fuzzy weight is determined by definition (5).The importance of the Khadi DMs in the decision-making situation is considered by Khadi domain expert (Khadi Mahajan) as very important ([0.85, 0.90, 0.95, 1.00]; 0.95, 0.05), very important ([0.85, 0.90, 0.95, 1.00]; 0.95, 0.05), important ([0.75, 0.85, 0.90, 0.95]; 0.90, 0.05) respectively (see Table 2). Using Eq. (5), we obtain the weights of the Khadi DMs as follows:

$\lambda_1 = 0.341,\ \lambda_2 = 0.341,\ \lambda_3 = 0.318.$

The weights of the criteria are obtained from Khadi domain expert's opinion. The average weight of each criterion is given by w = (w_1, w_2, w_3, w_4, w_5, w_6, w_7) = (0.28, 0.13, 0.20, 0.12, 0.07, 0.15, 0.05) with $\sum_{j=1}^{7} w_j = 1$.

Step 4. Formulate the aggregated trapezoidal fuzzy decision matrix based on the opinion of the Khadi DMs. Using the ITFWAA operator given by Eq. (6) we obtain aggregate intuitionistic trapezoidal fuzzy decision matrix[1] (see Table 12).

Table 12. The aggregate intuitionistic trapezoidal fuzzy decision matrix[1] $(\tilde{x}_{ij})_{4\times 7}$

([0.29,0.52,0.67,0.86];0.82,0.10)	([0.35,0.54,0.67,0.90];0.84,0.10)	([0.37,0.58,0.75,0.91];0.74,0.13)	([0.17,0.28,0.41,0.54];0.67,0.16)	([0.21,0.37,0.49,0.60];0.68,0.16)	([0.46,0.62,0.76,0.92];0.70,0.15)	([0.50,0.71,0.84,1.00];0.82,0.10)
([0.32,0.52,0.66,0.80];0.85,0.09)	([0.00,0.19,0.32,0.46];0.69,0.16)	([0.37,0.58,0.74,0.90];0.74,0.13)	([0.52,0.68, 0.81,1.00];0.83,0.10)	([0.21,0.37,0.49,0.60];0.68,0.16)	([0.06,0.21,0.36,0.52];0.54,0.23)	([0.04,0.17,0.30,0.42];0.60,0.20)
([0.00,0.18,0.33,0.47];0.71,0.14)	([0.25,0.44,0.58,0.76];0.79,0.11)	([0.23,0.44,0.60,0.76];0.71,0.14)	([0.07,0.19,0.31,0.44];0.63,0.18)	([0.40,0.51,0.62,0.80];0.79,0.13)	([0.39,0.58,0.73,0.89];0.71,0.14)	([0.00,0.12,0.25,0.38];0.57,0.22)
([0.14,0.38,0.52,0.66];0.77,0.11)	([0.15,0.39,0.52,0.66];0.77,0.11)	([0.14,0.30,0.46,0.52];0.64,0.18)	([0.33,0.54,0.66,0.78];0.77,0.11)	([0.00,0.11,0.23,0.34];0.54,0.23)	([0.14,0.29,0.48,0.64];0.61,0.20)	([0.50,0.71,0.84,1.00];0.82,0.10)

Step 5. Determine the reference sequence $\tilde{p}_0 = (\tilde{p}_{0j})_{1\times 7}$ based on ITFNs. The reference sequence is presented as follows:

$\tilde{p}_0 = (\tilde{p}_{0j})_{1\times 7}$ = {[1, 1, 1, 1]; 1, 0), ([1, 1, 1, 1]; 1, 0), ([1, 1, 1, 1]; 1, 0), ([1, 1, 1, 1]; 1, 0), ([1, 1, 1, 1]; 1, 0), ([1, 1, 1, 1]; 1, 0), ([1, 1, 1, 1]; 1, 0)}.

Step 6. To obtain the grey relational coefficient χ_{ij}, we first calculate the distance σ_{ij} between $\tilde{d}_{ij}$ and $\tilde{p}_{0j}$ (see Table 13). Comparing the distances, we determine the maximum distance σ_{max} and minimum distance σ_{min} (see Table 13). Then substitute these values into Eq. (10) to obtain the grey relational coefficient matrix (see Table 14).

Table 13. Calculation of the distances and determination of σ_{max} and σ_{min}

	b_1	b_2	b_3	b_4	b_5	b_6	b_7	$\min \sigma_{ij}$	$\max \sigma_{ij}$
σ_{1j}	0.4969	0.4650	0.4747	0.7358	0.6827	0.4652	0.3442	0.3442	0.7358
σ_{2j}	0.4940	0.8145	0.4788	0.3491	0.6827	0.8117	0.8372	0.3491	0.8372
σ_{3j}	0.8077	0.5737	0.6016	0.8169	0.5165	0.4917	0.8734	0.4917	0.8734
σ_{4j}	0.6472	0.6431	0.7226	0.5207	0.8886	0.7268	0.3442	0. 3442	0.8886
σ_{max}									0. 8886
σ_{min}								0.3442	

Table 14. Grey relational coefficient matrix[1]

$$= \begin{bmatrix} 0.8378 & 0.8672 & 0.8580 & 0.6682 & 0.6996 & 0.8670 & 1.0000 \\ 0.8403 & 0.6264 & 0.8542 & 0.9938 & 0.6996 & 0.6278 & 0.6153 \\ 0.6298 & 0.7746 & 0.7539 & 0.6252 & 0.8207 & 0.8424 & 0.5984 \\ 0.7224 & 0.7251 & 0.6757 & 0.8171 & 0.5916 & 0.6733 & 1.0000 \end{bmatrix}$$

Step 7. We obtain the degree or grade of grey relational coefficient κ_i (i = 1, 2, ..., 4) by using the equation (11) as follows:

$\kappa_1 = 0.8281$, $\kappa_2 = 0.7807$, $\kappa_3 = 0.7166$, $\kappa_4 = 0.7221$.

Step 8. Rank the alternatives (weavers) according to the descending order of κ_i (i = 1, 2, ..., 4):

$\kappa_1 > \kappa_2 > \kappa_4 > \kappa_3$.

Therefore, the merit panel of the weavers is presented as follows:

$\alpha_1 > \alpha_2 > \alpha_4 > \alpha_3$.

Therefore, Khadi Mahajan selects the three weavers α_1, α_2 and α_4.

Note 1: It is to be noted that using ITFWGA operator [15] as given by Eq. (8), we get aggregate intuitionistic trapezoidal fuzzy decision matrix[2] (see Table 15).

Table 15. The aggregate intuitionistic trapezoidal fuzzy decision matrix[2] $(\tilde{x}_{ij})_{4\times 7}$

([0.00,0.49,0.65,0.84];0.82,0.10)	([0.00,0.51,0.66,0.88];0.83,0.10)	([0.37,0.57,0.74,0.90];0.73,0.13)	([0.00,0.25,0.38,0.51];0.67,0.17)	([0.16,0.31,0.43,0.55];0.66,0.17)	([0.46,0.61,0.76,0.91];0.70,0.15)	([0.49,0.71,0.84,1.00];0.82,0.10)
([0.28,0.50,0.65,0.79];0.81,0.10)	([0.00,0.16,0.30,0.44];0.65,0.17)	([0.36,0.56,0.73,0.89];0.73,0.13)	([0.51,0.68,0.81,1.00];0.83,0.10)	([0.16,0.31,0.43,0.55];0.66,0.17)	([0.00,0.19,0.35,0.51];0.53,0.23)	([0.00,0.16,0.29,0.42];0.60,0.20)
([0.00,0.17,0.32,0.47];0.69,0.15)	([0.24,0.44,0.57,0.75];0.78,0.12)	([0.00,0.39,0.58,0.75];0.69,0.15)	([0.00,0.17,0.30,0.43];0.63,0.18)	([0.00,0.40,0.56,0.75];0.75,0.14)	([0.35,0.54,0.71,0.87];0.69,0.15)	([0.00,0.12,0.25,0.38];0.56,0.22)
([0.00,0.38,0.52,0.66];0.76,0.12)	([0.00,0.38,0.52,0.66];0.76,0.12)	([0.00,0.23,0.40,0.57];0.63,0.18)	([0.32,0.51,0.64,0.76];0.77,0.12)	([0.00,0.11,0.22,0.34];0.53,0.23)	([0.00,0.30,0.46,0.63];0.59,0.20)	([0.49,0.71,0.84,1.00];0.82,0.10)

To obtain the grey relational coefficient, we determine the distance σ_{ij} between $\tilde{d}_{ij}$ and $\tilde{p}_{0j}$ (see Table 16).

Table 16. Calculation of the distances and determination of σ_{max} and σ_{min}

	b_1	b_2	b_3	b_4	b_5	b_6	b_7	min σ_{ij}	max σ_{ij}
σ_{1j}	0.5743	0.5567	0.4840	0.7862	0.7299	0.4691	0.3464	0.3464	0.7862
σ_{2j}	0.5255	0.8335	0.4920	0.3512	0.7299	0.8294	0.8478	0.3512	0.8478
σ_{3j}	0.8152	0.5850	0.6689	0.8389	0.6559	0.5245	0.8744	0.5245	0.8744
σ_{4j}	0.6802	0.6802	0.7825	0.5401	0.8911	0.7585	0.3464	0.3464	0.8911
σ_{max}									0.8911
σ_{min}								0.3464	

Comparing the distances, we obtain the maximum distance σ_{max} and minimum distance σ_{min} (see Table 16). Then substitute these values into Eq. (10), we get the grey relational coefficient matrix (see Table 17).

Table 17. Grey relational coefficient matrix[2]

$$= \begin{bmatrix} 0.7765 & 0.7902 & 0.8520 & 0.6429 & 0.6737 & 0.8658 & 1.0000 \\ 0.8156 & 0.6192 & 0.8447 & 0.9940 & 0.6737 & 0.6212 & 0.6123 \\ 0.6282 & 0.7685 & 0.7106 & 0.6175 & 0.7190 & 0.8164 & 0.6000 \\ 0.7035 & 0.7035 & 0.6449 & 0.8035 & 0.5925 & 0.6577 & 1.0000 \end{bmatrix}$$

Next, using the Eq. (11), the degree or grade of grey relational coefficient κ_i (i = 1, 2, ..., 4) are obtained as follows:

$\kappa_1 = 0.7947$, $\kappa_2 = 0.7680$, $\kappa_3 = 0.6948$, $\kappa_4 = 0.7040$.

Therefore, we rank the alternatives according to the descending order of κ_i (i = 1, 2, ..., 4) as follows:

$\kappa_1 > \kappa_2 > \kappa_4 > \kappa_3$.

And the four weavers are ranked as follows:

$\alpha_1 > \alpha_2 > \alpha_4 > \alpha_3$.

Finally, we observe that the most suitable weavers are α_1, α_2 and α_4.

7. Conclusion

Selection of weavers is one of the key factors for a Khadi institution in the increasing open competitive markets. We have investigated MCGDM approach for weaver selection in Khadi industry. Linguistic variables are transformed into equivalent intuitionistic trapezoidal fuzzy numbers. Intuitionistic trapezoidal fuzzy weighted arithmetic average operator and intuitionistic trapezoidal fuzzy weighted geometric average operator are used to aggregate individual opinions of Khadi DMs into a group opinion. Intuitionistic trapezoidal fuzzy MCGDM based on GRA is presented. Finally, an illustrative example for weaver selection is provided in order to demonstrate the practicality of the proposed approach. We hope that the proposed approach can be effective for dealing with the other MCGDM problems such as teacher selection, investment, personnel selection, medical diagnosis, supplier selection and many other areas of management decision problems.

References

1. Anjum, D. **An analysis of khadi and village industry sector in J &K**, International Journal of Multidiciplinary Research, Vol. 1, No. 8, 2011, pp. 213-220
2. Atanassov, K. T. **Intuitionistic fuzzy sets**, Fuzzy Sets and Systems, Vol. 20, No. 1, 1986, pp. 87–96
3. Zadeh, L. A. **Fuzzy Sets**, Information and Control, Vol. 8, No. 3, 1965, pp.338-353
4. Deng, J. L. **Introduction to grey system theory**, The Journal of Grey System, Vol. 1, No. 1, 1989, pp. 1–24
5. Zhang, S. and Liu, S. **A GRA-based intuitionistic fuzzy multi-criteria group decision making method for personnel selection**, Expert Systems with Applications, Vol. 38, No. 9, 2011, pp. 11401-11405
6. Pramanik, S., and Mukhopadhyaya, D. **Grey relational analysis based intuitionistic fuzzy multi-criteria group decision-making approach for teacher selection in higher education**, International Journal of Computer Applications, Vol. 34, No. 10, 2011, pp. 21-29
7. Baskaran, V., Nachiappan, S., and Rahman, S. **Indian textile suppliers' sustainability evaluation using grey approach**, International Journal of Production Economics, Vol. 135, No. 2, 2012, pp. 647-658
8. Wang, J. Q. **Overview on fuzzy multi-criteria decision-making approach**, Control and Decision, Vol. 23, No. 6, 2008, pp. 601-606
9. Wang, J. Q., and Zhang, Z. H. **Programming method of multi-criteria decision-making based on intuitionistic fuzzy number with incomplete certain information**, Control and Decision, Vol. 23, No. 10, 2008, pp. 1145-1148
10. Wang, J. Q., and Zhang, Z. H. **Multi-criteria decision-making method with incomplete certain information based on intuitionistic fuzzy number**, Control and Decision, Vol. 24, No. 2, 2009, pp. 226-230
11. Jianqiang, W., and Zhang, Z. **Aggregation operators on intuitionistic trapezoidal fuzzy number and its application to multi-criteria decision making problems**, Journal of Systems Engineering and Electronics, Vol. 20, No. 2, 2009, pp. 321-326
12. Ye, J. **Expected value method for intuitionistic trapezoidal fuzzy multicriteria decision-making problems**, Expert Systems with Applications, Vol. 38, No. 9, 2011, pp. 11730-11734
13. Wei, G. **Some arithmetic aggregation operators with intuitionistic trapezoidal fuzzy numbers and their application to group decision making**, Journal of Computers, Vol. 5, No. 3, 2010, pp. 345-351
14. Costa, P.T., and McCrae, R.R. **Revised NEO personality inventory (REO-PI-R) and Neo five-factor inventory (NEO-FFI)**, Professional manual. Odessa, FL: Psychological Assessment Resources, 1992

15. Zhang, X., Jin, F., and Liu, P. **A grey relational projection method for multi-attribute decision making based on intuitionistic trapezoidal fuzzy number**, Applied Mathematical Modelling, Vol. 37, No. 5, 2012, pp. 3467-3477

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