

# A Grey-Based Fuzzy ELECTRE Model for Project Selection

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## Abstract

Project selection is considered as an important problem in project management. It is multi-criteria in nature and is based on various quantitative and qualitative factors. The main purpose of this paper is to present a new rank-based method for project selection in outranking relation. According to this approach, decision alternatives were clustered in the concordance matrix and the discordance matrix through the ELECTRE model based on intuitionistic trapezoidal fuzzy numbers. Then, the two matrices were integrated and ranked using grey relational coefficients and the Minkowski space distance. The results of the model were compared with grey relational projection method with intuitionistic trapezoidal fuzzy number. To illustrate the proposed methodology, a case study was conducted to select National Iranian Oil Company projects.

*Keywords:* Fuzzy GRA, Fuzzy ELECTRE, GRA based FELECTRE, Project selection.

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## 1. Introduction

Tonchia (2008) provides a good definition for the concept of 'project' in his book entitled *Industrial Project Management: Planning, Design, and Construction*. A project can be defined as a set of complex and coordinated activities with a clearly defined objective that can be achieved through synergetic and coordinated efforts within a given time, and with a predetermined amount of human and financial resources (Tonchia, 2008). In project selection problem, the manager must select one or more promising projects from a menu of opportunities. These projects might be Research and Development (R&D), Information technology (IT) or other capital spending projects. Normally the choice is limited by available resources, for example, capital, research talent, laboratory space, and limits of managerial oversight. While operating within these constraints, the manager must select the projects which seem most likely to satisfy corporate goals or objectives. Frequently, there are multiple goals (Graves, Ringuest, & Medaglia, 2003). In industrial enterprises and in the national economies there is often a need for a program system which would make it possible to carry out effectively multiple criteria selection of hundreds of projects simultaneously, with tens of criterion functions including nonlinear ones, and tens of resources limitations with respect to the synergistic effects and the hierarchical interdependences between the projects (Zelinka, Snášel, & Abraham, 2013). So, project selection problem is a multiple decision attribute problem. This criterion can be quantitative or

Qualitative. Quantitative attributes can be numerically defined, such as the total return expected. Qualitative criteria are intangible, such as the environmental risk. So, this problem is a type of multiple criteria decision Making (MCDM). There are a large number of multiple criteria methodologies for choosing between options for engineering and infrastructure investment projects. The main ones are: Checklist Methods, Multiple Attribute Utility methods (MAUT), Analytic Hierarchy Process (AHP) and Concordance Analysis or Outranking Methods. In order to avoid some of the problems associated with the MAUT approach, several methods specially designed for discrete cases have been devised. Amongst these, the outranking approaches merit special attention (Ballester & Romero, 1998). Outranking methods focus on pair wise comparisons of alternatives and are, thus, generally applied to discrete choice problems (Belton & Stewart, 2002). The origins of ELECTRE methods go back to 1965 at the European consultancy company SEMA, which is still active today (Figueira, Greco, & Ehrgott, 2005). In July 1966, Bernard Roy presented a paper in Rome in which he used his formal training in Mathematics to develop a practical decision making system, now known as ELECTRE. It is based on concordance as well as discordance analysis. The main question in this study is how the outranking relation-based models improve and develop with fuzzy data. The main focus is on the ELECTRE model with intuitionistic trapezoidal fuzzy data. Some models have

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been proposed to improve ELECTRE model with fuzzy and non-fuzzy data. However, these models are not capable of dealing with intuitionistic fuzzy numbers. The main models from ELECTRE family that have been proposed to solve the ranking problem in outranking relations are ELECTRE II, III, IV, TRI, and IS (Rogers, Bruen, & Maestre, 2000). Other models that are based on outranking relations and clustering algorithms have this issue too. The main models in this area are as follows: KOHONEN (Kohonen & Maps, 1995), K-means (MacQueen, 1967), C-means, and PROMETHEE. Major algorithms or methods for solving this problem in outranking relations are as followed: ELECTRE.II, ELECTRE.IV (Roy & Bouyssou, 1983), PROMETHEE.II (Brans, Vincke, & Mareschal, 1986), PROMETHEE.III, PROMETHEE.IV (Brans & Mareschal, 2005), grey base rough set (Li, Yamaguchi, Lin, Wen, & Nagai, 2006), grey base C-means and grey base KOHONEN (Faezy Razi, Eshlaghy, Nazemi, Alborzi, & Pourebrahimi, 2014), and grey based K-means. In the grey relational analysis model, the distance from optimal solution and, consequently, the possibility of a complete ranking is provided using the grey relational coefficient concept. Therefore, the proposed model for solving ranking problem in concordance matrix uses the grey relational coefficient concept. In summary, since the grey relational analysis model is able to rank all decision alternatives, intuitionistic trapezoidal was used to solve the ranking problem with fuzzy data in ELECTRE.

## 2. Literatures

Bashiri *et al.* (2011) proposed a decision support system for selecting project and related contracts. Their model is based on fuzzy TOPSIS method as well as Linear programming model (Bashiri, Badri, & Talebi, 2011). Davenshvar and Erol (2012) present the fuzzy ELECTRE approach for prioritizing the best effective projects to improve project selection process. They employed four evaluation criteria, mainly, net present value (NPV), quality, Contractor's technology and contractor's economic status (Daneshvar Rouyendegh & Erol, 2012). Chen and Song (2013) presented a multiple period, multiple project selection and assignment approach (MPPA) to assist the departments in handling continuous project based on information system (IS) requests (Chen, Liu, & Song, 2013). Silva *et al.* (2013) considered the social network-empowered criteria rather than the government funding, disciplines, productivity, and social connection for selecting research projects (Silva, Guo, Ma, Jiang, & Chen, 2013). Khalili-Damghani and Sadi-Nezhad (2013) presented a decision support system for the multi-objective sustainable project selection problem. The model used for project selection was TOPSIS-based fuzzy goal programming (Khalili-Damghani & Sadi-Nezhad, 2013). Lin Yang *et al.* (2013) used a combined approach which was based on the multi-objective

literature for the selection of a project management information system. The main criteria used in that study were as follows: Cost-base, Profit-base, Experience and ability, Technology and application, Maintenance service (Yang, Chiang, Huang, & Lin, 2013). Zaraket *et al.* (2014) presented a conceptual framework and mathematical model to select computer software project at the university. A binary mathematical programming model was used for project selection. Due to the nature of the problem, Tabu select method was used to obtain a solution (Zaraket, Olleik, & Yassine, 2014). Wu *et al.* (2014) used choquet integral method in fuzzy circumstances to solve the wind farm project plan selection problem. They used intuitionistic fuzzy number. The main criteria in their study were quality, economy, risk, environment, and contribution (Wu, Geng, Xu, & Zhang, 2014). Dutra *et al.* (2013) proposed an economic model based on probability theory for selecting and ranking projects. The methodology consisted of qualitative and economic methods, as well as the Monte Carlo simulation (Dutra, Ribeiro, & de Carvalho, 2014). Hassanzadeh *et al.* (2014) used a multi-objective binary mathematical programming model based on the concept of robust optimization to select research and development projects portfolio. The main objective was to achieve robust stability. Two main objectives of the study were cost and risk (Hassanzadeh, Nemati, & Sun, 2014). Huang and Zhao (2014) proposed a new methodology for selecting R&D projects and project scheduling problem that lacked historical data. In that methodology, net income and investment cost were evaluated by experts in uncertainty conditions. A mathematical programming model designed by the genetic algorithm was implemented in that study (Huang & Zhao, 2014). Vahdani (2014) presented a neural network model based on artificial intelligence literature for project selection. The studied factors in that study were as follows: Operational, managerial, financial, technological, legal and environmental (Vahdani, Mousavi, Hashemi, Mousakhani, & Ebrahimnejad, 2014).

## 3. Grey System Theory

Grey systems theory was first proposed by Deng (Ju-Long, 1982). The concepts of grey systems are different from those of probability and statistics, which address problems with samples of a reasonable size, and also different from those of fuzzy mathematics, which deal with problems with cognitive uncertainty (Mujumdar & Karmakar, 2008). It is specially designed for handling situations in which only limited data are available and has become very popular in many areas such as image coding, pattern recognition, etc. In grey system theory, if the system information is entirely certain, the system is called a white system; while the system information is uncertain, it is called a black system. A system with partial information certain and partial information uncertain is

grey system. The concept of a grey system is illustrated in Fig. 1 (Liu & Lin, 2006).

Grey theory comprises five main tools, grey prediction, grey relational analysis (GRA), grey decision, grey programming, and grey control.

### 3.1 Grey relational analysis based on grey number

The Grey Relational Analysis (GRA) method is based on the minimization of maximum distance from the ideal referential alternative. Based on similarity and dissimilarity, the relation is the relational measurement of attribute in different sequences. The aim of The Grey Relational Analysis (GRA) is to investigate the factors that affect the system (Das & Sahoo, 2011). Grey Relational Analysis (GRA) is an impact appraisal model that can compare the correlation between series and belongs to the category of the data analytic method or geometric method. Grey Relational Analysis (GRA) contains four steps to generate the global comparison among the alternatives;

- Preparation of factor compatibility;
- Derivation of reference sequences;
- Calculation of grey relational coefficient;
- Determination of grey relational grade (Chan & Tong, 2007). The scheme of grey relational analysis are indicated in Fig. 2.

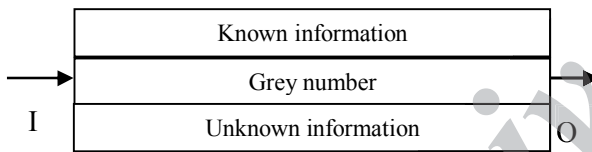


Fig.1. the concept of a grey system

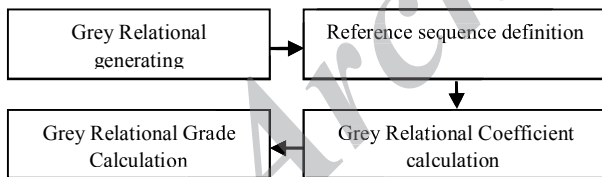


Fig. 2. Grey relational analysis

Assume the decision table for project selection is proposed by decision maker, the phases of Grey relational analysis based on trapezoidal fuzzy number are presented as follows (CAO, NIU, & FAN, 2013) :

(1) Definition of intuitionistic fuzzy numbers for projects criteria.

Let  $\tilde{a}$  be an intuitionistic trapezoidal fuzzy number in the set of real numbers, whose membership function and non-membership function are defined as follows:

$$\mu_{\tilde{a}}(x) = \begin{cases} \frac{x-a}{b-a}\mu_{\tilde{a}}, & a \leq x \leq b, \\ \mu_{\tilde{a}}, & b \leq x \leq c, \\ \frac{d-x}{d-c}\mu_{\tilde{a}}, & c \leq x \leq d, \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

$$V_{\tilde{a}}(x) = \begin{cases} \frac{(b-x)+V_{\tilde{a}}(x-a_1)}{b-a_1}, & a_1 \leq x \leq b, \\ V_{\tilde{a}}, & b \leq x \leq c, \\ \frac{(x-c)+V_{\tilde{a}}(d_1-x)}{d_1-c}\mu_{\tilde{a}}, & c \leq x \leq d, \\ 0, & \text{otherwise} \end{cases} \quad (2)$$

Let be  $\tilde{a}_1 = ([a_1, b_1, c_1, d_1]; \mu_{\tilde{a}_1}, v_{\tilde{a}_1})$  and  $\tilde{a}_2 = ([a_2, b_2, c_2, d_2]; \mu_{\tilde{a}_2}, v_{\tilde{a}_2})$  be two intuitionistic trapezoidal fuzzy numbers, then;

$$\tilde{a}_1 + \tilde{a}_2 = ([a_1 + a_2, b_1 + b_2, c_1 + c_2, d_1 + d_2]; \mu_{\tilde{a}_1} + \mu_{\tilde{a}_2} - \mu_{\tilde{a}_1}\mu_{\tilde{a}_2}, v_{\tilde{a}_1}v_{\tilde{a}_2}), \quad (3)$$

$$\tilde{a}_1 \otimes \tilde{a}_2 = ([a_1a_2, b_1b_2, c_1c_2, d_1d_2]; \mu_{\tilde{a}_1}\mu_{\tilde{a}_2}, v_{\tilde{a}_1} + v_{\tilde{a}_2} - v_{\tilde{a}_1}v_{\tilde{a}_2}), \quad (4)$$

Let  $\tilde{a}_1 = ([a_1, b_1, c_1, d_1]; \mu_{\tilde{a}_1}, v_{\tilde{a}_1})$  and  $\tilde{a}_2 = ([a_2, b_2, c_2, d_2]; \mu_{\tilde{a}_2}, v_{\tilde{a}_2})$  be two intuitionistic trapezoidal fuzzy numbers, then the normalized Hamming distance between  $\tilde{a}_1$  and  $\tilde{a}_2$  is defined as follows;

$$d(\tilde{a}_1, \tilde{a}_2) = \frac{1}{8} (|(1 + \mu_{\tilde{a}_1} - v_{\tilde{a}_1})a_1 - (1 + \mu_{\tilde{a}_2} - v_{\tilde{a}_2})a_2| + |(1 + \mu_{\tilde{a}_1} - v_{\tilde{a}_1})b_1 - (1 + \mu_{\tilde{a}_2} - v_{\tilde{a}_2})b_2| + |(1 + \mu_{\tilde{a}_1} - v_{\tilde{a}_1})c_1 - (1 + \mu_{\tilde{a}_2} - v_{\tilde{a}_2})c_2| + |(1 + \mu_{\tilde{a}_1} - v_{\tilde{a}_1})d_1 - (1 + \mu_{\tilde{a}_2} - v_{\tilde{a}_2})d_2|). \quad (5)$$

(2) Grey relational generating.

The data processing for decision table  $R = [\tilde{r}_{ij}]_{m \times n}$  calculated by equation (6) is presented as follows;

- for smaller-the-better:

$$r_{ij}^k = \frac{\max(a_{ij}^k) - a_{ij}^k}{\max(a_{ij}^k) - \min(a_{ij}^k)} \quad k = 1, 2, 3, 4. \quad (6)$$

- for larger - the - better:

$$r_{ij}^k = \frac{a_{ij}^k - \min(a_{ij}^k)}{\max(a_{ij}^k) - \min(a_{ij}^k)} \quad k = 1, 2, 3, 4.$$

(3) compute the positive ideal solution (PSI)  $\tilde{r}^+$  and negative ideal solution (NIS)  $\tilde{r}^-$

for intuitionistic trapezoidal fuzzy number, it is shown by equations (7) and (8) respectively;

$$\begin{aligned} \tilde{r}_j^+ &= ([\tilde{r}_j^{1+}, \tilde{r}_j^{2+}, \tilde{r}_j^{3+}, \tilde{r}_j^{4+}]; \mu_j^+, v_j^+) \\ &= ([\max(r_{ij}^1), \max(r_{ij}^2), \max(r_{ij}^3), \max(r_{ij}^4)]; \\ &\max(\mu_{ij}), \min(v_{ij})), \end{aligned} \quad (7)$$

$$\begin{aligned} \tilde{r}_j^- &= ([\tilde{r}_j^{1-}, \tilde{r}_j^{2-}, \tilde{r}_j^{3-}, \tilde{r}_j^{4-}]; \mu_j^-, v_j^-) \\ &= ([\min(r_{ij}^1), \min(r_{ij}^2), \min(r_{ij}^3), \min(r_{ij}^4)]; \\ &\min(\mu_{ij}), \max(v_{ij})). \end{aligned} \quad (8)$$

(4) Calculations of grey relational coefficients.

Calculate the grey relational coefficient of each alternative from positive ideal solution and negative ideal solution applying the (9) and (10) equation, respectively.

$$\varepsilon_{ij}^+ = \frac{N^+ + pM^+}{a_{ij}^+ + pM^+} \quad (9)$$

Where

$$d^+ (\tilde{r}_{ij}, \tilde{r}_j^+) = \frac{1}{8} (|(1 + \mu_{ij} - v_{ij})r_{ij}^1 - (1 + \mu_j^+ - v_j^+)r_j^{1+}| + |(1 + \mu_{ij} - v_{ij})r_{ij}^2 - (1 + \mu_j^+ - v_j^+)r_j^{2+}| + |(1 + \mu_{ij} - v_{ij})r_{ij}^3 - (1 + \mu_j^+ - v_j^+)r_j^{3+}| + |(1 + \mu_{ij} - v_{ij})r_{ij}^4 - (1 + \mu_j^+ - v_j^+)r_j^{4+}|).$$

$N^+ = \min \min d_{ij}^+, M^+ = \max \max d_{ij}^+, p$  Represents resolution coefficient, and  $p \in (0, 1)$ .

$$\varepsilon_{ij}^- = \frac{N^+ + pM^-}{d_{ij}^- + pM^-} \quad (10)$$

Where

$$d^- (\tilde{r}_{ij}, \tilde{r}_j^-) = \frac{1}{8} (|(1 + \mu_{ij} - v_{ij})r_{ij}^1 - (1 + \mu_j^- - v_j^-)r_j^{1-}| + |(1 + \mu_{ij} - v_{ij})r_{ij}^2 - (1 + \mu_j^- - v_j^-)r_j^{2-}| + |(1 + \mu_{ij} - v_{ij})r_{ij}^3 - (1 + \mu_j^- - v_j^-)r_j^{3-}| + |(1 + \mu_{ij} - v_{ij})r_{ij}^4 - (1 + \mu_j^- - v_j^-)r_j^{4-}|).$$

$N^- = \min \min d_{ij}^-, M^- = \max \max d_{ij}^-, p$  Represents resolution coefficient, and  $p \in (0, 1)$ .

(5) Determination of grey relational grade. Computing the grey relational grade of each project from positive ideal solution and negative ideal solution using the following equation (11) and (12), respectively

$$\varepsilon_{ij}^+ = \sum_{j=1}^n w_j \varepsilon_{ij}^+ \quad (11)$$

$$\varepsilon_{ij}^- = \sum_{j=1}^n w_j \varepsilon_{ij}^- \quad (12)$$

Where  $w_k$  is demonstrated the weights of the  $k^{th}$  project attribute. Weights  $w = (w_1, w_2, \dots, w_n)$  can be got by the Fuzzy Analytic Hierarchy Process (FAHP) or Fuzzy Analytic Network Process (FANP) also fuzzy entropy method .

#### 4. Fuzzy ELECTRE Method with Intuitionistic trapezoidal fuzzy number

The Fuzzy ELECTRE Method is included in eight steps. The Steps are as follows;

(1) Determine the Decision Matrix :

Let

$$X_{ij} = (\mu_{ij}, v_{ij}, \pi_{ij}),$$

$\mu_{ij}$  is the degree of membership of the  $i^{th}$  alternative with respect to  $j^{th}$  attribute;  $v_{ij}$  is the degree of non membership of the  $i^{th}$  alternative with respect to the  $j^{th}$  attribute,  $\pi_{ij}$  is the intuitionistic index of the  $i^{th}$  alternative with respect to the  $j^{th}$  attribute is an intuitionistic fuzzy decision matrix, where

$$0 \leq \mu_{ij} + v_{ij} \leq 1, i=1,2,\dots,m, j=1,2,\dots,n$$

$$\pi_{ij} = 1 - \mu_{ij} - v_{ij} \quad (13)$$

$$M = \begin{bmatrix} X_{11} & \dots & X_{1n} \\ \vdots & \ddots & \vdots \\ X_{m1} & \dots & X_{mn} \end{bmatrix} \quad (14)$$

In the decision matrix  $M$ , have  $m$  of alternatives (from  $A_1$  to  $A_m$ ) and  $n$  of attribute (from  $x_1$  to  $x_n$ ).the subjective importance of attributes,  $W$ , are given by

the decision maker .for example, attribute  $x_1$  has attribute weight  $w_1$ ,  $x_n$  has attribute weight  $w_n$  and the sum of weight of all attribute from  $x_1$  to  $x_n$  are equal to 1.

(2) Determine the concordance and discordance sets: It uses the concept of IFS relation to identify (determine) concordance and discordance set. In this Case, we classify different types of the concordance sets as strong concordance set and moderate concordance set as well as weak concordance set. We can also classify the discordance sets by the same concept.

The strong concordance set  $C_{kl}$  of  $A_k$  and  $A_l$  is composed of all criteria for which  $A_k$  is preferred to  $A_l$  .in other words , the strong concordance set  $C_{kl}$  can formulate as;

$$C_{kl} = \{j \mid \mu_{kj} \geq \mu_{lj}, v_{kj} < v_{lj} \text{ and } \pi_{kj} < \pi_{lj}\}. \quad (15)$$

The moderate concordance set  $C'_{kl}$  is defined as;

$$C'_{kl} = \{j \mid \mu_{kj} \geq \mu_{lj}, v_{kj} < v_{lj} \text{ and } \pi_{kj} \geq \pi_{lj}\}. \quad (16)$$

The weak concordance set  $C''_{kl}$  is defined as;

$$C''_{kl} = \{j \mid \mu_{kj} \geq \mu_{lj} \text{ and } v_{kj} \geq v_{lj} \text{ and } \pi_{kj} < \pi_{lj}\}. \quad (17)$$

The strong discordance set  $D_{kl}$  is composed of all criteria for which  $A_k$  is not preferred to  $A_l$ .

The strong discordance set  $D_{kl}$  can formulate as;

$$D_{kl} = \{j \mid \mu_{kj} < \mu_{lj} \text{ and } v_{kj} \geq v_{lj} \text{ and } \pi_{kj} \geq \pi_{lj}\}. \quad (18)$$

The moderate discordance set  $D'_{kl}$  is defined as;

$$D'_{kl} = \{j \mid \mu_{kj} < \mu_{lj} \text{ and } v_{kj} < v_{lj} \text{ and } \pi_{kj} < \pi_{lj}\}. \quad (19)$$

The weak discordance set  $D''_{kl}$  is defined as;

$$C''_{kl} = \{j \mid \mu_{kj} < \mu_{lj} \text{ and } v_{kj} < v_{lj} \text{ and } \pi_{kj} < \pi_{lj}\}. \quad (20)$$

(3) Calculate the concordance matrix:

The relative values of the concordance sets are measured by means of the concordance index. The concordance index is equal to the sum of the weights associated with those criteria and relation which are contained in the concordance sets. Therefore, the concordance index  $c_{kl}$  between  $A_k$  and  $A_l$  is defined as:

$$C_{kl} = w_c \times \sum_{j \in C_{KL}} w_j + w_{c'} \times \sum_{j \in C'_{KL}} w_j + w_{c''} \times \sum_{j \in C''_{KL}} w_j \quad (21)$$

where  $w_c, w_{c'}, w_{c''}$  are weight in different sets and defined in step 2 and  $w_j$  are weight of attributes that are also defined in step 1.

(4) Calculate the discordance matrix:

The discordance index  $d_{kl}$  is defined as follows:

$$D_{kl} = \frac{\max w_{D'} \times \text{dis}(X_{Kj}, X_{Lj})}{\max \text{dis}(X_{Kj}, X_{Lj})} \quad (22)$$

$$\text{dis}(X_{Kj}, X_{Lj}) = \sqrt{\frac{1}{2} ((\mu_{kj} - \mu_{lj})^2 + (v_{kj} - v_{lj})^2 + (\pi_{kj} - \pi_{lj})^2)} \quad (23)$$

(5) Determine the concordance dominance matrix:

This matrix can be calculated with the aid of a threshold value for the concordance index.  $A_k$  will only have a chance of dominating  $A_l$  , if its corresponding concordance index  $C_{kl}$  exceeds at least a certain threshold value  $\bar{c}$  i.e.,  $C_{kl} \geq \bar{c}$  ,and

$$\bar{c} = \frac{\sum_{k=1, k \neq l}^m \sum_{l=1, l \neq k}^m C_{kl}}{m \times (m-1)} \quad (24)$$

On the basis of the threshold value, a Boolean matrix  $F$  can be constructed, the elements of which are defined as  $f_{kl} = 1$  , if  $C_{kl} \geq \bar{c}$  ;  $f_{kl} = 0$  , if  $C_{kl} < \bar{c}$  .



Then each element of 1 on the matrix  $F$  represents a dominance of one alternative with respect to another one.

(6) Step 6. Determine the discordance dominance matrix: This matrix is constructed in a way analogous to the  $F$  matrix on the basis of a threshold value  $\bar{d}$  to the discordance indices. The elements of  $g_{kl}$  of the discordance dominance matrix  $G$  are calculated as

$$\bar{d} = \frac{\sum_{k=1, k \neq l}^m \sum_{l=1, l \neq k}^m d_{kl}}{m \times (m-1)} \quad (25)$$

$$g_{kl} = 1, \text{ if } d_{kl} \leq \bar{d}; g_{kl} = 0, \text{ if } d_{kl} > \bar{d}.$$

Also the unit elements in the  $G$  matrix represent the dominance relationships between any two alternatives.

(7) Determine the aggregate dominance matrix:

This step is to calculate the intersection of the concordance dominance matrix  $F$  and discordance dominance matrix. The resulting matrix, called the aggregate dominance matrix  $E$ , is defined by means of its typical elements  $e_{kl}$  as:

$$e_{kl} = f_{kl} \cdot g_{kl}. \quad (26)$$

Step 8. Eliminate the less favorable alternatives:

The aggregate dominance matrix  $E$  gives the partial preference ordering of the alternatives. If  $e_{kl} = 1$ , then  $A_k$  is preferred to  $A_l$  for both the concordance and discordance criteria, but  $A_k$  still has the chance of being dominated by the other alternatives. Hence the condition that  $A_k$  is not dominated by ELECTRE procedure is,

$$e_{kl} = 1, \text{ for at least one } l, l = 1, 2, \dots, m, k \neq l;$$

$$e_{ik} = 0, \text{ for at all } i, i = 1, 2, \dots, m, i \neq k, i \neq l.$$

This condition appears difficult to apply, but the dominated alternatives can be easily identified in the  $E$

matrix. If any column of the  $E$  matrix has at least one element of 1, then this column is 'ELECTREcally' dominated by the corresponding row. Hence we simply eliminate any column which has an element of 1.

### 5. Grey Based Fuzzy ELECTRE Method

In this paper a new hybrid grey based ELECRES is presented to select the best Projects. Roy (1968) originally used the concept of outranking relations to introduce the ELimination Et Choice Translating REALity (ELECTRE) method (Roy, 1968). Since then, various ELECTRE models have been developed based on the nature of the problem statement (to find a kernel solution or to rank the order of alternatives), the degree of significance of the criteria to be taken into account (true or pseudo), and the preferential information (weights, concordance index, discordance index, veto effect) (Tzeng & Huang, 2011). ELECTRE Technique is a clustering method closely related to the K-means and KOHONEN as well as PROMETHEE also SIR Method. These techniques are based on Outranking Relations and kernel solution. ELECTRE.I Method cannot derive the ranking of alternatives but the kernel set or clusters. Thus, grey-based ELECTRE is introducing to dominate insolvency to produce a ranking of alternatives. The flowchart of hybrid grey based ELECTRE is shown in Fig. 3.

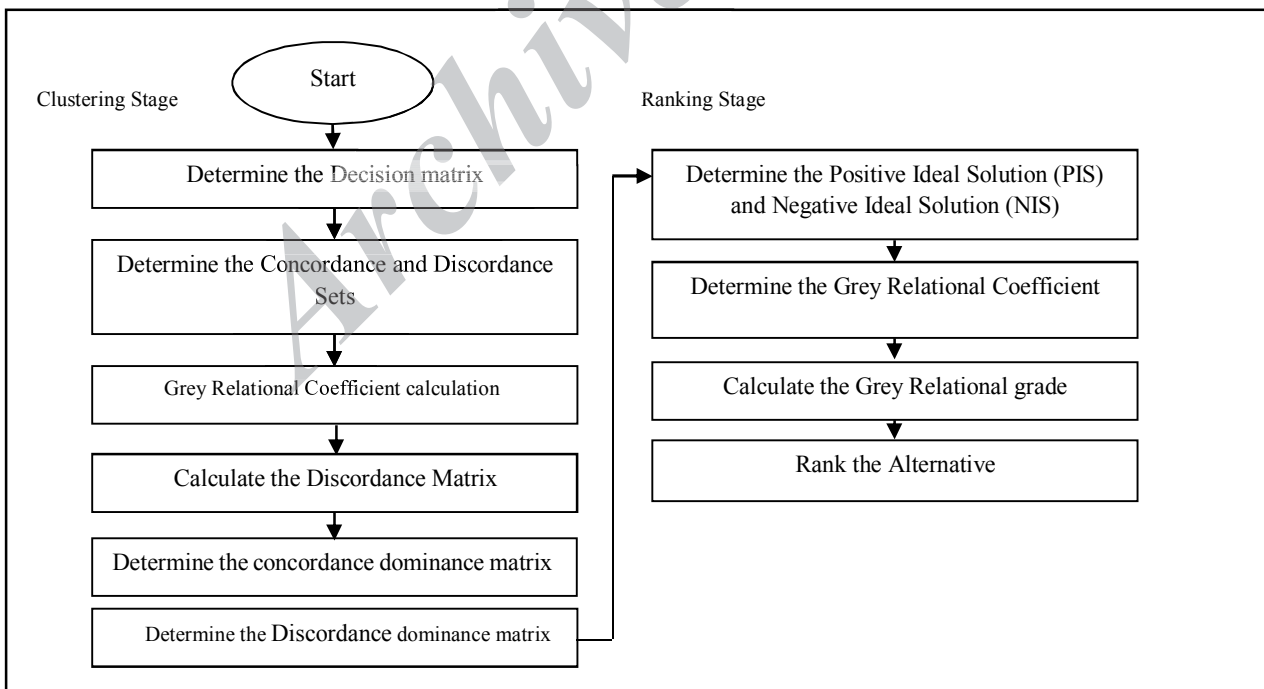


Fig. 3. Hybrid grey based ELECTRE genetic algorithm

The details of grey based ELECTRE algorithm are proposed as follows;

- (1) Generation of the Decision table.
- (2) Separation of the concordance and discordance references.
- (3) Calculation of the concordance cluster.
- (4) Determining the concordance dominance matrix (Concordance Cluster).
- (5) Determining the discordance dominance matrix (Discordance Cluster).
- (6) calculating the positive ideal solution (PSI)  $\tilde{r}^+$  and negative ideal solution (NIS)  $\tilde{r}^-$  of the intuitionistic fuzzy number; it is demonstrated by equations (27) and (28), respectively;
 
$$\tilde{r}_j^+ = \text{Max } \bar{C}_j \quad (27)$$

$$\tilde{r}_j^- = \text{Min } \bar{d}_j, \bar{d}_j > 0 \quad (28)$$
- (7) Computing the Grey relational coefficient by formula (9) and (10).

- (8) Calculating the Grey relational grade by formula (11) and (12).
- (9) Ranking the Alternatives.

### 6. Case Study

A case study is proposed to demonstrate the Grey based Fuzzy ELECTRE (GBFE) method application and validity of its results in the project selection problem. Input data are depicted in **Table 1**. In this case, Total Return Expected ( $C_1$ ) and Working Interested ( $C_2$ ) are the beneficial criteria and Environmental Risk ( $C_3$ ) and Technical Risk ( $C_4$ ) are the Cost criteria. Fuzzy Linguistic attributes and Decision table Related attributes depicts in tables 2 and 3, respectively.

Table 1  
Related attributes for 8 middle stream projects in the company

PPs	C1	C2	C3	C4
P1	([0,0.15,0.25,0.35];0.35,0.53,0.12)	([0.75,0.78,0.9,1];0.7,0.3,0)	([0,0.15,0.25,0.35];0.35,0.53,0.12)	([0.35,0.45,0.55,0.66];0.7,0.3,0)
P2	([0.55,0.65,0.75,0.85];0.49,0.44,0.07)	([0,0.15,0.25,0.35];0.35,0.53,0.12)	([0.55,0.65,0.75,0.85];0.49,0.44,0.07)	([0,0.15,0.25,0.35];0.35,0.53,0.12)
P3	([0.55,0.65,0.75,0.85];0.49,0.44,0.07)	([0.35,0.45,0.55,0.66];0.7,0.3,0)	([0.55,0.65,0.75,0.85];0.49,0.44,0.07)	([0.75,0.78,0.9,1];0.7,0.3,0)
P4	([0,0.15,0.25,0.35];0.35,0.53,0.12)	([0.55,0.65,0.75,0.85];0.49,0.44,0.07)	([0.15,0.25,0.35,0.4];0.56,0.12,0.32)	([0.15,0.25,0.35,0.4];0.56,0.12,0.32)
P5	([0.75,0.78,0.9,1];0.7,0.3,0)	([0.75,0.78,0.9,1];0.7,0.3,0)	([0.35,0.45,0.55,0.66];0.7,0.3,0)	([0,0.15,0.25,0.35];0.35,0.53,0.12)
P6	([0.15,0.25,0.35,0.4];0.56,0.12,0.32)	([0.75,0.78,0.9,1];0.7,0.3,0)	([0.75,0.78,0.9,1];0.7,0.3,0)	([0.55,0.65,0.75,0.85];0.49,0.44,0.07)
P7	([0,0.15,0.25,0.35];0.35,0.53,0.12)	([0.35,0.45,0.55,0.66];0.7,0.3,0)	([0.35,0.45,0.55,0.66];0.7,0.3,0)	([0.75,0.78,0.9,1];0.7,0.3,0)
P8	([0.75,0.78,0.9,1];0.7,0.3,0)	([0.15,0.25,0.35,0.4];0.56,0.12,0.32)	([0,0.15,0.25,0.35];0.35,0.53,0.12)	([0.75,0.78,0.9,1];0.7,0.3,0)

Table 2  
Linguistic values of intuitionistic trapezoidal fuzzy numbers for linguistic terms

Linguistic terms	Linguistic values of intuitionistic trapezoidal fuzzy numbers
Low	([0,0.15,0.25,0.35];0.35,0.53,0.12)
Fairly Low	([0.15,0.25,0.35,0.4];0.56,0.12,0.32)
Medium	([0.35,0.45,0.55,0.66];0.7,0.3,0)
Fairly High	([0.55,0.65,0.75,0.85];0.49,0.44,0.07)
High	([0.75,0.78,0.9,1];0.7,0.3,0)

Table 3  
Decision table Related attributes for 8 middle stream projects in the company

PPs	C1	C2	C3	C4
P1	(0.35,0.53,0.12)	(0.7,0.3,0)	(0.35,0.53,0.12)	(0.7,0.3,0)
P2	(0.49,0.44,0.07)	(0.35,0.53,0.12)	(0.49,0.44,0.07)	(0.35,0.53,0.12)
P3	(0.49,0.44,0.07)	(0.7,0.3,0)	(0.49,0.44,0.07)	(0.7,0.3,0)
P4	(0.35,0.53,0.12)	(0.49,0.44,0.07)	(0.56,0.12,0.32)	(0.56,0.12,0.32)
P5	(0.7,0.3,0)	(0.7,0.3,0)	(0.7,0.3,0)	(0.35,0.53,0.12)
P6	(0.56,0.12,0.32)	(0.7,0.3,0)	(0.7,0.3,0)	(0.49,0.44,0.07)
P7	(0.35,0.53,0.12)	(0.7,0.3,0)	(0.7,0.3,0)	(0.7,0.3,0)
P8	(0.7,0.3,0)	(0.56,0.12,0.32)	(0.35,0.53,0.12)	(0.7,0.3,0)

Assume that the subjective importance of attribute,  $W$ , is given by the decision maker,

$$W=[w_1, w_2, w_3, w_4]=[0.2, 0.1, 0.4, 0.3].$$

Applying step 2, determine the concordance and discordance sets. The decision maker also give the relative weight ( $w'$ ).

$$W'=[W_C, W_{C'}, W_{C''}, W_D, W_{D'}, W_{D''}]=[\frac{1}{3}, \frac{2}{3}, 1, \frac{1}{3}, 1, \frac{2}{3}].$$

Strong Concordance set; moderate concordance set and weak concordance set are show in Tables 4, 5 and 6, respectively.

Table 4  
Strong Concordance set for 8 middle stream projects in the company

Alternative	1	2	3	4	5	6	7	8
1	-	2,3	3	2	3	3	3	-
2	1,4	-	4	1	3	3,4	1,3,4	4
3	1	2	-	1,2	3	3	1,3	-
4	-	2	-	-	-	-	-	-
5	1,4	2,1	1,4	1,2	-	4	1,4	4
6	4	2	4	2	-	-	4	4
7	-	2	-	2	-	-	-	-
8	1	1,3	1,3	1	3	3	1,3	-

For example,  $C_{13} = \{3\}$ , which is in the 1<sup>st</sup> row and 3<sup>rd</sup> column of strong concordance set is 3.  $c_{18} = \{-\}$ , which is in the 1<sup>st</sup> row and 8<sup>th</sup> column of strong concordance set is empty.

Table 5  
Moderate Concordance set for 8 middle stream projects in the company

Alternative	1	2	3	4	5	6	7	8
1	-	-	-	3	-	-	-	-
2	-	-	-	3,4	-	-	-	-
3	-	-	-	3	-	-	-	-
4	-	-	-	-	-	-	-	-
5	-	-	-	4	-	-	-	-
6	1	1	1	1,4	-	-	1	-
7	-	-	-	-	-	-	-	-
8	-	2	-	2,3	-	-	-	-

Table 6  
Weak Concordance set for 8 middle stream projects in the company

Alternative	1	2	3	4	5	6	7	8
1	-	-	2,4	1	2	2	1,2,4	2,3,4
2	-	-	1,3	-	4	-	-	-
3	2,4	1,3	-	-	2	2	2,4	2,4
4	1,4	-	4	-	3	3	1,3,4	4
5	2	4	2	-	-	1,2,3	2,3	1,2
6	2	-	2	-	2,3	-	2,3	2
7	1,2,4	-	2,4	1	2,3	2,3	-	2,4
8	3,4	-	4	-	1	1	4	-

Strong Discordance set, moderate Discordance set and weak Discordance set are show in Tables 7, 8 and 9, respectively.

Table 7  
Strong Discordance set for 8 middle stream projects in the company

Alternative	1	2	3	4	5	6	7	8
1	-	1,4	1	-	4,1	4	-	1
2	2,3	-	2	2	1,2	2	2	1,3
3	3	4	-	-	1,4	4	-	1,3
4	2	1	1,2	-	1,2	2	2	1
5	3	3	3	-	-	-	-	3
6	3	3,4	3	-	4	-	-	3
7	3	1,3,4	1,3	-	1,4	4	-	1,3
8	-	4	-	-	4	4	-	-

Table 8  
Moderate Discordance set for 8 middle stream projects in the company

Alternative	1	2	3	4	5	6	7	8
1	-	-	-	-	-	1	-	-
2	-	-	-	-	-	1	-	2
3	-	-	-	-	-	1	-	-
4	3	3,4	3	-	4	1,4	-	2,3
5	-	-	-	-	-	-	-	-
6	-	-	-	-	-	-	-	-
7	-	-	-	-	-	1	-	-
8	-	-	-	-	-	-	-	-

Table 9  
Weak Discordance set for 8 middle stream projects in the company

Alternative	1	2	3	4	5	6	7	8
1	-	-	-	4	-	-	-	-
2	-	-	-	-	-	-	-	-
3	-	-	-	4	-	-	-	-
4	-	-	-	-	-	-	-	-
5	-	-	-	3	-	-	-	-
6	-	-	-	3	1	-	-	1
7	-	-	-	3,4	-	-	-	-
8	2	-	2	4	2	2	2	-

Applying step 3, concordance matrix is shown in Table 10.

Table 10  
Concordance Matrix (Concordance Cluster) for 8 middle stream projects in the company

Alternative	1	2	3	4	5	6	7	8
1	0	0.3333	0.6	0.7	0.4	0.5333	0.7333	0.8667
2	0.3333	0	0.7333	0.5667	0.5333	0.4667	0.3333	0.4
3	0.6	0.7333	0	0.5667	0.4	0.5333	0.6	0.6
4	0.9333	0.8	0.8	0	0.8	0.9333	0.9333	0.8667
5	0.4	0.5333	0.4	0.5667	0	0.8	0.6667	0.5333
6	0.4667	0.4	0.4667	0.6333	0.7333	0	0.7333	0.4667
7	0.7333	0.3333	0.6	0.7	0.6667	0.8	0	0.6
8	0.8333	0.3667	0.5667	0.6	0.5	0.5	0.5667	0

For example,

$$w_j = \left(\frac{1}{3} \times 0.2\right) + \left(\frac{1}{3} \times 0.4\right) + C_{87} = \sum_{j \in C_{87}} (1 \times 0.3) + \left(\frac{2}{3} \times 0.1\right) = 0.5667$$

and

$$w_j = (0.4 \times 1) + \left(0.1 \times \frac{1}{3}\right) + C_{46} = \sum_{j \in C_{46}} (1 \times 0.2) + (1 \times 0.3) = 0.9333$$

Applying step 4, Discordance matrix is shown in Table 11.

Table 11  
Discordance Matrix (discordance Cluster) for 8 middle stream projects in the company

Alternative	1	2	3	4	5	6	7	8
1	0	0.3334	0.3328	0.5215	0.3334	1	0	0.3334
2	0.3334	0	0.3334	0.1155	0.3334	0.9458	0.3334	1
3	0.3328	0.3334	0	0.6356	0.3334	1	0	0.2221
4	0.6667	1	1	0	1	1	0.2221	1
5	0.3334	0.2003	0.2003	0.5215	0	0	0	0.3334
6	0.2892	0.2003	0.2117	0.5215	0.6011	0	0	0.6011
7	0.2892	0.3334	0.3332	0.6667	0.3334	1	0	0.3334
8	0.6011	0.2892	0.6667	0.5215	0.6011	0.6011	0.6011	0

For example:

$$d_{12} = \frac{\max dis(x_{1j}, x_{21})}{\max dis(x_{1j}, x_{21})} = \frac{0.1027}{0.308} = 0.3334,$$

Where

$$dis(x_{12}, x_{22}) = \frac{1}{3} \times \left( \frac{1}{2} \times \sqrt{((0.35 - 0.49)^2 + (0.53 - 0.44)^2 + (0.12 - 0.07)^2)} \right) = 0.04096,$$

$$dis(x_{14}, x_{24}) = \frac{1}{3} \times \left( \frac{1}{2} \times \sqrt{((0.7 - 0.35)^2 + (0.3 - 0.53)^2 + (0 - 0.12)^2)} \right) = 0.1027.$$

and

$$dis(x_{11}, x_{21}) = \left( \frac{1}{2} \times \sqrt{((0.35 - 0.49)^2 + (0.53 - 0.44)^2 + (0.12 - 0.07)^2)} \right) = 0.1229,$$

$$dis(x_{12}, x_{22}) = \left( \frac{1}{2} \times \sqrt{((0.7 - 0.35)^2 + (0.3 - 0.53)^2 + (0 - 0.12)^2)} \right) = 0.308,$$

$$dis(x_{13}, x_{23}) = \left( \frac{1}{2} \times \sqrt{((0.35 - 0.49)^2 + (0.53 - 0.44)^2 + (0.12 - 0.07)^2)} \right) = 0.1229,$$

$$dis(x_{14}, x_{24}) = \left( \frac{1}{2} \times \sqrt{((0.7 - 0.35)^2 + (0.3 - 0.53)^2 + (0 - 0.12)^2)} \right) = 0.308.$$

Applying step 5, positive ideal solution (PIS)  $\tilde{r}^+$  and negative ideal solution (NIS)  $\tilde{r}^-$  is shown as follows;

$$\tilde{r}^+ = (0.9333, 0.8, 0.8, 0.7, 0.8, 0.8, 0.9333, 0.8667)$$

$$\tilde{r}^- = (0.2892, 0.2003, 0.2003, 0.1155, 0.3334, 0.6011, 0.2221, 0.2221)$$

Applying step 6, grey relational coefficient of each alternative from PIS and NIS using the following equation, respectively, is shown as follows;

$$[\varphi_{ij}^+] = \begin{bmatrix} 0.3334 & 0.4374 & 0.5833 & 0.6667 & 0.4666 & 0.5385 & 0.6999 & 0.8751 \\ 0.4998 & 0.3684 & 0.8749 & 0.6667 & 0.6363 & 0.5833 & 0.4999 & 0.5385 \\ 0.6999 & 0.8749 & 0.3684 & 0.6667 & 0.5384 & 0.6363 & 0.6999 & 0.6999 \\ 0.6667 & 0.8235 & 0.8236 & 0.3999 & 0.8235 & 0.6667 & 0.6667 & 0.7368 \\ 0.5383 & 0.6363 & 0.5385 & 0.6667 & 0.3684 & 1 & 0.7778 & 0.6363 \\ 0.5833 & 0.5385 & 0.5833 & 0.7368 & 0.8749 & 0.3684 & 0.8749 & 0.5833 \\ 0.6999 & 0.4375 & 0.5833 & 0.6667 & 0.6363 & 0.7778 & 0.3334 & 0.5833 \\ 0.9332 & 0.4827 & 0.6087 & 0.6363 & 0.5599 & 0.5599 & 0.6087 & 0.3499 \end{bmatrix}$$

In our study, we used the Minkowski space distance and value of p is set to 2. It represents Euclidean grey space distance. For example:

$$d_{12}^+ = \sqrt{[(0.3333 - 0.8)^2]} = 0.467,$$

$$d_{47}^+ = \sqrt{[(0.7 - 0.9333)^2]} = 0.2333.$$

Thus

$$N^+ = \min \min d_{ij}^+ = 0,$$

$$M^+ = \max \max d_{ij}^+ = 0.9333,$$

$$P = 0.5,$$

$$\varphi_{11}^+ = \frac{0.46665}{0.9333 + 0.46665}.$$

$$[\varphi_{ij}^-] = \begin{bmatrix} 0.6046 & 0.9091 & 0.9103 & 0.6556 & 0.9091 & 0.3835 & 0.6046 & 0.9091 \\ 0.7687 & 0.6883 & 0.7687 & 0.8391 & 0.7687 & 0.3723 & 0.7687 & 0.3561 \\ 0.7695 & 0.7686 & 0.6883 & 0.5040 & 0.7687 & 0.3561 & 0.6883 & 0.953 \\ 0.4452 & 0.3334 & 0.3334 & 0.7929 & 0.3334 & 0.3334 & 0.8058 & 0.3334 \\ 1 & 0.7687 & 0.7687 & 0.7016 & 0.5702 & 0.5699 & 0.5702 & 1 \\ 0.5864 & 0.5246 & 0.5318 & 0.8475 & 1 & 0.4239 & 0.4239 & 1 \\ 0.8683 & 0.7989 & 0.7992 & 0.4987 & 0.7989 & 0.3625 & 0.6657 & 0.7989 \\ 0.5385 & 0.8683 & 0.4987 & 0.5963 & 0.5385 & 0.5385 & 0.5385 & 0.6657 \end{bmatrix}$$

Applying step 7, by using calculation of the weighted grey correlation projection of alternative  $A_1$  onto the positive ideal solution and  $\tilde{r}^+$  and the negative ideal solution  $\tilde{r}^-$ , is shown as follows;

$$p_1^+ = 4.6, p_2^+ = 4.7, p_3^+ = 5.2, p_4^+ = 5.6, p_5^+ = 5.2, p_6^+ = 5.1, p_7^+ = 4.72, p_8^+ = 4.74, p_1^- = 9, p_2^- = 5.3, p_3^- = 5.5, p_4^- = 3.7, p_5^- = 5.9, p_6^- = 5.3, p_7^- = 5.6$$

,  $p_8^- = 4.8$ . Applying step 8, calculation related to relative closeness;

$$CC_1 = 0.438, CC_2 = 0.47,$$

$$CC_3 = 0.486, CC_4 = 0.602, CC_5 = 0.468, CC_6 = 0.49, CC_7 = 0.457,$$

$$CC_8 = 0.497.$$

Step 9, Rank the Alternatives;

$$A_4 > A_8 > A_6 > A_3 > A_2 > A_5 > A_7 > A_1.$$



The results of ranking decision alternatives using gray relational analysis with intuitionistic trapezoidal fuzzy number are depicted below.

$$A_3 > A_1 > A_7 > A_4 > A_2 > A_5 > A_8 > A_6 .$$

## 7. Conclusion

Project selection is a complex decision making problem. It handles a large amount of data, which can come from subjective and objective attributes; hence, it would be useful to develop suitable decision making models to facilitate the project selection task. In this paper, we proposed a new MCDM ranking method: the Grey based fuzzy ELECTRE model for project selection and evaluation. The paper provides values to experts by providing a generic model for project selection and evaluation, and to researchers and decision makers by demonstrating a novel application of outranking relation as well as evaluation of clustering. The presented method has multiple benefits:

- Using Fuzzy ELECTRE method to select the best projects may decrease the unnecessary information and compensate for the insufficiency of decision making.
- The application of Grey relational analysis (GRA) based on Fuzzy number can effectively select the most suitable projects under vague and Fuzzy environment.

Based on the model presented in this paper, decision alternatives were first placed in two discordance and concordance clusters using ELECTRE. Then, the alternatives were ranked using grey confidence level concept in gray relational analysis model. After the model was validated, decision alternative A1 was added as A9 to the original decision matrix. Running the algorithm revealed no change in the ranking of the new model, which means:

$$A_4 > A_8 > A_6 > A_3 > A_2 > A_5 > A_7 > A_1 = A_9 .$$

After performing the above steps in grey relational analysis, the stability in ranking was not provided (unlike grey based ELECTRE), and the new ranking was as follows:

$$A_3 > A_1 > A_7 > A_4 > A_9 > A_2 > A_5 > A_8 > A_6 .$$

Therefore, the stability of the grey based ELECTRE technique is confirmed compared to grey relational analysis in the studied alternative levels.

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