Grey Relational Analysis based Intuitionistic Fuzzy Multi-criteria Group Decision-making Approach for Teacher Selection in Higher Education

Surapati Pramanik
Assistant Professor
Nandalal Ghosh B.T. College, Panpur, P.O.- Narayanpur, North 24 Parganas West Bengal, 743126, India

Dulal Mukhopadhyaya
Professor
Department of Education, University of Kalyani, Kalyani, Nadia, West Bengal, 743126, India

ABSTRACT
Teacher selection is a group decision-making process under multiple criteria involving subjectivity, imprecision, and vagueness, which are best represented by intuitionistic fuzzy sets. An intuitionistic fuzzy set, which is characterized by membership function (degree of acceptance), non-membership function (degree of rejection) and the degree of indeterminacy or the degree of hesitancy, is a more general and suitable way to deal with imprecise information, when compared to a fuzzy set. The purpose of this study is to develop an intuitionistic fuzzy multi criteria group making method with grey relational analysis for teacher selection in higher education. Intuitionistic fuzzy weighted averaging operator is used to aggregate individual opinions of decision makers into a group opinion. Eight criteria obtained from expert opinions are considered for selection process. The criteria are namely academic performances, teaching aptitude, research experience, leadership quality, personality, management capacity, and values. Weights of the criteria are obtained by using a questionnaire. The weights of decision makers are considered as equal i.e. their importance are equal. The rating of an alternative with respect to certain criteria offered by decision maker is represented by linguistic variable that can be expressed by intuitionistic fuzzy sets. Grey relational analysis is used for ranking and selection of alternatives to constitute a panel of selected candidates. An educational problem for teacher selection is provided to illustrate the effectiveness of the proposed model.

General terms
Intuitionistic Fuzzy Multi-criteria Group Decision-making.

Key words: Intuitionistic Fuzzy sets, Multi Criteria Group Decision-Making, Grey System Theory, Grey Relational Analysis, Grey Relational Coefficient.

1. INTRODUCTION
Multi criteria decision-making (MCDM) problem generally consists of finding the most desirable alternative from all the feasible alternatives. Classical MCDM [1, 2] deals with crisp numbers i.e. the ratings and the weights of criteria are measured by crisp numbers. Fuzzy MCDM [3, 4] deals with fuzzy or intuitionistic fuzzy numbers i.e. the ratings and the weights are expressed by linguistic variable characterized by fuzzy or intuitionistic fuzzy numbers. In 1965, Zadeh [5] published seminal paper studying with fuzzy sets. In 1986, Atanassov [6] extended the concept of fuzzy sets to intuitionistic fuzzy sets (IFSs).

Teacher selection process for higher education is a special case of personnel selection. The traditional methods generally conclude based on subjective judgment of decision makers, which makes the accuracy of the results highly questionable. In order to select the most suitable teacher for higher education to perform teaching learning activities, combining the subjective judgment and the objective analysis to develop effective selection approaches is very demanding for new challenge in open competitive education arena. Liang and Wang [7] presented a fuzzy MCDM algorithm for personnel selection. Karsak (8) developed a fuzzy MCDM approach based on ideal and anti-ideal solutions for the selection of the most suitable candidate. Gibney and Shang [9] and Günör, et al.[10] presented the use of the analytical hierarchy process (AHP) in the personnel selection process, respectively. Dağdeviren (11) proposed a hybrid model, which employs analytical network process (ANP) and modified technique for order preference by similarity to ideal solution (TOPSIS) for supporting the personnel selection process in the manufacturing systems. Dursun and Karsak [12] presented a fuzzy MCDM approach by using TOPSIS with 2-tuples for personnel selection. Robertson and Smith [13] presented good reviews on personnel selection studies. They investigated the role of job analysis, contemporary models of work performance, and set of criteria used in personnel selection process. A comprehensive survey of the state of the art in MCDM can be found in the book authored by Ehrgott and Gandibleux [14].

In this study, we present an intuitionistic fuzzy multi criteria group decision-making model with grey relational analysis for teacher selection in higher education.

Rest of the paper is organized in the following way. Section 2 presents preliminaries of fuzzy sets and intuitionistic fuzzy sets Section 3 presents operational definitions. Section 4 describes grey relational analysis. Section 5 is devoted to present intuitionistic fuzzy multi-criteria group decision-making based on grey relational analysis for teacher selection in higher education. In section 6, an educational problem for teacher selection is provided to illustrate the effectiveness of the proposed model. Reliability, validity, limitation and advantage of the proposed approach are discussed in subsections 6.1-6.4. Finally, section 7 presents the concluding remarks.

2. PRELIMINARIES OF FUZZY SETS

In 1965, Zadeh first introduced the concept of fuzzy sets as a mathematical way for representing impreciseness.

2.1 Definition

Fuzzy set: A fuzzy set $\tilde{A}$ in a universe of discourse X is defined by $\tilde{A} = \{\langle x, \mu_{\tilde{A}}(x) \rangle \mid x \in X\}$, where $\mu_{\tilde{A}}(x) : X \to [0, 1]$ is called the membership function of $\tilde{A}$.

2.2 Definition

An intuitionistic fuzzy set (IFS) $\overset{\sim i}{A}$, in a universe of discourse X, is defined by $\overset{\sim i}{A} = \{\langle x, \mu_{\overset{\sim i}{A}}(x), \nu_{\overset{\sim i}{A}}(x)\rangle \mid x \in X\}$, where the functions $\mu_{\overset{\sim i}{A}}(x)$,: $X \to [0, 1]$ and $\nu_{\overset{\sim i}{A}}(x)$: $X \to [0, 1]$ define the degree of membership and degree of non-membership respectively of the element $x \in X$ to the set $\overset{\sim i}{A}$ that is a subset of X, and every $x \in X$, $0 \le \mu_{\overset{\sim i}{A}}(x) + \nu_{\overset{\sim i}{A}}(x) \le 1$.

2.3 Definition

The value of $\pi_{\overset{\sim i}{A}}(x) = 1 - (\mu_{\overset{\sim i}{A}}(x) + \nu_{\overset{\sim i}{A}}(x))$ is called the degree of non-determinacy (or uncertainty or hesitancy) of the element $x \in X$ to the intuitionistic fuzzy set

2.4 Definition

Hamming distance is defined as

$$H(\overset{\sim i}{A}, \overset{\sim i}{B}) = \delta$$

$$\frac{1}{2}\sum_{x \in E}\left(\left|\mu_{\overset{\sim i}{A}}(x) - \mu_{\overset{\sim i}{B}}(x)\right| + \left|\nu_{\overset{\sim i}{A}}(x) - \nu_{\overset{\sim i}{B}}(x)\right| + \left|\pi_{\overset{\sim i}{A}}(x) - \pi_{\overset{\sim i}{B}}(x)\right|\right)$$

2.5 Conversion between linguistic variables and intuitionistic fuzzy number (IFN)

In the case of intuitionistic fuzzy sets, the description of linguistic variable is more realistic. For example, the ratings of alternative with respect to qualitative criteria could be expressed using linguistic variables such as very poor, poor, good, fair, very good etc. Linguistic variable can be converted into IFNs (see Table 1).

3. OPERATIONAL DEFINITIONS OF THE TERMS STATED IN THE PROBLEM

i) **Academic performance:** Academic performance implies the grade or % of marks obtained in respective examinations.

ii) **Teaching aptitude:** Degree of knowledge in general information with respect to education, international thinkers, philosophers, psychology of education, strategies of instruction and information communication technology (ICT).

iii) **Subject knowledge:** Degree of knowledge of a person in his/her respective field of study to be delivered during his/her instruction.

iv) **Research experience:** Research experience of a person implies his/her research articles published in peer-reviewed journals with ISSN number.

v) **Leadership quality:** Leadership quality of a person implies the ability a) to make tough decision b) to conduct seminar/workshop/symposium c) to communicate effectively.

vi) **Personality:** Research on personality has revealed that personality is related to physiological processes [15] and there exists ‘‘robust evidence that genetic factors substantially influence personality traits” [16], with heritability averaging around .40 [17]. Personality describes the breadth, depth, originality, and complexity of an individual’s mental and experimental life. It includes the factors curious, imaginative, and open-minded [18]. Five factors of personality due to McCrae & Costa [19] are extraversion versus introversion, agreeableness versus antagonism, conscientiousness versus undirectedness, neuroticism versus emotional stability, and openness versus not openness. Five factor model (FFM) is now widely accepted as a meaningful way to organize personality traits and has been shown to have cross-cultural generalizability. The emergence of the FFM led to increase research work on personality, with the conclusion that personality has indeed meaningful relationships with performance, motivation, job satisfaction, leadership, and other work outcomes [20]. Aidla & Vadi [21] concluded from their study that personality traits should be considered when selecting new teachers. The researchers considered a working definition of personality as follows: Personality implies the five factors of personality traits of FFM.

vii) **Management capacity:** Management capacity of a person implies his/her ability to manage in the actual teaching learning process.

viii) **Values:** Schwartz value theory [22] is the most widely used and most well developed value theory. Based on the placement of the values in the circumplex structure, Schwartz [22] has identified 10 value domains, which are essentially fuzzy sets. The 10 value domains and sample values for each include 1) Power (authority, wealth, social recognition), 2) Achievement (ambition, competence, success). 3) Hedonism (pursuit of pleasure, enjoyment, gratification of desires), 4) Stimulation (variety, excitement, novelty), 5) Self-direction (creativity, independence, self-respect), 6) Universalism (social justice, equality, wisdom, environmental concern), 7) Benevolence (honesty, helpfulness, loyalty), 8) Conformity (politeness, obedience, self-discipline/restraint), 9) Tradition (respect for tradition and the status quo, acceptance of customs) and 10) Security (safety, stability of society). Schwartz and Bilsky [23, 24] have tested the circumplex structure extensively and cross-culturally. They obtained quite consistent result based on samples over 40 countries.

The researchers considered a working definition of value as follows: Values will implicitly refer to personal values that serve as guiding principles about how individuals ought to behave.

4. GREY RELATIONAL ANALYSIS (GRA)

The calculation process for GRA [25] is expressed as follows: Suppose X be a factor set of grey relation, $X = \{X_0, X_1, ..., X_m\}$, where $X_0 \in X$ represents the referential sequence; $X_i \in X$ denotes the comparative sequence, and $i = 1, \ldots, m$. X_0 and X_i consist of n elements and can be expressed as follows:

$X_0 = (x_0(1), x_0(2), ..., x_0(k), ..., x_0(n))$,

$X_i = (x_i(1), x_i(2), ..., x_i(k), ..., x_i(n))$, where $i = 1, \ldots, m$; $k = 1, \ldots, n$; $n \in N$, and $x_0(k)$ and $x_i(k)$ are the numbers of referential sequences and comparative sequences at point *k*, respectively. In practical applications, the referential sequence can be an ideal objective and the comparative sequences are alternatives. The best alternative corresponds to the largest degree of grey relation. If the grey relational coefficient (GRC) of the referential sequences and comparative sequences at point *k* is $\tau(x_0(k), x_i(k))$, then the grey relational grade for X_0 and Xi will be $\tau(X_0, X_i)$ subject to the four conditions:

1. Normal interval:
   $0 < \tau(X_0, X_i) \le 1$,
   $\tau(X_0, X_i) = 1 \Leftrightarrow X_0 = X_i$,
   $\tau(X_0, X_i) = 0 \Leftrightarrow X_0, X_i \in \Phi$, where Φ is empty set.
2. Dual symmetry:
   $X_0, X_i \in X$
   $\tau(X_0, X_i) = \tau(X_i, X_0) \Leftrightarrow X = \{X_0, X_i\}$
3. Wholeness:
   $\tau(X_0, X_i) \overset{\text{often}}{\neq} \tau(X_i, X_0)$
4. Approachability:
   If $|x_0(k) - x_i(k)|$ getting larger, $\tau(x_0(k), x_i(k))$ becomes smaller. The essential condition and quantitative model for grey relation are produced based on the above four prerequisites. The grey relational coefficient of the referential sequences and comparative sequences at point k can be expressed as follows:

$$\tau(x_0(k), x_i(k)) = \frac{\min_i \min_k |x_0(k) - x_i(k)| + \rho \max_i \max_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \rho \max_i \max_k |x_0(k) - x_i(k)|} \quad (1)$$

The symbol ρ represents the equation's "contrast control," sometimes also be referred to as the "environmental coefficient" or the "distinguishing coefficient". This coefficient is a free parameter. Its value, over a broad appropriate range of values, does not affect the ordering of the grey relational grade values, but a good value of the contrast control is needed for clear identification of key system factors. For the end points 0 and1, i.e. for $\rho = 1$, the comparison environment is unaltered and for $\rho = 0$, the comparison environment disappears. In cases where data variation is large, ρ usually ranges from 0.1 to 0.5 for reducing the influence of extremely large $\max_i \max_k |x_0(k) - x_i(k)|$. In general, ρ is set as 0.5.

5. INTUITIONISTIC FUZZY MULTI-CRITERIA GROUP DECISION-MAKING BASED ON GREY RELATIONAL ANALYSIS

In this section, we present intuitionistic fuzzy multi criteria group decision-making (MCGDM) using grey relational analysis. For a MCGDM problem, let A = {$A_1, A_2, ..., A_m$} ($m \ge 2$) be a finite set of alternatives, D = {$D_1, D_2, ..., D_p$} ($p \ge 2$) be a set of decision makers, and C = {$C_1, C_2, ..., C_n$} be a set of criteria. The weight information of the criteria and the decision maker are completely unknown. Let us denote M = {1, 2, ..., m}, P = {1, 2, ..., p), N = {1, 2, ..., n).

Step 1. Construction of intuitionistic fuzzy decision matrices of decision makers: We assume that the rating of alternative A_i ($i \in$ M) with respect to criteria C_j($j \in$ N) offered by the K-th decision maker ($k \in$ P) is linguistic variable [26] α_{ij}^k that can be expressed by IFSs (see Table1). A MCGDM problem can then be expressed by the following decision matrix:

$$X = \left(x_{ij}^k\right) = \begin{bmatrix} x_{11}^k, x_{12}^k, ..., x_{1n}^k \\ x_{21}^k, x_{22}^k, ..., x_{2n}^k \\ . \quad . \quad . \\ . \quad . \quad . \\ . \quad . \quad . \\ x_{m1}^k, x_{m2}^k, ..., x_{mn}^k \end{bmatrix}, k \in P \quad (2)$$

where $x_{ij}^k = \left(\mu_{ij}^k, \nu_{ij}^k, \pi_{ij}^k\right)$.

Step 2. Determination of the weights of the decision makers: We assume that the decision making group consists of p decision makers. The importance of the decision makers in the selection committee may not be equal. The importance of decision makers are considered as linguistic variables expressed by intuitionistic fuzzy numbers (IFNs). Let $D_k = (\mu_k, \nu_k, \pi_k)$ be an intuitionistic IFN that represents the rating of the k-th decision maker. Then the weight [27] of the k-th decision maker can be determined as:

$$\gamma_k = \frac{\left(\mu_k + \pi_k\left(\frac{\mu_k}{\mu_k + \nu_k}\right)\right)}{\sum_{k=1}^{p}\left(\mu_k + \pi_k\left(\frac{\mu_k}{\mu_k + \nu_k}\right)\right)}, \text{ where } \sum_{k=1}^{p}\gamma_k = 1 \quad (3)$$

The linguistic variables for the importance of the decision makers are provided in the Table 2. If the importance of all the decision makers is same namely extremely importance, the rating of the k-th decision maker can be expressed as (1, 0, 0). Then the weight of each decision maker will be 1/p.

Step 3. Construction of the aggregated intuitionistic fuzzy decision matrix based on the opinions of decision makers: Let X = $\left(x_{ij}^k\right)_{m \times n}$ be an intuitionistic fuzzy decision matrix of the k-th decision maker. $\gamma = (\gamma_1, \gamma_2, ..., \gamma_p)$, be the weight set of the decision makers and $\sum_{k=1}^{p}\gamma_k = 1$, $\gamma_k \in [0, 1]$. In the group decision-making process, all individual decisions need to be fused into a group opinion to construct an aggregate intuitionistic fuzzy decision matrix. In order to do, we use intuitionistic fuzzy weighted average (IFWA) operator due to Xu [28] as follows:

$$X_{ij} = \text{IFGA}_\gamma\left(x_{ij}^{(1)}, x_{ij}^{(2)}, ..., x_{ij}^{p}\right) = \gamma_1 x_{ij}^{(1)} \oplus \gamma_2 x_{ij}^{(2)} \oplus ... \oplus \gamma_p x_{ij}^{(p)}$$

$$= \left(1 - \prod_{k=1}^{p}\left(1 - \mu_{ij}^{(k)}\right)^{\gamma_k}, \prod_{k=1}^{p}\left(\nu_{ij}^{(k)}\right)^{\gamma_k}, \prod_{k=1}^{p}\left(1 - \mu_{ij}^{(k)}\right)^{\gamma_k} - \prod_{k=1}^{p}\left(\nu_{ij}^{(k)}\right)^{\gamma_k}\right) \quad (4)$$

The aggregate intuitionistic fuzzy decision matrix then can be defined as:

$$X = \begin{bmatrix} (\mu_{11}, \nu_{11}, \pi_{11})(\mu_{12}, \nu_{12}, \pi_{12})... & (\mu_{1n}, \nu_{1n}, \pi_{1n}) \\ (\mu_{21}, \nu_{21}, \pi_{21})(\mu_{22}, \nu_{22}, \pi_{22})... & (\mu_{2n}, \nu_{2n}, \pi_{2n}) \\ . \quad\quad . & . \\ . \quad\quad . & . \\ . \quad\quad . & . \\ (\mu_{m1}, \nu_{m1}, \pi_{m1})(\mu_{m2}, \nu_{m2}, \pi_{m2})... & (\mu_{mn}, \nu_{mn}, \pi_{mn}) \end{bmatrix}$$

$$= \begin{bmatrix} x_{11}\ x_{12} \dots\ x_{1n} \\ x_{21}\ x_{21} \dots x_{2n} \\ . \quad . \quad . \\ . \quad . \quad . \\ . \quad . \quad . \\ x_{m1}\ x_{m2} \dots x_{mn} \end{bmatrix} \quad (5)$$

Here $x_{ij} = (\mu_{ij}, \nu_{ij}, \pi_{ij})$ (i = 1, 2, ..., m; j=1,2, ..., n) is an element of the aggregate intuitionistic fuzzy decision matrix.

$$\mu_{ij} = 1 - \prod_{k=1}^{p}\left(1-\mu_{ij}^{(k)}\right)^{\gamma_k},\ \nu_{ij} = \prod_{k=1}^{p}\left(\nu_{ij}^{(k)}\right)^{\gamma_k},\ \pi_{ij} = \prod_{k=1}^{p}\left(1-\mu_{ij}^{(k)}\right)^{\gamma_k} - \prod_{k=1}^{p}\left(\nu_{ij}^{(k)}\right)^{\gamma_k},\ i \in M,\ j \in N$$

Step4. Determination weights of the criteria: In the decision-making situation, decision makers may feel that all criteria are not equal importance. Here the importance of the criteria is obtained from expert opinion through questionnaire method i.e. the weights of the criteria are previously determined such that the sum of the weights of the criteria is equal to unity. Incidental sampling is employed to collect data. Data was collected from 30 teachers (Professors, associate professor, assistant professor). They were chosen from department of Education and B. Ed Colleges from University of Kalyani, University of Kolkata, University of Burdwan, University of North Bengal, and West Bengal State University. After extended interviews and long discussions with the experts, the list of criteria that are identified as playing important role in model formulation of the problem. After structured procedures of filling in specific questionnaire by our domain experts, the criteria for teacher selection are identified as academic performances, subject knowledge, teaching aptitude, research experience, leadership quality, personality, management capacity, and values. We have average weight of each criteria w_j (j = 1, 2, ..., 8) as w_1 = .2612, w_2 = .1804, w_3 = .1908, w_4 = .1076, w_5 = .0754, w_6 = .0754, w_7 = .0562, w_8 =.054, with $\sum_{j=1}^{8} w_j = 1$.

Alternately, the entropy weights of the criteria may be used. In order to obtain weight, a set of grades of importance, intuitionistic fuzzy entropy may be used due to Vlachos & Sergiadis [29] as follows:

$$E_j = -\frac{1}{n \ln 2}\sum_{i=}^{m}[\mu_{ij}\ln\mu_{ij} + \nu_{ij}\ln\nu_{ij} - (1-\pi_{ij})\ln(1-\pi_{ij}) - \pi_{ij}\ln 2] \quad (6)$$

Here if μ_{ij} =0, ν_{ij} = 0, π_{ij} = 1, then $\mu_{ij}\ln\mu_{ij}$ = 0, $\nu_{ij}\ln\nu_{ij}$ = 0, $(1-\pi_{ij})\ln(1-\pi_{ij})$ = 0 respectively.

The entropy weight of the j-th criteria is defined as follows:

$$w_j = \frac{1-E_j}{n - \sum_{j=1}^{n} E_j} \quad (7)$$

Step5. Determination of the reference sequence based on IFNs:

$$\tilde{x}^+ = \left(\left(\mu_1^+, \nu_1^+, \pi_1^+\right), \left(\mu_2^+, \nu_2^+, \pi_2^+\right), \dots \left(\mu_n^+, \nu_n^+, \pi_n^+\right)\right) \quad (8)$$

where $\tilde{x}_{ij}^+ = \left(\mu_j^+, \nu_j^+, \pi_j^+\right) = \left(\max_i \mu_{ij}, \min_i \nu_{ij}, \min_i \pi_{ij}\right)$, j = 1, 2, …, n (9)

Reference sequence should be the optimal sequence of the criteria values. Since the aspired level of the membership value, non-membership value and indeterminacy value are 1, 0, 0 respectively, the point consisting of highest membership value, minimum non-membership value and minimum indeterminacy value would represent the reference value or ideal point or utopia point. In the intuitionistic fuzzy decision matrix, the maximum value $\tilde{x}_j^+$ = (1, 0, 0) can be used as the reference value. Then the reference sequence $\tilde{x}^+$ is presented as $\tilde{x}^+$ =

$$[(1,0,0), (1,0,0), \dots, (1,0,0)] \quad (10)$$

Step6. Calculation of the grey relational coefficient of each alternative from positive ideal solution (PIS) using the following equation:

$$\tau_{ij} = \frac{\min_{1\le i\le m}\min_{1\le j\le n}\delta\left(\tilde{x}_{ij}, \tilde{x}_{ij}^+\right) + \rho \max_{1\le i\le m}\max_{1\le j\le n}\delta\left(\tilde{x}_{ij}, \tilde{x}_{ij}^+\right)}{\delta\left(\tilde{x}_{ij}, \tilde{x}_{ij}^+\right) + \rho \max_{1\le i\le m}\max_{1\le j\le n}\delta\left(\tilde{x}_{ij}, \tilde{x}_{ij}^+\right)} \quad (11)$$

τ_{ij} is the grey relational coefficient between $\tilde{x}_{ij}$ and $\tilde{x}_{ij}^+$. ρ is the distinguishing coefficient or the identification coefficient, $\rho \in$ [0,1]. Smaller value of distinguishing coefficient will yield in large range of grey relational coefficient. Generally, ρ = 0.5 is considered for decision- making situation. $\rho \in [0, 1]$ is the distinguishable coefficient used to adjust the range of the comparison environment, and to control level of differences of the relation coefficients. When ρ =1, the comparison environment is unaltered; when ρ =0, the comparison environment disappears.

Step7. Calculation of the degree of grey relational coefficient of each alternative from PIS using the following equation:

$$\eta_i = \sum_{j=1}^{n} w_j \tau_{ij},\ j = 1, 2, \dots, n. \quad (12)$$

Step8. Ranking all the alternatives: We rank all the alternatives A_i (i = 1, 2, ..., m) according to the decreasing order of their grey relational grades η_i (i = 1, 2, ..., m). Greater the value of η_i implies the better alternative A_i.

Step 9. End.

6. EXAMPLE OF TEACHER SELECTION PROCESS

Suppose that a university is going to recruit in the post of an assistant professor. After initial screening, five candidates (i.e. alternatives) A_1, A_2, A_3, A_4, A_5 remain for further evaluation. A committee of five decision makers or experts, D_1, D_2, D_3, D_4, D_5 has been formed to conduct the interview and select the most appropriate candidate. Eight criteria obtained from expert opinions, namely, academic performances (C_1), subject knowledge (C_2), teaching aptitude (C_3), research- experiences (C_4), leadership quality (C_5), personality (C_6), management capacity (C_7), values (C_8) are considered for selection criteria. Five decision makers D_k(k = 1, 2, 3, 4 ,5) use linguistic variables shown in Table 1 to evaluate the ratings of the candidates A_i(i=1, 2, 3, 4, 5) with respect to the criterion C_j (j = 1, 2,...,8). They construct the decision matrices $X^{(k)} = \left(x_{ij}^k\right)_{5\times 8}$ (k = 1, 2, 3, 4, 5) as listed in Table 1-7. Construct a panel of selected candidate according to merit.

Table 1. Conversion between linguistic variables and IFNs

Linguistic variables	IFNs
Extreme good (EG)/Extreme high(EH)	(0.95, 0.05, 0.00)
Very good (VG)/Very high (VH)	(0.85, 0.10, 0.05)
Good(G)/High(H)	(0.75, 0.15, 0.10)
Medium good(MG)/Medium high	(0.65, 0.25, 0.10)
Fair(F)/Medium(M)	(0.50, 0.40, 0.10)
Medium poor(MP)/Medium low(ML)	(0.35, 0.55, 0.10)
Poor (P)/Low(L)	(0.25, 0.65, 0.10)
Very poor (VP)/Very low(VL)	(0.15, 0.80, 0.05)
Extreme poor(EP)/Extreme low(EL)	(.05, 0.95, 0.00)

Table 2. Linguistic variable for the importance of the experts or decision makers

Linguistic variables	IFNs
Very important	(1.0, 0, 0)
Important	(.75, .20, .5)
Medium	(.50, 40, .10)
Unimportant	(.25,60, .15)
Very unimportant	(.10, .80, .10)

E_k= (1, 0, 0) can be considered as the intuitionistic fuzzy number for rating k-th decision maker or expert.

Table 3. Decision matrix $X^{(1)}$

A_i	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	VG	G	VG	G	MG	G	G	M
A_2	VG	MG	G	G	VG	F	MG	G
A_3	EG	MG	G	MG	MG	F	F	MP
A_4	EG	G	VG	MG	G	G	F	F
A_5	VG	G	G	MG	MG	G	G	G

Table 4. Decision matrix $X^{(2)}$

A_i	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	VG	MG	G	G	MG	G	G	M
A_2	VG	G	V	G	G	MG	MG	G
A_3	EG	MG	G	MG	G	MG	MG	MP
A_4	EG	G	G	MG	MG	G	G	G
A_5	VG	MG	G	MG	MG	G	G	G

Table 5. Decision matrix $X^{(3)}$

A_i	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	VG	G	VG	G	G	G	G	G
A_2	VG	G	G	G	VG	F	MG	G
A_3	EG	MG	G	MG	MG	F	G	MP
A_4	EG	F	F	MG	F	G	F	G
A_5	VG	G	MG	MG	MG	G	G	F

Table 6. Decision matrix $X^{(4)}$

A_i	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	VG	G	VG	G	MG	G	G	M
A_2	VG	MG	G	G	VG	F	MG	G
A_3	EG	MG	G	MG	MG	F	F	MP
A_4	EG	G	VG	MG	G	G	F	F
A_5	VG	G	G	MG	MG	G	G	G

Table 7. Decision matrix $X^{(5)}$

A_i	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8
A_1	VG	VG	VG	G	F	F	G	MG
A_2	VG	VG	G	G	VG	G	MG	G
A_3	EG	F	G	MG	F	G	G	G
A_4	EG	F	G	MG	G	G	F	F
A_5	VG	G	G	MG	G	F	G	F

Step 1. Construct the intuitionistic fuzzy decision matrices of each decision maker. Convert the linguistic evaluation shown in Table 3-7 into IFNs by using Table 1. Then, the intuitionistic fuzzy decision matrices $X^{(k)}$ (k = 1, 2, 3, 4, 5) of each decision maker are constructed (see equations (13-17)).

Step 2. Determine the weight of the decision makers. The importance of the decision makers in the group decision-making process is shown in Table 6. These intuitionistic fuzzy linguistic variables can be converted into IFNs. Here, importance of decision maker is considered as very important i.e. (1, 0, 0). Using equation (3), we obtain the weights of the decision makers λ_k = 0.20 (k =1, 2, 3, 4, 5).

Step 3. Construct the aggregated intuitionistic fuzzy decision matrix based on the opinions of decision makers. Utilize the IFWA operator given by the equation (4) to aggregate all the intuitionistic fuzzy decision matrices X (k) (k = 1, 2, 3, 4, 5) into a complex intuitionistic fuzzy decision matrix X (see equation (18)).

Step 4. Consider the weights of the criteria obtained from expert opinions. We have average weight of each criteria w_j (j = 1, 2, ..., 8) as w_1 = .2612, w_2 = .1804, w_3 = .1908, w_4 = .1076, w_5= .0754, w_6 = .0754, w_7 = .0562, w_8 = .054, such that $\sum_{j=1}^{8} w_j = 1$.

Step 5. Determine the reference sequence based on IFNs. The reference sequence is

$$\tilde{x}^+ = [(1,0,0), (1,0,0), (1,0,0), (1,0,0), (1,0,0), (1,0,0), (1,0,0), (1,0,0)].$$

Step6. Calculate the grey relational coefficient (see Table 8) of each alternative from PIS using the equation (11). Grey relational coefficient matrix is obtained by using the Table 9.

Table 8. Grey relational coefficient matrix τ_{ij}

$$(\tau_{ij})_{5\times 8} = \begin{bmatrix} 0.7619 & .6038 & .6400 & .6154 & .7273 & .4706 & .5161 & .6154 \\ 0.7619 & .6274 & .7273 & .6154 & .5161 & .5714 & .6154 & .4706 \\ 1.0000 & .4923 & .6154 & .5161 & .5161 & .4706 & .5161 & .3951 \\ 1.0000 & .5333 & .4923 & .5161 & .5517 & .6154 & .4507 & .4923 \\ 0.7619 & .5926 & .5926 & .5161 & .5333 & .5714 & .6154 & .5333 \end{bmatrix}$$

Table 9. Calculation of $\min \delta_{ij}$ and $\max \delta_{ij}$

	c_1	c_2	c_3	c_4	c_5	c_6	c_7	c_8	$\min \delta_{ij}$	$\max \delta_{ij}$
δ_{1j}	.15	.26	.23	.25	.17	.41	.35	.25	.15	.41
δ_{2j}	.15	.24	.17	.25	.35	.29	.25	.41	.15	.41
δ_{3j}	.05	.38	.25	.35	.35	.41	.35	.54	.05	.54
δ_{4j}	.05	.33	.38	.35	.31	.25	.44	.38	.05	.44
δ_{5j}	.15	.27	.27	.35	.33	.29	.25	.33	.15	.35
δ_{min}									.05	
δ_{max}										.54

Step7. Calculate the degree of grey relational coefficient of each alternative from PIS using the following equation:

$$\eta_i = \sum_{j=1}^{n} w_j \tau_{ij}, \ j= 1, 2, ..., 8; i=1, 2, 3, 4, 5.$$

η_1= 0.6475, η_2 = 0.6584, η_3 = 0.6465, η_4 = 0.6459, η_5 = 0.6206.

Step8. Rank all the alternatives A_i (i = 1, 2, 3, 4, 5) according to the decreasing order of their grey relational grades η_i (i = 1, 2, 3, 4, 5). Greater the value of η_i implies the better alternative A_i.

Here, the relationship between grey relational grades is as follows: $\eta_2 > \eta_1 > \eta_3 > \eta_4 > \eta_5$.
Then, the five candidates are ranked as $A_2 \succ A_1 \succ A_3 \succ A_4 \succ A_5$.
Therefore, the most appropriate candidate is A_2.

Note1: Sensitivity analysis with the change of weights of the criteria:
Using the equation (7), the researchers obtained the entropy weights of the criteria as follows:
w_1 = 0.1726, w_2 = 0.1212, w_3 = 0.1311, w_4 = 0.1179, w_5 = 0.1196, w_6 = 0.1150, w_7 = 0.1153, w_8 = 0.1071.

Then using the equation (12), the researchers obtained as
η_1= 0.6277, η_2= 0.0.6242, η_3 = 0.5915, η_4= 0.5927, η_5 = 0.5994.

The relationship between grey relational grades is as follows:
$\eta_1 > \eta_2 > \eta_5 > \eta_4 > \eta_3$.
Then, the five candidates are ranked as:
$A_1 \succ A_2 \succ A_5 \succ A_4 \succ A_3$.

Therefore, the most appropriate candidate is A_1.Therefore it is observed the change in weights of the criteria will produce change in the ranking of the candidates.

6.1 Reliability of the proposed approach

The selection process should follow rules that ensure its reliability. Furthermore, the criteria were selected based on the personal opinions and points of view of the experts on the specific topics, the reliability of the model is heavily depended on the levels of expertise of the domain experts. In this case, we used the questionnaire method, which includes interviews and filling in questionnaire by experts. The experts are the senior Professors of the Department of Education, University of Kalyani, Kalyani, Nadia, West Bengal, India. They have provided the actors and factors of the selected criteria for teacher selection model.

6.2 Validity of the proposed approach

Validity evidence is mainly based on three broad sources: content, relations to other variables, and construct. However, this does not imply that there are different types of validity. Validity is a unitary concept. It should be noted that different types of tests are employed for different purposes and, therefore, need different types of evidence. Our present study is related to construct validity.

6.3 Limitations of the proposed approach

For teacher selection, here, only eight criteria are considered. However, priority of the criteria for teacher selection may differ for different sectors of higher education and they differ for different nations. Therefore, detailed studies are needed to find other criteria or attributes of effective teacher.

Here incidental sampling or accidental sampling is employed for collecting the weights of the criteria for eight specified criteria instead of probability sampling.

Group decision making is a complex phenomenon. A common problem in the teacher selection process involves the biases of those experts doing the rating have a tendency to creep into the selection process [30]. One frequently encountered problem in selection process is the halo effect [31], which implies a rater's tendency to let one attribute of the candidate influence their overall assessment. To deal with such situations, organization can use standardized interview questions to gather information and apply explicit criteria for evaluations to overcome rater biases such as halo effect.

6.4 Advantage of the proposed approach

The proposed approach is very flexible. New criteria could easily be incorporated in the model according to the need, desire and practical situations of the higher educational organizations. The decision makers rate the candidate by linguistic variable approach that is easy to understand and apply. In this paper, we showed how the proposed model could provide a well-structured, coherent, and justifiable selection practice. The problem of choosing weights could be overcome by using entropy weight of Vlachos and Sergiadis [29] as discussed in the paper. As the concepts of grey-fuzzy system are very recent, the number of experts for calculation purposes would be very little in number. In that case, the educational organizations can take the help of computer engineer for calculation.

$$X^{(1)} = \begin{bmatrix} (.85,.10,.05) & (.75,.15,.10) & (.85,.10,.05) & (.75,.15,.10) & (.65,.25,.10) & (.75,.15,.10) & (.75,.15,.10) & (.50,.40,.10) \\ (.85,.10,.05) & (.65,.25,.10) & (.75,.15,.10) & (.75,.15,.10) & (.85,.10,.05) & (.50,.40,.10) & (.65,.25,.10) & (.75,.15,.10) \\ (.95,.05,.00) & (.65,.25,.10) & (.75,.15,.10) & (.65,.25,.10) & (.65,.25,.10) & (.50,.40,.10) & (.50,.40,.10) & (.35,.55,.10) \\ (.95,.05,.00) & (.75,.15,.10) & (.85,.10,.05) & (.65,.25,.10) & (.75,.15,.10) & (.75,.15,.10) & (.50,.40,.10) & (.50,.40,.10) \\ (.85,.10,.05) & (.75,.15,.10) & (.75,.15,.10) & (.65,.25,.10) & (.65,.25,.10) & (.75,.15,.10) & (.75,.15,.10) & (.75,.15,.10) \end{bmatrix} \tag{13}$$

$$X^{(2)} = \begin{bmatrix} (.85,.10,.05) & (.65,.25,.10) & (.75,.15,.10) & (.75,.15,.10) & (.65,.25,.10) & (.75,.15,.10) & (.75,.15,.10) & (.50,.40,.10) \\ (.85,.10,.05) & (.75,.15,.10) & (.85,.10,.05) & (.75,.15,.10) & (.75,.15,.10) & (.65,.25,.10) & (.65,.25,.10) & (.75,.15,.10) \\ (.95,.05,.00) & (.65,.25,.10) & (.75,.15,.10) & (.65,.25,.10) & (.75,.15,.10) & (.65,.25,.10) & (.65,.25,.10) & (.35,.55,.10) \\ (.95,.05,.00) & (.75,.15,.10) & (.75,.15,.10) & (.65,.25,.10) & (.65,.25,.10) & (.75,.15,.10) & (.75,.15,.10) & (.75,.15,.10) \\ (.85,.10,.05) & (.65,.25,.10) & (.75,.15,.10) & (.65,.25,.10) & (.65,.25,.10) & (.75,.15,.10) & (.75,.15,.10) & (.75,.15,.10) \end{bmatrix} \tag{14}$$

$$X^{(3)} = \begin{bmatrix} (.85,.10,.05) & (.75,.15,.10) & (.85,.10,.05) & (.75,.15,.10) & (.75,.15,.10) & (.75,.15,.10) & (.75,.15,.10) & (.75,.15,.10) \\ (.85,.10,.05) & (.75,.15,.10) & (.75,.15,.10) & (.75,.15,.10) & (.85,.10,.05) & (.50,.40,.10) & (.65,.25,.10) & (.75,.15,.10) \\ (.95,.05,.00) & (.65,.25,.10) & (.75,.15,.10) & (.65,.25,.10) & (.65,.25,.10) & (.50,.40,.10) & (.75,.15,.10) & (.35,.55,.10) \\ (.95,.05,.00) & (.50,.40,.10) & (.50,.40,.10) & (.65,.25,.10) & (.50,.40,.10) & (.75,.15,.10) & (.50,.40,.10) & (.75,.15,.10) \\ (.85,.10,.05) & (.75,.15,.10) & (.65,.25,.10) & (.65,.25,.10) & (.65,.25,.10) & (.75,.15,.10) & (.75,.15,.10) & (.50,.40,.10) \end{bmatrix} \tag{15}$$

$$X^{(4)} = \begin{bmatrix} (.85,.10,.05) & (.75,.15,.10) & (.85,.10,.05) & (.75,.15,.10) & (.65,.25,.10) & (.75,.15,.10) & (.75,.15,.10) & (.50,.40,.10) \\ (.85,.10,.05) & (.65,.25,.10) & (.75,.15,.10) & (.75,.15,.10) & (.85,.10,.05) & (.50,.40,.10) & (.65,.25,.10) & (.75,.15,.10) \\ (.95,.05,.00) & (.65,.25,.10) & (.75,.15,.10) & (.65,.25,.10) & (.65,.25,.10) & (.50,.40,.10) & (.50,.40,.10) & (.35,.55,.10) \\ (.95,.05,.00) & (.75,.15,.10) & (.85,.10,.05) & (.65,.25,.10) & (.75,.15,.10) & (.75,.15,.10) & (.50,.40,.10) & (.50,.40,.10) \\ (.85,.10,.05) & (.75,.15,.10) & (.75,.15,.10) & (.65,.25,.10) & (.65,.25,.10) & (.75,.15,.10) & (.75,.15,.10) & (.75,.15,.10) \end{bmatrix} \tag{16}$$

$$X^{(5)} = \begin{bmatrix} (.85,.10,.05) & (.85,.10,.05) & (.85,.10,.05) & (.75,.15,.10) & (.50,.40,.10) & (.50,.40,.10) & (.75,.15,.10) & (.65,.25,.10) \\ (.85,.10,.05) & (.85,.10,.05) & (.75,.15,.10) & (.75,.15,.10) & (.85,.10,.05) & (.75,.15,.10) & (.65,.25,.10) & (.75,.15,.10) \\ (.95,.05,.00) & (.50,.40,.10) & (.75,.15,.10) & (.65,.25,.10) & (.50,.40,.10) & (.75,.15,.10) & (.75,.15,.10) & (.75,.15,.10) \\ (.95,.05,.00) & (.50,.40,.10) & (.75,.15,.10) & (.65,.25,.10) & (.75,.15,.10) & (.75,.15,.10) & (.50,.40,.10) & (.50,.40,.10) \\ (.85,.10,.05) & (.75,.15,.10) & (.75,.15,.10) & (.65,.25,.10) & (.75,.15,.10) & (.50,.40,.10) & (.75,.15,.10) & (.50,.40,.10) \end{bmatrix} \tag{17}$$

$$X = \begin{bmatrix} (.85,.10,.05) & (.74,.17,.09) & (.77,.14,.09) & (.75,.15,.10) & (.83,.11,.06) & (.59,.30,.11) & (.65,.25,0.10) & (.75,.15,.10) \\ (.85,.10,.05) & (.76,.15,.09) & (.83,.11,.06) & (.75,.15,.10) & (.65,.25,.10) & (.71,.18,.11) & (.75,.15,0.10) & (.59,.30,.11) \\ (.95,.05,.00) & (.62,.28,.10) & (.75,.15,.10) & (.65,.25,.10) & (.65,.25,.10) & (.59,.30,.11) & (.65,.25,0.10) & (.46,.43,.11) \\ (.95,.05,.00) & (.67,.22,.11) & (.62,.28,.10) & (.65,.25,.10) & (.69,.20,.11) & (.75,.15,.10) & (.56,.33,0.11) & (.62,.27,.11) \\ (.85,.10,.05) & (.73,.17,.10) & (.73,.17,.10) & (.65,.25,.10) & (.67,.23,.10) & (.71,.19,.10) & (.75,.15,0.10) & (.67,.22,.11) \end{bmatrix} \tag{18}$$

7. CONCLUSION

Teacher selection problem demands a systematic approach to incorporate an organization's values and the needs of its constituents. Grey relational analysis based intuitionistic fuzzy multi-criteria group decision- making approach is a practical, versatile and powerful tool that identifies the criteria and offers a consistent structure and process for evaluating candidates by employing the concept of acceptance, rejection and indeterminacy simultaneously. In this study, we demonstrated how the proposed approach could provide a well-structured, coherent, and justifiable selection practice. A major concern with the introduction of grey-fuzzy hybridized model into the teacher selection process is the preconceived notion that it is complex process. In this study, committee members who were not extensively trained in grey system and intuitionistic fuzzy system quickly understand the process and could easily express their views in terms of intuitionistic fuzzy linguistic variables, which are very useful to express the degree of rejection, acceptance and indeterminacy.

For promotion of teachers i.e. from assistant professor to associate professor or from associate professor to professor, or dean selection can be solved by using the proposed approach by incorporating necessary criteria. Uncertain dynamic intuitionistic fuzzy weighted averaging operator due to Xu and Yager [32] seems to be very useful for multi-criteria decision making as well as multi attribute decision-making problem. The above-mentioned operator can be used for proposed model to deal with dynamic situation in teacher selection.

Grey relational analysis combined with intuitionistic fuzzy set has enormous chance of success for multi-criteria decision-making problems, since it considers three components of intuitionistic fuzzy information of decision makers namely, degree of acceptance, degree of rejection and degree of indeterminacy. Therefore, in future, the proposed approach can be used for dealing with multi-criteria decision-making problems such as personnel selection in academia, project evaluation, supplier selection, manufacturing system, and many other areas of management decision problems.

Method fully based on grey system and grey related analysis may be used for teacher selection. After emergence of fuzzy sets, the paradigm shift occurred in decision-making arena. It is hoped that if grey system and intuitionistic fuzzy logic are used simultaneously, new area of research will be opened for educational problems.

Although this paper has shown the effectiveness of the proposed approach, many areas need to be explored and developed. In intuitionistic fuzzy sets, although degree of rejection (non-membership) is independent of degree of acceptance (membership) but degree of indeterminacy (hesitancy) is dependent on degree of acceptance and rejection. However, in reality degree of indeterminacy may be independent of degree of acceptance and rejection. Therefore, the researchers feel that the degree of indeterminacy with independent characteristics should be incorporated in the selection process. That study will be really genuine and new dimension in educational research. In this sense, the concept of neutrosophic set due to Smarandache [33] appears to be a promising one to deal with realistic teacher selection process.

8. ACKNOWLEDGMENTS

The authors are grateful to all the teachers and M. Ed. Students for the session 2010-2011of the Department of Education, University of Kalyani, Kalyani for their encouragements and constant support during the present study. Laying aside all their important works, Prof. P. C. Biswas, Prof. S. Nandi, Dr. Debjani Guha and Dr. Bijan Sarkar, department of Education, University of Kalyani spent their specious time and intellect in providing us their sincere and valuable suggestions in conducting the study.

9. REFERENCES

[1] Hwang, L, and Lin, M. J. 1987 Group Decision Making under Multiple Criteria: Methods and Applications. Springer-Verlag, Heidelberg.

[2] Lin, L., Yuan, X. H., and Xia, Z. Q. 2007. Multicriteria fuzzy decision-making based on intuitionistic fuzzy sets. Journal of Computers and Systems Sciences 73(1), 84-88.

[3] Lin, L., Yuan, X. H., and Xia, Z. Q. 2007. Multicriteria fuzzy decision-making based on intuitionistic fuzzy sets. Journal of Computers and Systems Sciences 73(1), 84-88.

[4] Liu, H. W., & Wang, G. J. 2007. Multi-criteria decision-making methods based on intuitionistic fuzzy sets. European Journal of Operational Research 179, 220-233.

[5] Zadeh, L.A. 1965. Fuzzy Sets, Information and Control 8, 338-353.

[6] Atanassov, K. T. 1986. Intuitionistic fuzzy sets. *Fuzzy Sets and Systems* 20(1), 87–96.

[7] Liang, S. L., & Wang, M. J. 1994. Personnel selection using fuzzy MCDM algorithm. European Journal of Operational Research 78, 22–33.

[8] Karsak, E. E. 2001. Personnel selection using a fuzzy MCDM approach based on ideal and anti-ideal solutions. Lecture Notes in Economics and Mathematical Systems 507, 393–402.

[9] Gibney, R., & Shang, J. 2007. Decision making in academia: A case of the dean selection process. Mathematical and Computer Modelling 46(7-8), 1030–1040.

[10] Günör, Z., Serhadlıog˘lu, G., & Kesen, S. E. 2009. A fuzzy AHP approach to personnel selection problem. Applied Soft Computing 9, 641–646.

[11] Dağdeviren, M. 2010. A hybrid multi-criteria decision-making model for personnel selection in manufacturing systems. Journal of Intelligent Manufacturing 21, 451–460.

[12] Dursun, M., & Karsak, E. E. 2010. A fuzzy MCDM approach for personnel selection. Expert Systems with Applications 37, 4324–4330.

[13] Robertson, I. T., & Smith, B. 2001. Personnel selection. Journal of Occupational and Organizational Psychology 74, 441–472.

[14] Ehrgott, M., & Gandibbleux, X. 2002. Mulitple criteria optimization: state of the art annotated bibliography survey. Kluwer Academic Publishers, Boston.

[15] Olver, J. M., & Mooradian, T. A. 2003. Personality traits and personal values: a conceptual and empirical integration. Personality and Individual Differences 35, 109–125.

[16] Caspi, A., Roberts, B. W., & Shiner, R. L. 2005. Personality development: stability and change. Annual Review of Psychology 56, 453–484.

[17] Bouchard, T. J. Jr., (1997). Genetic influence on mental abilities, personality, vocational interests and work attitudes. In C. L. Cooper & I. T. Robertson (Eds.), *International review of industrial and organizational psychology* (Volume. 12, pp. 373–395). John Wiley & Sons Ltd.

[18] Goldberg, L. R. 1993. The structure of phenotypic personality traits. American Psychologist 48, 26–34.

[19] Costa, P. T., & McCrae, R. R. (1992). Revised NEO personality inventory (NEO-PI-R) and Neo five-factor inventory (NEO-FFI). Professional manual. Odessa, FL: Psychological Assessment Resources.

[20] Parks, L., & Guay, R.P. 2009. Personality, values, and motivation. Personality and Individual Differences 47, 675–684.

[21] Aidla, A., & Vadi, M. 2010. Personality traits attributed to Estonian school teachers. Review of International Comparative Management 11(4), 591-602.

[22] Schwartz, S. H. 1994. Are there universal aspects in the structure and contents of human values? Journal of Social Issues 50, 19–45.

[23] Schwartz, S. H., & Bilsky, W. 1987. Toward a psychological structure of human values. Journal of Personality and Social Psychology 53, 550–562.

[24] Schwartz, S. H., & Bilsky, W. 1990. Theory of the universal content and structure of values: extensions and cross-cultural replications. Journal of Personality and Social Psychology 58, 878–891.

[25] Deng, J. L. 1989. Introduction to grey system theory. The Journal of Grey System 1(1), 1–24.

[26] Zhang, S. F. & Liu, S. Y. 2011. A GRA-based intuitionistic fuzzy multi-criteria group decision making method for personnel selection. Expert Systems with Applications 38 11401–11405.

[27] Boran, F. E., Genc, S., Kurt, M., & Akay, D. 2009. A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method. Expert Systems with Applications 36(8), 11363–11368.

[28] Xu, Z. S. 2007. Intuitionistic fuzzy aggregation operators. IEEE Transaction of Fuzzy Systems 15(6), 1179–1187.

[29] Vlachos, I. K., & Sergiadis, G. D. 2007. Intuitionistic fuzzy information -Applications to pattern recognition. Pattern Recognition Letters 28, 197–206.

[30] Arvey, R. D., & Campion, J. E. (1982). The employment interview: A summary and review of recent research, Personnel Psychology 35(2), 281–322.

[31] Campion, M.A., Pursell, E. D., & Brown, B. K. 1988. Structured interviewing; raising the psychometric properties of the employment interview. Personnel Psychology 41(1), 25–42.

[32] Xu, Z. S., & Yager, R. R. 2008. Dynamic intuitionistic fuzzy multi-attribute decision making. International Journal of Approximate Reasoning 48(1), 246–262.

[33] Smarandache, F. 2005. Neutrosophic set. A generalization of intuitionistic fuzzy sets. International Journal of Pure and Applied Mathematics 24, 287-297.