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Research Article

Evaluating Risks of Mergers & Acquisitions by Grey Relational Analysis Based on Interval-Valued Intuitionistic Fuzzy Information

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Purpose. The purpose of our research is to explore a new grey relational analysis method when information of decision making is interval-valued, intuitionistic, fuzzy, and uncertain in risk analysis of Mergers & Acquisitions. *Design/Methodology/Approach*. We proposed a new method to evaluate risks of Mergers & Acquisitions. The process of our method is to determine the positive and negative ideal solutions of interval-valued intuitional fuzzy uncertain language firstly. Then, calculate grey relational grades of every evaluating value for positive or negative ideal solutions. Third, determine the weights of attributes by a linear programming model if part of attribute information is known. Fourth, calculate grey relational grades of each alternative for the positive or negative ideal solutions. Lastly, calculate relative grey relational grades and sort the alternatives. *Findings*. Our case analysis demonstrated that the new grey relational analysis is an effective tool to evaluate the risks of Mergers & Acquisition when information of decision making is interval-valued, intuitionistic, fuzzy, and uncertain. At the same time, we also bring forward the steps of evaluation. *Originality/Value*. Because risks of Mergers & Acquisitions decide its success or failure to some extent, it is very important to evaluate them by feasible and available method. However, the information of risks is fuzzy and uncertain usually. The new grey relational analysis based on Interval-Valued Intuitionistic Fuzzy Information does not only evaluate risks of Mergers & Acquisitions but also can be widely applied to similar problems of decision making in other fields.

1. Introduction

Mergers & Acquisitions (M&A) are often regarded as part of a corporate searching for value creation and the maximization of shareholder value, including efficient growth, asset redeployment, and market power increase [1]. However, because of information asymmetry and dynamic change of environment, it is difficult to arrive at expectable purpose. Many enterprises did not only realize all kinds of synergetic effects mentioned in enterprises M&A theory, but also even recession occurred. It shows that in the process of enterprise M&A to rapid expansion, many variables objectively exist, which makes the M&A process and act results have considerable uncertainty and risks [2].

At present, risk management has become the core issue of M&A. There are two kinds of studies about risks of M&A. One is about which factors cause risks, another is about how to evaluate them. Many factors influence success of M&A; Xiu and Zhao [3] divided the common risks of M&A into three kinds: risks before M&A, risks during M&A, and risks after M&A [3]. Correct strategy is important and necessary undoubtedly before Mergers & Acquisitions, which can ensure that acquisitions are on the right track. Many activities of M&A failed from wrong strategies, the business which is being purchased does not match its own strategy well [4]. In addition, as time goes on, many conditions in the environment may change, such as law, policy, industry, market, and technology. During M&A, because of moral hazard and adverse selection, if managerial motivations sometimes do not keep up same pace with shareholders, or their private profits have conflictions with shareholders, performance will be under expectation. Zhang (2006) investigated pricing risk of a target company and gave it a brief description. Pricing risk comes from information asymmetry and different valuation techniques. Financial risk also comes out if there exists high financing cost resulting in paying difficulty or tax increases suddenly because an acquirer has insufficient knowledge of tax rules. After M&A, integration becomes a very important issue. Bruce Wasserstein (1998) argued that successful M&A does not only depend on the value created by the acquired company but also depend on integration of post M&A. An acquirer has to face the confliction of technology, organization, management, and culture [5].

Risk identification is the first step of risk evaluation in M&A. Another is to choose an appropriate method of evaluation. There are few papers on how to evaluate risks of M&A. Chen et al. [2] built the coal enterprises M&A risk evaluation system and constructed a risk prediction model based on support vector machine (SVM) [2]. They also employed data envelopment analysis (DEA) model to evaluate M&A risks by collecting 13 enterprises related data during 2004-2008 [6]. Xie and Song [7] used the maximum entropy (ME) method to analyze the risk of Mergers & Acquisitions when only preacquisition information is available [7]. Although few researches focus on evaluating risks of M&A, there are many papers about risk evaluation. Some scholars used grey relational analysis (GRA) to evaluate risk of an affair. Chen et al. [8] established the safety risk evaluation index system for Air Traffic Management (ATM) and used GRA to calculate the correlation coefficients and correlation degree between the safety risk in ATM and the factors [8]. Zheng et al. [9] used GRA method to evaluate the sluice according to the specific conditions of the sick-dangerous sluices and some special managing principle [9]. Akay [10] classified industrial jobs into two categories, low risk and high risk, by using GRA approach, together with the comparisons in terms of classification accuracy between GRA approach and other methods that used the same dataset, including logistic regression, decision tree, neural networks, neural-fuzzy classification, ant colony optimization, memory-based reasoning, and ensemble model. GRA outperforms other alternative methods and yields at least 10% improvement in classification accuracy compared to the best results achieved among the earlier studies [10]. Others combined GRA with some methods. Li and Niu [11] combined the theory of the whole life cycle with AHP and GRA to determine the risk factors and the size of each risk [11]. Su et al. [12] combined the qualitative and quantitative methods to assess risk of projects. They used AHP method of investment appraisal to determine the risk weights and used GRA method to establish a model to assess the correlation of risk [12]. Wang and Shang [13] constructed an applicable evaluation index system of ship financing risks, selected the relevant data of Chinese listed shipping enterprises, used entropy method, factor analysis method, and GRA method to evaluate financing risks of Chinese listed shipping enterprises [13]. Tang et al. [14] introduced the dynamic grey BP neural network model based on GRA to develop a new method for warning of corporate human resources management risk [14]. Qiu et al. [15] used the fuzzy Delphi analytic hierarchy process (FDAHP) and GRA to assess the risk of water inrush [15].

The above literatures show GRA is a very popular and effective method in risk evaluation, which is not only used exclusively but also combined with other methods. Nevertheless, past researches paid more attention to how to evaluate risk based on mass, deterministic data, or information. When the future is not stable and changes dynamically, it is a puzzled problem if we have to depend on experts' knowledge and experience to judge changes of the future without enough information, and they only can give fuzzy and uncertain remarks for risks. In other words, the experts' remarks are fuzzy and uncertain linguistic information for an attribute. In order to solve the problem, we try to convert experts' linguistic remarks into interval-valued intuitionistic fuzzy numbers and then employ GRA to calculate risk order of M&A alternatives. The reason that we choose interval-valued intuitionistic fuzzy method lies in, compared with other methods, that it is a better tool to handle with fuzziness and uncertainty of experts' comments in the process of decision making. The paper contributes to use GRA evaluate risk of M&A under interval-valued intuitionistic fuzzy condition.

The rest of the paper is organized as follows. In the next section, it is preliminary theory about interval-valued intuitional fuzzy uncertain linguistic variable, set, expected and precision function, and distance. In Section 3, we propose a new grey relational analysis based on interval-valued intuitional fuzzy uncertain linguistic information, including how to calculate positive and negative solutions, attribute weight, grey relational grades and relative grey relational grades. In Section 4, it explains how to employ the new grey relational analysis by a case of evaluating the risk of M & A and demonstrates the feasibility and availability of the method. Our conclusions are offered in the final section.

2. Preliminary Theory

Suppose $S = \{s_1, s_2, \ldots, s_n\}$ is a finite, orderly, and discrete set of evaluating risk. For example, a linguistic set with nine risky variables is expressed as $S = \{s_1 =$ extremely high, $s_2 =$ very high, $s_3 =$ high, $s_4 =$ slightly high, $s_5 =$ fair, $s_6 =$ slightly low, $s_7 =$ low, $s_8 =$ very low, and $s_9 =$ extremely low$\}$. In order to reserve all information during the process of decision making, discrete linguistic variable set S can be extended to continuous set $\overline{S} = \{s_\alpha \mid \alpha \in R\}$ [16, 17]. Suppose $s_\alpha, s_\beta \in \overline{S}$, if $\alpha > \beta$, $s_\alpha > s_\beta$; if $\alpha = \beta$, $s_\alpha = s_\beta$. Supposing $\overline{s} = [s_a, s_b]$, $s_a, s_b \in \overline{S}$ which indicate upper limit and lower limit of $\tilde{s}$, $\tilde{s}$ is an fuzzy uncertain linguistic variable [16, 18]. In the theory of interval-value intuitional fuzzy uncertain information, the next four definitions are very important.

Definition 1. Suppose $A = \{< [s_{\theta(x)}, s_{\tau(x)}], [{\mu_A}^L(x), {\mu_A}^U(x)], [{\nu_A}^L(x), {\nu_A}^U(x)]\} >| x \in X\}$ is a set of interval-valued fuzzy uncertain linguistic variables. $< [s_{\theta(x)}, s_{\tau(x)}], [{\mu_A}^L(x), {\mu_A}^U(x)], [{\nu_A}^L(x), {\nu_A}^U(x)]\} >$ are interval-valued intuitional fuzzy uncertain linguistic (IVIFUL) variables, where $[s_{\theta(x)}, s_{\tau(x)}]$ are fuzzy uncertain linguistic variables, $[{\mu_A}^L(x), {\mu_A}^U(x)]$ and $[{\nu_A}^L(x), {\nu_A}^U(x)]$ are intervalued membership grade and nonmembership grade respectively that an alternative belongs to the set $[s_{\theta(x)}, s_{\tau(x)}]$ [19].

Definition 2. Supposing that a $=<$ $[s_{\theta(a)}, s_{\tau(a)}]$, $[\mu^L(a), \mu^U(a)]$, $[\nu^L(a), \nu^U(a)]$ $>$ is an interval-valued intuitionistic fuzzy uncertain linguistic variable, expected function $E(a)$ is defined as

$$E(a) = \frac{1}{2} \times \left(\frac{\mu^L(a) + \mu^U(a)}{2} + 1 - \frac{\nu^L(a) + \nu^U(a)}{2} \right) \times s_{(\theta(a)+\tau(a))/2} = s_{(\theta(a)+\tau(a))\times(\mu^L(a)+\mu^U(a)+2-\nu^L(a)-\nu^U(a)))/8} \quad (1)$$

Precision function $P(a)$ is defined as [20]:

$$P(a) = \frac{1}{2} \times \left(\frac{\mu^L(a) + \mu^U(a)}{2} + \frac{\nu^L(a) + \nu^U(a)}{2} \right) \times s_{(\theta(a)+\tau(a))/2} = s_{(\theta(a)+\tau(a))\times(\mu^L(a)+\mu^U(a)+\nu^L(a)+\nu^U(a)))/4} \quad (2)$$

Definition 3. Suppose that a_1 $=<$ $[s_{\theta(a1)}, s_{\tau(a1)}]$, $[\mu^L(a_1), \mu^U(a_1)]$, $[\nu^L(a_1), \nu^U(a_1)]$ $>$ and a_2 $=<$ $[s_{\theta(a_2)}, s_{\tau(a_2)}]$, $[\mu^L(a_2), \mu^U(a_2)]$, $[\nu^L(a_2), \nu^U(a_2)]$ $>$ are two IVIFUL variables, then,

(1) if $E(a_1) > E(a_2)$, then $a_1 \succ a_2$;
(2) if $E(a_1) = E(a_2)$, then,
 if $P(a_1) > P(a_2)$, then $a_1 \succ a_2$;
 if $P(a_1) = P(a_2)$, then $a_1 \sim a_2$ [21].

Definition 4. Distance between a_1 and a_2 is defined as [22]:

$$d(a_1, a_2) = \frac{1}{6} \times \Bigg(\frac{(|\theta(a_1) - \theta(a_2)| + |\tau(a_1) - \tau(a_2)|)}{9} + \left|\mu^L(a_1) - \mu^L(a_2)\right| + \left|\mu^U(a_1) - \mu^U(a_2)\right| + \left|\nu^L(a_1) - \nu^L(a_2)\right| + \left|\nu^U(a_1) - \nu^U(a_2)\right| \quad (3)$$

3. Grey Relational Analysis Based on IVIFUL Information

Supposing that there is a multiattribute decision-making problem, $A = \{A_1, A_2, \ldots, A_m\}$ is a set of risky attributes [23], where $w_j \geq 0$, $j = 1, 2, \ldots, n$, $\sum_{j=1}^{n} w_j = 1$. $D = (a_{ij})_{m\times n}$ is a decision-making matrix consisting of evaluating value a_{ij} of the attribute R_j, where, $a_{ij} =< [s_{\theta(a_{ij})}, s_{\tau(a_{ij})}]$, $[\mu^L(a_{ij}), \mu^U(a_{ij})]$, $[\nu^L(a_{ij}), \nu^U(a_{ij})]$ $>$ is an interval-valued intuitionistic fuzzy uncertain linguistic variable [24].

During the process of decision making, if weights of attributes are known, GRA is used to sort alternatives. However, only some of attribute weights are known sometimes. Normally, they belong to the set $PW = \{w_i \geq w_j,\ i \neq j;\ w_i - w_j \geq \alpha_i w_i,\ 1 \geq \alpha_i \geq 0;\ w_i - w_j \geq w_k - w_l,\ i \neq j \neq k \neq l;\ \beta_j \leq w_j \leq \beta_{j+}\varepsilon_j,\ 0 \leq \beta_j \leq \beta_{j+}\varepsilon_j \leq 1\}$. When faced with specific multiattribute problems, part of attribute-weight information is a subset of PW, denoted by Φ. Because a part of attribute-weight vectors are known, it is necessary to find a way to calculate all attribute-weight vectors. According to GRA, a decision-maker should choose the alternative that has the maximum grey relational grade with positive ideal solution and minimum one with negative ideal solution [25]. A positive and negative ideal solution is denoted by A^+ and A^- respectively [26]. Both of them can be calculated as follows. Firstly, calculate expected function $E(a_{ij})$ and precision function $P(a_{ij})$ of a_{ij} for every alternative by Equation (1) and (2). Then, sort the evaluating value $a_{1j}, a_{2j}, \ldots, a_{mj}$ of the attribute R_j ($j = 1, 2, \ldots, m$) and choose the maximum value as positive ideal solution a_j^+, the minimum value as negative ideal solution a_j^-. Lastly, we can get positive and negative ideal solution sets A^+ and A^- [27],

$$A^+ = \{a_1^+, a_2^+, \ldots, a_n^+\} = \left\{\max_i a_{i1}, \max_i a_{i2}, \ldots, \max_i a_{in}, \right\} \quad (4)$$

$$A^+ = \{a_1^-, a_2^-, \ldots, a_n^-\} = \left\{\min_i a_{i1}, \min_i a_{i2}, \ldots, \min_i a_{in}, \right\} \quad (5)$$

Grey relational coefficients, between evaluating value a_{ij} of one alternative and a positive ideal solution or negative ideal solution, are calculated as follows [15]:

$$\xi_{ij}^+ = \frac{\min_{1\leq i\leq m}\min_{1\leq j\leq n} d(a_{ij}, a_j^+) + \rho \max_{1\leq i\leq m}\max_{1\leq j\leq n} d(a_{ij}, a_j^+)}{d(a_{ij}, a_j^+) + \rho \max_{1\leq i\leq m}\max_{1\leq j\leq n} d(a_{ij}, a_j^+)} \quad (6)$$

$$\xi_{ij}^- = \frac{\min_{1\leq i\leq m}\min_{1\leq j\leq n} d(a_{ij}, a_j^-) + \rho \max_{1\leq i\leq m}\max_{1\leq j\leq n} d(a_{ij}, a_j^-)}{d(a_{ij}, a_j^-) + \rho \max_{1\leq i\leq m}\max_{1\leq j\leq n} d(a_{ij}, a_j^-)} \quad (7)$$

Because optimal alternative has the maximum grey relational degrade with positive ideal solution and the minimum with negative ideal solution [28], the weights of attributes are calculated by the multiobjective programming model (P-1).

$$\begin{aligned} (P-1)\ \max\quad & \xi^+ = \sum_{j=1}^{n} w_j \xi_{ij}^+, \quad i = 1, 2, \ldots, m \\ \min\quad & \xi^- = \sum_{j=1}^{n} w_j \xi_{ij}^-, \quad i = 1, 2, \ldots, m \\ \text{s.t.}\quad & w \in w_1 + w_2 + \cdots + w_n = 1 \\ & w_j \geq 0 \end{aligned} \quad (8)$$

Because it is same for the importance of every objective, the above model can be translated to single objective programming model (P-2).

$$(P-2)\ \max\quad z=\sum_{i=1}^{m}\sum_{j=1}^{n}w_j\left(\xi_{ij}^{+}-\xi_{ij}^{-}\right)$$
$$\text{s.t.}\quad w\in\Phi \qquad (9)$$
$$w_1+w_2+\cdots+w_n=1$$
$$w_j\geq 0$$

The attribute-weight vector $W=(w_1,w_2,\ldots,w_n)$ can be solved by the above model (P-2).

According to the above analysis, GRA based on IVIFULI is summarized as follows.

Step one: calculate positive and negative solutions A^+ and A^- of interval-valued intuitionistic fuzzy uncertain language by (4) and (5).

Step two: calculate grey relational coefficient between evaluating value of every alternative and positive-negative ideal solutions by (6) and (7).

Step three: if attribute weights are known, go to next step. If only part of attribute weights is known, solve complete attribute-weight vector $W=(w_1,w_2,\ldots,w_n)$ by the model (P-2) according to the known part of attribute information.

Step four: calculate grey relational coefficient of positive or negative ideal solutions for every alternative by following equations.

$$\xi_i^{+}=w_1\xi_{i1}^{+}+w_2\xi_{i2}^{+}+\cdots+w_n\xi_{in}^{+},\quad i=1,2,\ldots,m \qquad (10)$$

$$\xi_i^{-}=w_1\xi_{i1}^{-}+w_2\xi_{i2}^{-}+\cdots+w_n\xi_{in}^{-},\quad i=1,2,\ldots,m \qquad (11)$$

Step five: calculate the relative grey relational grade (RGRG) of positive ideal solution for every alternative [29].

$$\xi_i=\frac{\xi_i^{+}}{\xi_i^{+}+\xi_i^{-}},\quad i=1,2,\ldots,m \qquad (12)$$

Step six: sort all alternatives by RGRGs and choose the best. The bigger the RGRG is, the better one alternative is.

4. Case Analysis

Under the influence of various complex factors, M&A is a kind of risk activity that makes its earning with full of uncertainty. It is available to help decision-makers to understand risk severity by evaluating it objectively. Consequently, risk evaluation is a basis to make a decision of M&A investment, control and transfer risks, and decrease the loss of risks. ZM Company is a state-own corporation group whose developing strategy is to expand share in thermoelectric market. The company is going to acquire a thermopower plant. There are five targets to be chosen, namely, five alternatives. Before purchasing the target, it employed five professional experts to analyze the risks of M&A. The experts put forward that five risks are necessary to be considered, R_1-Political and legal risk; R_2-Market risk; R_3-Information risk; R_4- Financial risk; R_5-Integration risk. On account of the fuzziness and uncertainty in M&A, decision-makers decided to use IVIFUL variable to evaluate the risk of every alternative. The experts gave the evaluating value a_{ij} of the attribute R_j of the alternative A_i according to their experience and knowledge. Decision-making matrix $A=(a_{ij})_{m\times n}$ is shown as in Table 1.

Next, we will sort the alternatives and choose the best by the above-mentioned method. The steps are as follows.

The first step: determine interval-valued intuitional fuzzy positive solution A^+ and negative solution A^-. By (1) and (2), calculate expected function and precision function of the interval-valued intuitional fuzzy linguistic evaluating value. For example, expected functions and precisions of $a_{11},a_{21},\ldots,a_{51}$ are

$$\begin{aligned}E(a_{11})&=s_{4.05},\\E(a_{21})&=s_{3.69},\\E(a_{31})&=s_{4.25},\\E(a_{41})&=s_{5.04},\\E(a_{51})&=s_{5.85},\end{aligned}\qquad (13)$$

and

$$\begin{aligned}P(a_{11})&=s_{4.98},\\P(a_{21})&=s_{4.47},\\P(a_{31})&=s_{7.03},\\P(a_{41})&=s_{7.12},\\P(a_{51})&=s_{8.26},\end{aligned}\qquad (14)$$

Because $E(a_{51})>E(a_{41})>E(a_{31})>E(a_{11})>E(a_{21})$, then $a_{51}>a_{41}>a_{31}>a_{11}>a_{21}$. Therefore, $a_1^{+}=\max_i a_{i1}=a_{51}([s_8,s_9],[0.61,0.74],[0.23,0.36])$, $a_1^{-}=\min_i a_{i1}=a_{21}([s5,s7],[0.43,0.55],[0.15,0.36])$. Similarly, calculate the rest of a_1^{+} $(i=2,3,\ldots,5)$ and a_1^{-} $(i=2,3,\ldots,5)$. Consequently, positive and negative solutions, A^+ and A, are shown as follows:

$$\begin{aligned}A^{+}=\{&([s_8,s_9],[0.61,0.74],[0.23,0.36])\\&([s_6,s_8],[0.85,0.96],[0.12,0.17])\\&([s_7,s_8],[0.68,0.71],[0.31,0.33])\\&([s_8,s_9],[0.83,0.97],[0.12,0.13])\\&([s_6,s_8],[0.65,0.88],[0.16,0.21])\}\\A^{-}=\{&([s_5,s_7],[0.43,0.55],[0.15,0.36])\\&([s_4,s_6],[0.55,0.60],[0.28,0.41])\\&([s_3,s_4],[0.44,0.55],[0.37,0.50])\\&([s_3,s_4],[0.61,0.74],[0.24,0.33])\\&([s_3,s_4],[0.47,0.66],[0.24,0.33])\}\end{aligned}\qquad (15)$$

TABLE 1: Decision-making matrix.

	R_1	R_2	R_3	R_4	R_5
A_1	$([s_4, s_6], [0.74, 0.88], [0.14, 0.24])$	$([s_6, s_7], [0.40, 0.57], [0.24, 0.37])$	$([s_6, s_7], [0.66, 0.82], [0.15, 0.27])$	$([s_4, s_6], [0.71, 0.83], [0.16, 0.23])$	$([s_6, s_8], [0.65, 0.88], [0.16, 0.21])$
A_2	$([s_5, s_7], [0.43, 0.55], [0.15, 0.36])$	$([s_7, s_8], [0.53, 0.71], [0.33, 0.35])$	$([s_5, s_6], [0.52, 0.78], [0.15, 0.36])$	$([s_8, s_9], [0.83, 0.97], [0.12, 0.13])$	$([s_4, s_5], [0.61, 0.74], [0.10, 0.38])$
A_3	$([s_6, s_8], [0.56, 0.66], [0.33, 0.46])$	$([s_4 s_6], [0.55, 0.60], [0.28, 0.41])$	$([s_7, s_8], [0.68, 0.71], [0.31, 0.33])$	$([s_3, s_4], [0.61, 0.74], [0.24, 0.33])$	$([s_6, s_7], [0.47, 0.62], [0.35, 0.46])$
A_4	$([s_7, s_8], [0.54, 0.76], [0.23, 0.37])$	$([s_6, s_8], [0.85, 0.96], [0.12, 0.17])$	$([s_3, s_4], [0.44, 0.55], [0.37, 0.50])$	$([s_4, s_5], [0.47, 0.53], [0.36, 0.46])$	$([s_7, s_8], [0.57, 0.64], [0.23, 0.47])$
A_5	$([s_8, s_9], [0.61, 0.74], [0.23, 0.36])$	$([s_5, s_6], [0.63, 0.88], [0.15, 0.27])$	$([s_4, s_5], [0.78, 0.93], [0.11, 0.13])$	$([s_5, s_6], [0.54, 0.67], [0.24, 0.32])$	$([s_3, s_4], [0.47, 0.66], [0.24, 0.33])$

The second step: determine the grey relational coefficients ξ^+ and ξ^- between evaluating value of every alternative and positive ideal solution or negative ideal solution.

$$\xi^+ = \left(\xi^+_{ij}\right)_{5\times 5} = \begin{pmatrix} 1.00 & 0.60 & 0.45 & 0.42 & 0.45 \\ 0.47 & 0.47 & 0.67 & 0.49 & 1.00 \\ 0.53 & 0.51 & 0.56 & 1.00 & 0.54 \\ 0.63 & 0.43 & 1.00 & 0.37 & 0.53 \\ 0.78 & 1.00 & 0.42 & 0.33 & 0.59 \end{pmatrix}$$
$$\xi^- = \left(\xi^-_{ij}\right)_{5\times 5} = \begin{pmatrix} 0.48 & 0.56 & 0.37 & 0.62 & 1.00 \\ 0.49 & 0.62 & 0.37 & 0.57 & 0.41 \\ 1.00 & 0.54 & 0.46 & 0.33 & 0.60 \\ 0.56 & 1.00 & 0.38 & 1.00 & 0.50 \\ 0.56 & 0.38 & 1.00 & 0.54 & 0.45 \end{pmatrix} \quad (16)$$

The third step: if weight vectors of attributes W are known (if part of weight information is known, go to step six) and $W = (0.05, 0.15, 0.25, 0.25, 0.3)$, calculate the grey relational grade ξ_i^+ or ξ_i^+ of every alternative with positive or negative ideal solution by (8) and (11). The results are shown as follows:

$$\begin{aligned} \xi_i^+ &= 0.49, \\ \xi_i^+ &= 0.68, \\ \xi_i^+ &= 0.65, \\ \xi_i^+ &= 0.60, \\ \xi_i^+ &= 0.56, \\ \xi_i^- &= 0.66, \\ \xi_i^- &= 0.47, \\ \xi_i^- &= 0.51, \\ \xi_i^- &= 0.67, \\ \xi_i^- &= 0.61. \end{aligned} \quad (17)$$

The fourth step: calculate relative grey relational grade of every alternative ξ_i by (12).

$$\begin{aligned} \xi_1 &= 0.43, \\ \xi_2 &= 0.59, \\ \xi_3 &= 0.56, \\ \xi_4 &= 0.47, \\ \xi_5 &= 0.483. \end{aligned} \quad (18)$$

The fifth step: sort the alternatives according to their relative grey relational grades and choose the optimal. Because $R_1 > R_2 > R_4 > R_3 > R_5$, so the optimal one is R_1.

The sixth step: calculate weight vectors W by the model (P-2) if part of weight-vector information of attributes is known. For example, $\Phi = \{0.05 \le w_1 \le 0.25, 0.10 \le w_2 \le 0.45, 0.15 \le w_3 \le 0.35, 0.20 \le w_4 \le 0.40, 0.25 \le w_5 \le 0.65, \}$, calculate the difference between positive solution ξ_{ij}^+ and negative solution ξ_{ij}^- firstly, then according to the model P-2, build a linear programing model as follows:

$$\begin{aligned} (P\text{-}3) \quad \max \quad & z \\ & = 0.3233w_1 - 0.0998w_2 + 0.5258w_3 \\ & \quad - 0.4495w_4 + 0.1519w_5 \\ \text{s.t.} \quad & w_1 + w_2 + w_3 + w_4 + w_5 = 1 \\ & 0.05 \le w_1 \le 0.25 \\ & 0.10 \le w_2 \le 0.45 \\ & 0.15 \le w_3 \le 0.35 \\ & 0.20 \le w_4 \le 0.40 \\ & 0.25 \le w_5 \le 0.65 \end{aligned} \quad (19)$$

By *optimtool* of *Matlab* software, solve the model (P-3) and obtain the weight vectors $W = (0.05, 0.15, 0.15, 0.40, 0.25)$. Then, return to step three and calculate the grey relational grade of every alternative with positive or negative ideal solution,

$$\xi_i^+ = 0.49,$$
$$\xi_i^+ = 0.64,$$
$$\xi_i^+ = 0.72,$$
$$\xi_i^+ = 0.53,$$
$$\xi_i^+ = 0.53,$$
$$\xi_i^- = 0.66, \quad (20)$$
$$\xi_i^- = 0.50,$$
$$\xi_i^- = 0.48,$$
$$\xi_i^- = 0.76,$$
$$\xi_i^- = 0.56.$$

Next, calculate relative grey relational grade of every alternative by (12),

$$\xi_1 = 0.42,$$
$$\xi_2 = 0.56,$$
$$\xi_3 = 0.60, \quad (21)$$
$$\xi_4 = 0.40,$$
$$\xi_5 = 0.49.$$

Because $\xi_3 = 0.60$ is the biggest, the third alternative R_3 is the best one.

Evidently, when experts describe the information of alternatives with intervalue, intuition, fuzziness and uncertainty, traditional models such as fuzzy comprehensive evaluation or grey rational analysis, can do nothing for evaluating the risk of an alternative. Especially when part of weight information is known, it is a very difficult problem to deduce the weight of every attribute. ZM Company chose the alternative R_3 finally, and at present, R_3, the thermoelectric factory operates very well. Its heating area has reached more than 6.4 million square meters, annual power generation is over 455 million kwh, annual revenue is about 430 million yuan, annual return is 45.15 million yuan, and annual rate of profit is 10.5 percent. The actual situation of R_3 alternative supports IVIFULIV is an effective and feasible appraisal method.

5. Conclusions

When a corporation decides whether it acquires a target company or not, much information may be interval-value, intuitional, fuzzy and uncertain. It is difficult to solve the problem for traditional method of decision making. Consequently, we brought forward a grey relational analysis based on IVIFULIV to sort alternatives. At the same time, we also studied how to calculate the weights based on linear programming model when part of weight information of attributes is known. During the process of analysis, it is important and necessary to determine expected functions, precision functions, positive and negative matrixes, grey relational grades, relative grey relational grades and linear programming model. The case analysis illustrated how to use the method and verified its feasibility and availability. Although the method that we proposed is applied to evaluate risk of M&A, in fact, it is a universal method. In other words, the method adapts to solve multiattribute decision-making problems when the environment is uncertain and complex. Despite many advantages, there are still some limitations about our research. More comparisons should be made with other methods such as fuzzy comprehensive evaluation to demonstrate advantages of IVIFULIV. Moreover, the method is so complex that only professional experts can master and make use of it. Therefore, we will develop a small and visualized platform to employ IVIFULIV for convenient application.

Data Availability

The data used to support the findings of our study are included in Table 1 within the article titled "Evaluating Risks of Mergers & Acquisitions by Grey Relational Analysis Based on Interval-valued Intuitionistic Fuzzy Information".

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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