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Evaluation and Classification of Overseas Talents in China Based on the BWM for Intuitionistic Relations

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Abstract: Efficient utilization of human resources is an important force for the sustainable development of society and the economy. Against the backdrop of the development of economic globalization, the Chinese Government is presently implementing the strategy of "Strengthening the Nation with Talent" to assist the exploitation and management of human resources. Overseas talents have recently become an important resource. How to scientifically evaluate and classify overseas talents has become an important research topic, and it is necessary to seek a systematic decision aid. This paper introduces a novel methodology to evaluate and classify overseas talents in China under the intuitionistic relations environment. Firstly, we determine the weighted values of decision makers and criteria through defining geometry consistency. Secondly, we construct a non-linear Best-Worst-Method (BWM) model with intuitionistic preference relations. A highlight of this BWM model for intuitionistic relations is taking both positive and negative aspects into consideration, which is different from the original BWM. Finally, the proposed methodology is applied to an illustrative example of overseas talent evaluation, indicating the simultaneous efficiency and practicability of the method.

Keywords: multi-criteria decision making; human resource management; overseas talents' evaluation and classification; Best-Worst-Method (BWM) for intuitionistic relations

1. Introduction

International competition is becoming more and more severe, as a result of the development of economic globalization. Human resources have become part of the core of national competitiveness. This paper will focus on the evaluation of overseas talents in the Chinese situation. As the world's largest developing country, China has unique advantages in attracting overseas talents. First of all, the Chinese culture provides an open and inclusive environment that is suitable for the development of overseas talents. China has always advocated cultural exchange between different nationalities, different countries and different areas. Moreover, China has always had a good tradition of respecting talents, recruiting remarkable people without stereotyping. After the reform and opening-up policy initiated in 1978, China has opened its door to welcome international friends from all over the world. Secondly, the rapid development of the Chinese economy and society has provided a broad space for overseas talents to start businesses. More and more overseas students and immigrants are being drawn to China and are becoming a new force in Chinese social development. Based on data from the Chinese Service Center for Scholarly Exchange, the ratio of overseas students who returned to work has reached 70%–80% percent. Thirdly, the Chinese Government attaches great importance to the role of overseas talents. At present, China is in an economic transition stage, and innovation has become the driving force. Overseas talents' innovation behavior is an essential influencing factor in the nation's innovative economic development [1]. Therefore, the Chinese Government strongly supports the introduction of overseas talents and expects them to contribute to technology industries. A series of talent introduction policies have been issued in succession, resulting in step by step improvement. In 2008, the central committee staff office of the Chinese Communist Party implemented a national plan named the Recruitment Program of Global Experts/Thousand-Talent Scheme. Moreover, some detailed plans followed this policy, for instance, the Young Overseas High-level Talents Introduction Plan, starting from 2011, whose purpose is to introduce the outstanding young talents of around 35 years of age; the Foreign High-level Experts Introduction Plan, starting from 2012, whose purpose is to introduce the overseas non-Chinese-origin experts who should work in China for three years continuously and nine months per year at least.

However, the gradual expansion of overseas talents in China creates new requirements for the management of overseas talent. In order to evaluate and classify foreign talents who have come to China, the Chinese government is required to build up a complete, systematic and scientific talents evaluation system. Therefore, this study aims to construct a targeted overseas talent evaluation index system based on the Chinese context and explores a combination of geometry consistency and the non-linear best-worst-method model. Furthermore, the study may enrich talent evaluation theory and provide a reference for overseas talents' management by the Chinese Government and other developing countries.

According to the theory of talent evaluation, building a reasonable talent evaluation system is the foundation of human resource utilization. Academics have continuously explored human resource management. Lai [2] described the employee selection process as a multi-objective decision making problem. Iwamura and Lin [3] explained that the employee selection process required the accomplishment and aggregation of different factors. Labib, Williams and O'Connor [4] suggested an employee selection process that uses the Analytic Hierarchy Process (AHP) with four stages. As Chou, Sun and Yen [5] said, the pure AHP model for human resource evaluation and management has some shortcomings. On the one hand, the traditional evaluation method, such as the pure AHP method, mainly used explicit information to describe the evaluations. On the other hand, the criteria's weights, which have great influence on the final results, are mostly obtained by the preference of decision makers [6]. To overcome these drawbacks, some scholars introduced fuzzy theory to the AHP methodology. Golec and Kahya [7] presented a hierarchical structure for selecting and evaluating the right employee based on five-scale measure tables. Zhong [8] analyzed the performance of high-level talents with the fuzzy evaluation method, which described the decisions by numbers from 1–9 and their reciprocals. Zhao et al. [9] studied the creative talents evaluation index system based on the nine-scale AHP method. Chou, Hsu and Yen [10] analyzed a country's competitiveness in terms of their technological human resources with three kinds of criteria. In the last two years, some Chinese scholars did research on human resource and relevant policies [11–15]. Although these methods have further developed the traditional evaluation methods through the introduction of fuzzy theory, they are still not practical enough to deal with the case in our paper. As our study objective is overseas talents, they can be considered as the alternatives. The relevant government departments can organize some experts who are decision makers to evaluate alternatives using several criteria. That makes this problem turn into a multi-criteria decision making problem, which can be solved by Multi-Criteria Decision Making (MCDM) methods. Many scholars have studied this field [16–19]. We decided to utilize one kind of MCDM method to discuss the overseas talents' evaluation and classification issues. Different useful tools have been produced for MCDM problems, such as the TOPSIS method [20], pairwise comparison [21] and elimination and choice translation reality [22]. Among them, pairwise comparison is a more practical tool for solving the overseas talents' evaluation problem. Lazim and Norsyahida [23] studied pairwise comparison to deal with the MCDM problem. Suppose there is a set $\{x_1, x_2, ..., x_3\}$ with n alternatives. We can compare them pairwise and obtain the following original decision matrix under a certain criterion:

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ x_{n1} & x_{n2} & \cdots & x_{nn} \end{bmatrix} \tag{1}$$

where x_{ij} stands for the comparison result of x_i over x_j. Generally speaking, Decision Makers (DMs) can express their decision results based on Multiplicative Preference Relations (MPRs) [24] and Fuzzy Preference Relations (FPRs) [25]. However, DMs may sometimes not be sure about the intensities of preferences. This means that their results may be fluctuating in a certain range during the decision making process. In 1987, Satty and Vargas introduced Interval-Valued Multiplicative Preference Relations (IVMPRs) [26]. In 2004, Xu introduced Interval-Valued Fuzzy Preference Relations (IVFPRs) [27]. These two extensions allowed DMs to use interval valued numbers [28] to express their comparison results. However, IVFPRs and IVMPRs pay more attention to the preferred degree of alternative x_i over x_j, ignoring the non-preferred degree. In order to cope with this issue, the concept of Intuitionistic Multiplicative Preference Relations (IMPRs) [29] and Intuitionistic Fuzzy Preference Relations (IFPRs) [30] appear as extensions of the traditional multiplicative preference relations. An IMPR is given as $R = (\alpha_{ij})_{n\times n}$, where $\alpha_{ij} = (\rho_{\alpha_{ij}}, \sigma_{\alpha_{ij}})$ is an Intuitionistic Multiplicative Number (IMN) given on the $1/9 - 9$ scale, where $\rho_{\alpha_{ij}}$ stands for the preferred degree and $\sigma_{\alpha_{ij}}$ stands for the non-preferred degree of alternative x_i over x_j, including the hesitation information. An IFPR is given as $A = (a_{ij})_{n\times n}$, where $a_{ij} = [a_{ij}^-, a_{ij}^+]$ is an interval multiplicative number in which the preferred degree is located. In order to evaluate overseas talents fully, we not only consider the preferred degree of one talent over another, but also discuss the non-preferred degree.

Many scholars have introduced various kinds of preference relations by studying decision matrix X [27,31–34]. Their applications are about different fields of multi-criteria decision making problems, such as management information systems, forecast theory and economic systems [29,35,36]. In general, we should make $n(n-1)$ times of comparisons to finish the pairwise decision matrix X. Most studies about the original decision matrix have a similar assumption that is $x_{ij} = x_{ji}$. Under this assumption, the number of pairwise comparisons decreased from $n(n-1)$ to $n(n-1)/2$. If the number of alternatives is small, the pairwise comparison method is applicable. For example, Celik, Kandakoglu and Deha Er [37] proposed a multi-stage evaluation model under multiple criteria in order to manage the academic personnel selection and development in maritime education and training institutions. However, if the alternatives' number is large, such as 20 candidates and 190-times of comparison, most published methods are not suitable. We need a method to decrease the comparison times, as well as ensuring reliability. Rezaei [38] proposed a decision making method: the Best-Worst-Method (BWM) Rezaei, Wang and Tavasszy [39] use BWM to propose an integrative approach that includes capabilities and willingness as two dimensions for evaluating and subsequently segmenting suppliers. Rezaei [40] applied a linear BWM to a car choosing problem. Compared to the other MCDM methods, BWM has not been applied and published widely. Rezaei et al. [41] apply the BWM to find the best suppliers from among the qualified suppliers. BWM's biggest highlight is the pairwise comparison times dropping from $n(n-1)/2$ to $2n-3$. As BWM noted, it is not hard for people to pick out the best one and the worst one among the alternatives under a certain criterion. Determining how much the best one is superior to the others and how much the others are superior to the worst are the difficult parts. BWM is an effective method to deal with comparison times' problems. The BWM expressed the comparison results by numbers from $\{1,2,3,4,5,6,7,8,9\}$ and ignored the reciprocals of each pair to avoid the trouble caused by unequal distance between fractional comparisons. Rezaei [38] discussed a practical application of a college students' cell phone selection problem. The result showed that without considering the reciprocals, the method was credible, as well. However, ignoring the reciprocals is not sufficient for some other situations, especially for the talent assessment problems, in which unequal distance between fractional comparisons does exist. This paper proposes a non-linear BWM model to cope with the overseas talents evaluation problem. As discussed above, this model will be built under the intuitionistic relations environment. This means that compared with the original BWM, decision makers not only assess how much the best one is superior to the others, but also assess how much the others are superior to the worst. So do the others to the worst. Then, constructing the non-linear BWM would simultaneously increase the efficiency and practicability of our method.

Besides, the consistency degree of decision matrix X is a very important property, which also attracts many scholars' attention. In the process of pairwise comparison, generalized consistency means that if alternative x_i is better than x_k and x_k is better than x_j, then x_i is better than x_j. Furthermore, if the three preferred degrees of x_i over x_k, x_k over x_j and x_i over x_j satisfy the preference relations, then they satisfy consistency. Wang and Chen [42] discussed comparison consistency depending on the incomplete fuzzy linguistic preference relations. Liu et al. [43] introduced a goal programming model to deal with the incomplete interval multiplicative preference relation problems, which was based on the consistency property. Then, we also introduce a weight-determining system, based on geometry consistency defined in this paper. This methodology will help to calculate the weight vector of decision makers and criteria. For evaluating the overseas talent problem, we consider the weighting issues under the intuitionistic preference relations environment, which contains preferred degree and non-preferred degree. Decision makers are weighed according to their geometry consistent degree, the criteria's weights obtained subsequently. Further, decision makers and criteria can obtain their weights by the consistency degree. We use an example from Jiang et al. [44], in which they focused on calculating the missing elements and did not give enough consideration to the consistency of decision matrices, to demonstrate the validity of our method.

The main contributions of this paper are two-fold. Firstly, we construct an evaluation system and introduce a geometry consistency degree to measure the criteria weights, with its validity demonstrated by a published example. Secondly, we construct a non-linear BWM model for intuitionistic preference relations and show its practicability by solving an overseas talent evaluation and classification problem. Both of the two points contribute to MCDM problems. The rest of the paper is organized as follows. Section 2 introduces definitions about the weight determination. In Section 3, we give the concrete procedures about BWM for intuitionistic relations. In Section 4, we examine a real example, which also belongs to an ongoing project led by the relevant department of Tianjin. The paper concludes in Section 5 with a summary of the advantages and drawbacks of our developments and suggesting some further research for the future.

2. Discussion on Criteria Weight

Saaty and Vargas gave the concept of interval-valued multiplicative relation in 1987, as follows:

Definition 1. *An Interval Valued Multiplicative Relation (IVMR) U on a non-empty finite set $X = \{x_1, x_2, ..., x_n\}$ is defined as $U = (u_{ij})_{n\times n}$, where $u_{ij} = [u_{ij}^-, u_{ij}^+]$ is named the interval valued fuzzy number and satisfies $0 \le u_{ij}^- \le u_{ij}^+$, $u_{ij}^- = 1/u_{ji}^+$, $u_{ij}^+ = 1/u_{ji}^-$, and u_{ij} indicates that x_i is between u_{ij}^- and u_{ij}^+ times as important as x_j [26].*

Xia et al. proposed that we can write the interval valued fuzzy number $u_{ij} = [u_{ij}^-, u_{ij}^+]$ in another way: $\alpha_{ij} = (\rho_{\alpha_{ij}}, \sigma_{\alpha_{ij}}) = (u_{ij}^-, 1/u_{ij}^+)$. This introduced the definition of intuitionistic multiplicative preference relations.

Definition 2. *Let $X = \{x_1, x_2, ..., x_n\}$ be a non-empty finite set with n elements. Then, the Intuitionistic Multiplicative Preference Relation (IMPR) is defined as $A = (\alpha_{ij})_{n\times n}$, where $\alpha_{ij} = (\rho_{\alpha_{ij}}, \sigma_{\alpha_{ij}})$ is named an Intuitionistic Multiplicative Number (IMN) for all $i, j \in \{1, 2, ..., n\}$; ρ_{ij} indicates the intensity to which x_i is preferred to x_j; σ_{ij} indicates the intensity to which x_i is not preferred to x_j; both should satisfy the following conditions: $\rho_{ij} = \sigma_{ji}$, $\rho_{ji} = \sigma_{ij}$, $\rho_{ii} = \sigma_{ii} = 1$, $0 \le \rho_{ij}\sigma_{ij} \le 1$, $1/9 \le \rho_{ij}, \sigma_{ij} \le 9$ [45].*

In addition, let $\tau_{ij} = 1/(\rho_{ij}\sigma_{ij})$, i.e., $\tau_{ij}\rho_{ij}\sigma_{ij} = 1$. Here, τ_{ij} represents the hesitation degree to which x_i is preferred to x_j, satisfying $\tau_{ij} \in [1, 81]$.

Obviously, Definition 2 developed the Definition 1 in the aspect of considering the hesitance, making the decision results closer to the practical problems.

Definition 3. *Let $X = \{x_1, x_2, ..., x_n\}$ be a non-empty finite set with n elements. Its associated multiplicative reciprocal preference relation $X = (x_{ij})$ with $x_{ij} \in [1/9, 9]$ and $x_{ij} \cdot x_{ji} = 1$, $\forall i, j \in \{1, 2, ..., n\}$ [46]. The corresponding fuzzy reciprocal preference relation associated with X is given as follows:*

$$p_{ij} = f(x_{ij}) = \frac{1}{2}(1 + \log_9 x_{ij}) \tag{2}$$

where $p_{ij} \in [0, 1]$ and $p_{ij} + p_{ji} = 1$, $\forall i, j \in \{1, 2, ..., n\}$.

Depending on Definitions 2 and 3, we give the next definition:

Definition 4. *Let $A = (a_{ij})_{n \times n}$ be the IMPR, where $a_{ij} = (\rho_{a_{ij}}, \sigma_{a_{ij}})$. Then, its Corresponding Interval Fuzzy Preference Relation (CIFPR) matrix is $P = (p_{ij})_{n \times n}$, where p_{ij} is given as follows:*

$$p_{ij} = [\frac{1 + \log_9 \rho_{a_{ij}}}{2}, \frac{1 + \log_9 (1/\sigma_{a_{ij}})}{2}] = [\frac{1 + \log_9 \rho_{a_{ij}}}{2}, \frac{1 - \log_9 \sigma_{a_{ij}}}{2}] = [p_{ij}^-, p_{ij}^+] \tag{3}$$

where $0 \le p_{ij}^- \le p_{ij}^+ \le 1$, $p_{ij}^- \le p_{ij}^+$, $0 \le p_{ij}^- + p_{ij}^+ \le 1$.

Definition 5. *Let $A = (a_{ij})_{n \times n}$ be the IMPR, where $a_{ij} = (\rho_{a_{ij}}, \sigma_{a_{ij}})$, and its CIFPR be $P = (p_{ij})_{n \times n}$, where $P = [p_{ij}^-, p_{ij}^+]$. Then, its fuzzy-based geometric index matrix $G^f = (f_{a_{ij}})_{n \times n}$ is defined as:*

$$G^f = (f_{a_{ij}})_{n \times n} = \frac{\sqrt{p_{ij}^- p_{ij}^+}}{\sqrt{p_{ij}^- p_{ij}^+} + \sqrt{(1 - p_{ij}^-)(1 - p_{ij}^+)}} \tag{4}$$

i.e., $G^f = \frac{\sqrt{(1 + \log_9 \rho_{a_{ij}})(1 - \log_9 \sigma_{a_{ij}})}}{\sqrt{(1 + \log_9 \rho_{a_{ij}})(1 - \log_9 \sigma_{a_{ij}})} + \sqrt{(1 - \log_9 \rho_{a_{ij}})(1 + \log_9 \sigma_{a_{ij}})}}$.

In addition, we define:

$$G_c^f = (f_{a_{ij}^c})_{n \times n} = \frac{\sqrt{(1 + \log_9 \sigma_{a_{ij}})(1 - \log_9 \rho_{a_{ij}})}}{\sqrt{(1 + \log_9 \sigma_{a_{ij}})(1 - \log_9 \rho_{a_{ij}})} + \sqrt{(1 - \log_9 \sigma_{a_{ij}})(1 + \log_9 \rho_{a_{ij}})}} \tag{5}$$

where $a_{ij}^c = (\sigma_{a_{ij}}, \rho_{a_{ij}})$

Deriving from Definition 5, we obtain the following propositions about fuzzy-based geometric index.

(1) $f_{a_{ij}} + f_{a_{ij}^c} = 1$.
(2) It is obvious that, $G_a^f > 0$; $f_{a_{ij}} = \frac{1}{2}$, if $\rho_{a_{ij}} = \sigma_{a_{ij}}$; $f_{a_{ij}} > \frac{1}{2}$, if $\rho_{a_{ij}} > \sigma_{a_{ij}}$; $f_{a_{ij}} < \frac{1}{2}$, if $\rho_{a_{ij}} < \sigma_{a_{ij}}$; G^f indicates which kind of preference relation of x_i over x_j is dominant, the preferred degree or the non-preferred degree.
(3) Let $a^1 = (\rho_{a^1}, \sigma_{a^1})$ and $a^2 = (\rho_{a^2}, \sigma_{a^2})$ be two IMNs. If $\rho_{a^1} \ge \rho_{a^2}$ and $\sigma_{a^1} \le \sigma_{a^2}$, then $f_{a^1} \ge f_{a^2}$.

Definition 6. *A CIFPR $P = (p_{ij})_{n \times n}$ with respect to an IMPR $A = (a_{ij})_{n \times n}$ is called geometry consistent, if it satisfies the next equation:*

$$g_{a_{ij}}^m = g_{a_{ik}}^m g_{a_{kj}}^m \tag{6}$$

i.e.,

$$\sqrt{\frac{p_{ij}^{-}p_{ij}^{+}}{(1-p_{ij}^{-})(1-p_{ij}^{+})}}=\sqrt{\frac{p_{ik}^{-}p_{ik}^{+}}{(1-p_{ik}^{-})(1-p_{ik}^{+})}}\sqrt{\frac{p_{kj}^{-}p_{kj}^{+}}{(1-p_{kj}^{-})(1-p_{kj}^{+})}} \tag{7}$$

where $g_{a_{ij}}^{m}$, $g_{a_{ik}}^{m}$, $g_{a_{kj}}^{m}$ are the multiplicative-based geometric indexes.

Definition 7. *For a fuzzy preference relation $P=(p_{ij})_{n\times n}$, where p_{ij} denotes the preference value for alternative x_i over x_j, $p_{ij}+p_{ji}=1$, $p_{ii}=0.5$ [47], its according geometry consistency matrix $\overline{P}=(\overline{p}_{ij})_{n\times n}$ satisfies:*

$$\overline{p_{ij}}=\frac{1}{n}\Sigma_{j=1}^{n}(\overline{p_{ik}}+\overline{p_{kj}})-0.5. \tag{8}$$

Jiang et al. [44] proposed the method that decomposed an intuitionistic multiplicative preference number $U=(\alpha_{ij})_{n\times n}=(\rho_{ij},\sigma_{ij})$ into two matrices: a preferred matrix $C=(c_{ij})_{n\times n}$ describing the positive information and a non-preferred matrix $D=(d_{ij})_{n\times n}$ describing the negative information given by DM with respect to alternative x_i over x_j [44]. Then, we develop the next definition to calculate the missing elements of an incomplete IMP's corresponding interval fuzzy preference relation matrix $P=(p_{ij})_{n\times n}$ by calculating the missing elements of $P^{-}=(c_{ij})_{n\times n}$ and $P^{+}=(d_{ij})_{n\times n}$, respectively.

Definition 8. *For an incomplete intuitionistic multiplicative preference relations $U=(\alpha_{ij})_{n\times n}=(\rho_{ij},\sigma_{ij})_{n\times n}$, i.e., some elements are unknown, let $P=(p_{ij}^{-},p_{ij}^{+})_{n\times n}$ be its corresponding fuzzy relation. We separate the matrix P into two parts, denoted by decomposing the matrix. One part is $P^{-}=(\gamma_{ij})_{n\times n}$, where $\gamma_{ij}=p_{ij}^{+}$, if $i<j$; $\gamma_{ij}=0.5$, if $i=j$; $\gamma_{ij}=p_{ij}^{-}$, if $i>j$; the other part is $P^{+}=(p_{ij}^{-})_{n\times n}$, where $\gamma_{ij}=p_{ij}^{-}$, if $i<j$; $\gamma_{ij}=0.5$, if $i=j$; $\gamma_{ij}=p_{ij}^{+}$, if $i>j$,*

From Equation (7), we rewrite it in the following way:

$$\sqrt{p_{ij}^{-}p_{ij}^{+}}\sqrt{(1-p_{ik}^{-})(1-p_{ik}^{+})}\sqrt{(1-p_{kj}^{-})(1-p_{kj}^{+})}=\sqrt{(1-p_{ij}^{-})(1-p_{ij}^{+})}\sqrt{p_{ik}^{-}p_{ik}^{+}}\sqrt{p_{kj}^{-}p_{kj}^{+}} \tag{9}$$

Based on Equation (9), we introduce the consistency degree CD of CIFPR $P=(p_{ij})_{n\times n}$:

$$CD_t=\Sigma_{i,j=1}^{n}=\mid\zeta-\eta\mid \tag{10}$$

for expert e_t, $t\in\{1,2,...,m\}$, where $\zeta=\sqrt{p_{ij}^{-}p_{ij}^{+}}\sqrt{(1-p_{ik}^{-})(1-p_{ik}^{+})}\sqrt{(1-p_{kj}^{-})(1-p_{kj}^{+})}$, $\eta=\sqrt{(1-p_{ij}^{-})(1-p_{ij}^{+})}\sqrt{p_{ik}^{-}p_{ik}^{+}}\sqrt{p_{kj}^{-}p_{kj}^{+}}$ and $i\leq j,i,j,k\in\{1,2,...,n\}$.

In addition, we can get the weight values for expert e_t with respect to the consistency degree by:

$$w_t=\frac{1/S_t}{\sum_{t=1}^{m}S_t}. \tag{11}$$

where $S_t=CD_t/min\{CD_t|t=1,...,m\}$

Apply Equation (4) to get $G_t^f=(f_{\alpha_{ij}})_{n\times n}$ to calculate the the score value $RS_l^t=(\sum_{j=1}^{n}f_{\alpha_{ij}})_{n\times 1}$. Then, we can obtain the weight value of criteria c_l:

$$w_{c_l}=\frac{RS_i}{\sum_{i=1}^{n}RS_i} \tag{12}$$

where $RS_i=(\sum_{t=1}^{m}w_tRS_i^t)$.

Example 1. *This example is chosen from Jiang et al. [44], which is calculated by the method proposed by Y. Jiang et al. in detail. In this example, there are five alternatives $x_i(i=1,2,3,4,5)$ to choose from and a decision group with three decision makers e_t, $t=1,2,3$, whose weight vector is equal $w=(1/3,1/3,1/3)^T$.*

Decision makers compare each pair of alternatives and give judgments, expressed as the incomplete IMPRs U^t $(t = 1,2,3)$, shown as follows, where the missing elements have been marked differently.

$$U_1 = \begin{bmatrix} (1,1) & (5/3,1/4) & (\rho^*_{13},1/9) & (3,1/7) & (1/2,\sigma^*_{15}) \\ (1/4,5/3) & (1,1) & (\rho^*_{23},\sigma^*_{23}) & (3/5,1) & (1/4,3) \\ (1/9,\rho^*_{13}) & (\sigma^*_{23},\rho^*_{23}) & (1,1) & (\rho^*_{34},5/3) & (1/9,7) \\ (1/7,3) & (1,3/5) & (5/3,\rho^*_{34}) & (1,1) & (1/7,3) \\ (\sigma^*_{15},1/2) & (3,1/4) & (7,1/9) & (3,1/7) & (1,1) \end{bmatrix} \quad (13)$$

$$U_2 = \begin{bmatrix} (1,1) & (3,1/6) & (3,1/7) & (2,1/5) & (\rho^*_{15},1/2) \\ (1/6,3) & (1,1) & (2/3,1/2) & (\rho^*_{24},1) & (1/3,2) \\ (1/7,3) & (1/2,2/3) & (1,1) & (2/3,3/5) & (1/8,8/3) \\ (1/5,\rho^*_{24}) & (1,\rho^*_{24}) & (3/5,2/3) & (1,1) & (1/4,\sigma^*_{45}) \\ (1/2,\rho^*_{15}) & (2,1/3) & (8/3,1/8) & (\sigma^*_{45},1/4) & (1,1) \end{bmatrix} \quad (14)$$

$$U_3 = \begin{bmatrix} (1,1) & (\rho^*_{12},1/2) & (4,1/8) & (5,1/6) & (1/2,5/8) \\ (1/2,\rho^*_{12}) & (1,1) & (1,1/9) & (3/5,1) & (1/3,1) \\ (1/8,4) & (1/9,1) & (1,1) & (1/3,1/3) & (\rho^*_{35},\sigma^*_{35}) \\ (1/6,5) & (1,1/3) & (1/3,1/3) & (1,1) & (1/6,2) \\ (5/8,1/2) & (2/3,3/4) & (\sigma^*_{35},\rho^*_{35}) & (2,1/6) & (1,1) \end{bmatrix} \quad (15)$$

Firstly, calculate the unknown elements of the decision results of the matrices A_1, A_2 and A_3. By Definition 4, obtain the corresponding fuzzy matrices. By Definition 8, decomposethe corresponding fuzzy matrices into two parts. By Definition 7, calculate the missing elements of A_1: $\sigma^*_{15} = 0.6289$, $\sigma^*_{23} = 0.4854$, $\rho^*_{13} = 4.4977$, $\rho^*_{23} = 2.2496$, $\rho^*_{34} = 0.7777$; the missing elements of A_2: $\sigma^*_{15} = 2.8110$, $\rho^*_{13} = 0.4543$, $\rho^*_{24} = 0.7340$; the missing elements of A_3: $\sigma^*_{35} = 2.7139$, $\rho^*_{12} = 3.3753$, $\rho^*_{35} = 0.1734$. Secondly, calculate the consistency degree of each DM's decision matrix by applying Equation (9) and obtaining: $CD_1 = 0.1786$, $CD_2 = 0.0550$, $CD_3 = 0.0389$. By Equation (11), we obtain the weight values for every expert: $w_1 = 0.4824$, $w_2 = 0.3034$, $w_3 = 0.2142$. Finally, apply Equation (12) to the weight vector of the criteria $(3.5340, 2.1758, 1.3782, 1.9237, 3.4884)'$, and then, the ranking result is $x_1 > x_5 > x_2 > x_4 > x_3$.

The final results calculated by Jiang et al. [44] is: $S(\alpha'_1) = 6.0127$, $S(\alpha'_2) = 0.5342$, $S(\alpha'_3) = 0.2766$, $S(\alpha'_4) = 0.4939$, $S(\alpha'_5) = 6.0250$, with a ranking $x_5 > x_1 > x_2 > x_4 > x_3$. Obviously, there exists a difference about the ranking position about alternatives x_1 and x_5, while their final scare values are really close to each other. Y. Jiang et al. focused on calculating missing values and ignored the consistency degree's influence. Our paper uses a simple way to calculate the unknown elements and takes the decision matrices' consistency degree into consideration, with simpler calculating processes and a reasonable conclusion.

3. A Non-Linear BWM for an Intuitionistic Relation

In order to cope with the overseas talent evaluating problem, we will introduce intuitionistic preference relations to express decision results. Additionally, a non-linear BWM model is constructed to rank alternatives

3.1. BWM for Intuitionistic Relations

Definition 9. *Let $X = \{x_1, x_2, ..., x_n\}$ be a non-empty finite set with n alternatives and $C = \{c_1, c_2, ..., c_m\}$ be a set with m criteria. Determine the best element x_B and the worst element x_W with respect to a certain criterion. Denote the comparison value x_B over x_j by x_{Bj}, $\forall x_j \in X$, in the form of an intuitionistic multiplicative number (IMN), composing a set $S_B = \{x_{B1}, ..., x_{Bn}\}$ and elements in it called best-grade comparisons. Denote the comparison value x_i over x_W by x_{iW}, $\forall x_i \in X$, in the from of an IMN, composing a set $S_W = \{x_{1W}, ..., x_{nW}\}$, and elements in it are called the worst-grade comparisons. Moreover, the elements of S_B and S_W, $x_{ij} = (\alpha_{x_{ij}}, \beta_{x_{ij}})$,* *where $\alpha_{x_{ij}}$ is the preferred degree that x_i over x_j expressed by one integer between one and nine, and β_{ij} is the non-preferred degree that x_i over x_j, expressed by one number among $\{1, 1/2, ..., 1/9\}$, satisfying the conditions that, $\alpha_{x_{ij}} = \beta_{x_{ji}}$, $\beta_{x_{ij}} = \alpha_{x_{ji}}$ and $\alpha_{x_{ij}}\beta_{x_{ji}} \leq 1$, which indicates that the hesitant degree is under consideration.*

Definition 10. *For any three comparisons x_{ij}, x_{ik} and x_{kj} of a comparison set S, if it satisfies the following equation [36]:*

$$x_{ij} = x_{ik}x_{kj} \tag{16}$$

i.e.,

$$(\alpha_{x_{ij}}, \beta_{x_{ij}}) = (\alpha_{x_{ik}}, \beta_{x_{ik}})(\alpha_{x_{kj}}, \beta_{x_{kj}}) = (\alpha_{x_{ik}}\alpha_{x_{kj}}, \beta_{x_{ik}}\beta_{x_{kj}}) \tag{17}$$

we consider that the comparison set S based on X is consistent.

In order to discuss the consistence degree of the comparison result of Definition 9, introduce the following definition:

Definition 11. *For a set $X = \{x_1, ..., x_n\}$ with n elements, each element x_i has a weight value w_i satisfying $\sum_{i=1}^{n} w_i = 1$ and $w_i \geq 0$ for all i, where w_i stands for the importance degree of x_i in X. If the comparison value expressed by an IMN $x_{ij} = (\alpha_{x_{ij}}, \beta_{x_{ij}})$, satisfies $\alpha_{x_{ij}} = \frac{w_i}{w_j}$ and the non-preferred degree x_i over x_j satisfies $\beta_{x_{ij}} = \frac{w_j}{w_i}$, for all $i, j = 1, ..., n$, then it means that this comparison $x_{ij} = (\alpha_{x_{ij}}, \beta_{x_{ij}})$ is a standard comparison.*

For a decision maker, it is easy to determine the best talent or the worst alternative under certain criteria. Additionally, choosing which is the better one between two alternatives is also not difficult. The trouble we usually fall into is the question to which degree one alternative is superior to another. In the next phase, we will study this question with a non-linear BWM model under intuitionistic preference relations. Let x_i and x_j be any two comparable alternatives of set X. First of all, just as the original BWM [38], the DM picks up the best one x_B and the worst one x_W under a criterion. According to Definition 9, the DM gives the preferred degree x_B over x_i expressed by $x_{Bi} = (\alpha_{x_{Bi}}, \beta_{x_{Bi}})$, and the preferred degree x_i over x_W, expressed by $x_{iW} = (\alpha_{x_{iW}}, \beta_{x_{iW}})$. According to Definition 11, the standard condition: $\alpha_{x_{Bi}} = \frac{w_B}{w_i}$, $\beta_{x_{Bi}} = \frac{w_i}{w_B}$, $\alpha_{x_{iW}} = \frac{w_i}{w_W}$, $\beta_{x_{iW}} = \frac{w_W}{w_i}$. As DMs are all reasonable people, the equation is likely, $x_{Bi} = \frac{x_{BW}}{x_{iW}}$, i.e., $x_{Bi}x_{iW} = x_{BW}$ may not always exist. By Definition 10, this condition is also called consistent. Next, we will discuss the worst case about this condition: $x_{Bi}x_{iW} \neq x_{BW}$. By Definition 10, $(w_B/w_j)(w_j/w_W) = w_B/w_W$, considering the worst consistency condition exists when $\alpha_{x_{Bj}} = \alpha_{x_{jW}} = \alpha_{x_{BW}} = 9$, $\beta_{x_{Bj}} = \beta_{x_{jW}} = \beta_{x_{BW}} = 1/9$; then, we get two deviations ξ, η and obtain the following equations. The original equations are:

$$(\alpha_{x_{Bj}} - \xi)(\alpha_{x_{jW}} - \xi) = \alpha_{x_{BW}} + \xi \tag{18}$$

$$(\beta_{x_{Bj}} - \eta)(\beta_{x_{jW}} - \eta) = \beta_{x_{BW}} + \eta \tag{19}$$

The equations that have the worst consistency degree are:

$$(\alpha_{x_{BW}} - \xi)(\alpha_{x_{BW}} - \xi) = \alpha_{x_{BW}} + \xi \tag{20}$$

$$(\beta_{x_{BW}} - \eta)(\beta_{x_{BW}} - \eta) = \beta_{x_{BW}} + \eta \tag{21}$$

Rewrite Equations (20) and (21) in the following way:

$$\xi^2 - (2x+1)\xi + (x^2 - x) = 0 \tag{22}$$

$$\eta^2 - (2y+1)\eta + (y^2 - y) = 0 \tag{23}$$

where $x = \alpha_{x_{BW}}$, $y = \beta_{x_{BW}}$.

By entering all of the possible values of $x \in \{1, 2, ..., 9\}$ and $y \in \{1, 1/2, ..., 1/9\}$, we calculate and summarize in Tables 1 and 2, where Table 1 is a little different from the one appearing in [38].

Table 1. The maximum value of ξ about x.

$\alpha_{x_{BW}}$	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
ξ	0	0.4384	1.0000	1.6277	2.2984	3.0000	3.7251	4.4689	5.2280

Table 2. The maximum value of ξ about y.

$\beta_{x_{BW}}$	**1**	**1/2**	**1/3**	**1/4**	**1/5**	**1/6**	**1/7**	**1/8**	**1/9**
η	0	2.1180	1.7908	1.6160	1.5062	1.4304	1.3747	1.3321	1.2519

Here, we denote max ξ by the α consistency index (α-CI) ξ^* and max η by the β consistency index (β-CI) η^*. In addition, the consistent ratios value are $CR_\alpha = \frac{\xi^*}{CI}$, where the value of CI depends on the value of $\alpha_{x_{BW}}$, and $CR_\beta = \frac{\eta^*}{CI}$, where the value of CI depends on the value of $\beta_{x_{BW}}$.

3.2. Model Construction

In this section, we introduce the optimization model of BWM for intuitionistic preference relations. First of all, the decision maker should make sure the criteria set $C = \{C_1, C_2, ..., C_n\}$, with respect to an alternative set $X = \{x_1, x_2, ..., x_n\}$, which will be identified to give the pairwise comparisons. Additionally, just choose the best element x_B and the worst element x_W. Then, decision makers enter the comparison results about x_B to others and the remaining ones to x_W, satisfying the roles of Definition 9. Following that, comparison sets S_B and S_W are obtained. Since the deviation results derive from two aspects, the preferred degree and the non-preferred degree, we should consider the following problem:

$$min\{|\frac{w_B}{w_k} - \alpha_{x_{Bk}}|, |\frac{w_k}{w_W} - \alpha_{x_{kW}}|\}; min\{|\frac{w_k}{w_B} - \beta_{x_{Bk}}|, |\frac{w_W}{w_k} - \beta_{x_{kW}}|\} \tag{24}$$

where $w_k \geq 0, \sum w_k = 1, k = 1, 2, ..., n$.

We can deal with the problem by solving the next systems:

$min\ \xi$ s.t.:

$$\begin{cases} |\frac{w_B}{w_k} - \alpha_{x_{Bk}}| \leq \xi, \\ |\frac{w_k}{w_W} - \alpha_{x_{kW}}| \leq \xi, \\ w_k \geq 0, \\ \sum w_k = 1. \end{cases} \tag{25}$$

where $k = 1, 2, ..., n$.

$min\ \eta$ s.t.:

$$\begin{cases} |\frac{w_k}{w_B} - \beta_{x_{Bk}}| \leq \eta, \\ |\frac{w_W}{w_k} - \beta_{x_{kW}}| \leq \eta, \\ w_k \geq 0, \\ \sum w_k = 1. \end{cases} \tag{26}$$

where $k = 1, 2, ..., n$. Next, we will give an example to show how this model works.

Example 2. *This a simple example, and we use it to show the above method with numbers. Here are three alternatives and four criteria. The expert compares every alternative under each criterion, depending on Definition 9. The comparison results are shown in Table 3, where* $C_w = \sum_{i=1}^4 w_i C_i$, $w_1 = 0.4$, $w_2 = 0.3$, $w_3 = 0.2$, $w_4 = 0.1$, *which are predefined by the special decision makers according to the relative department's order.*

Table 3. The comparison results of every alternative under each criterion by the expert.

	C_1	C_2	C_3	C_4
(x_{B1},x_{1W})	$((9,\frac{1}{9}),(1,1))$	$((8,\frac{1}{8}),(1,1))$	$((6,\frac{1}{7}),(1,1))$	$((7,\frac{1}{8}),(1,1))$
(x_{B2},x_{2W})	$((3,\frac{1}{4}),(4,\frac{1}{5}))$	$((3,\frac{1}{4}),(5,\frac{1}{5}))$	$((2,\frac{1}{3}),(4,\frac{1}{5}))$	$((3,\frac{1}{5}),(4,\frac{1}{4}))$
(x_{B3},x_{3W})	$((1,1),(9,\frac{1}{9}))$	$((1,1),(8,\frac{1}{8}))$	$((1,1),(6,\frac{1}{7}))$	$((1,1),(7,\frac{1}{8}))$

Apply the novel method by utilizing Equations (25) and (26) obtaining Equations (27) and (28):
$min\ \xi$, s.t.:

$$\begin{cases} |\frac{w_3}{w_1}-9| \le \xi_\alpha, \\ |\frac{w_2}{w_1}-4| \le \xi_\alpha, \\ |\frac{w_3}{w_2}-3| \le \xi_\alpha, \\ w_1+w_2+w_3=1, \\ w_1,w_2,w_3 \ge 0. \end{cases} \tag{27}$$

$min\ \eta$, s.t.:

$$\begin{cases} |\frac{w_1}{w_3}-1/9| \le \xi_\beta, \\ |\frac{w_2}{w_3}-1/5| \le \xi_\beta, \\ |\frac{w_1}{w_2}-1/5| \le \xi_\beta, \\ w_1+w_2+w_3=1, \\ w_1,w_2,w_3 \ge 0. \end{cases} \tag{28}$$

We can calculate the weights of all three alternatives with Equations (27) and (28). In addition, we can get the weights under the other criteria in the same way, and we summarize them in Table 4, where $(w_1^\alpha,w_2^\alpha,w_3^\alpha)$ are the weights of alternatives x_1,x_2,x_3 with the positive aspect and $(w_1^\beta,w_2^\beta,w_3^\beta)$ are the weights of talent x_1,x_2,x_3 with the negative aspect. The calculated weights are not the same as each other; however, the rankings are the same. It is easy to see that $CR(\alpha)=\frac{\xi^*}{CI(8)}=0.192$ and $CR(\beta)=\frac{\eta^*}{CI(1/7)}=0.036$. We can either rank the three alternatives based on the combination of the positive and negative aspect or only consider one aspect. The proposed non-linear model has a close connection with the original BWM, because of Definition 4. Transformation formula Equation (3) can change the number field of BWM into $[0,1]$, in the form of a fuzzy number. Equation (3) changes the intuitionistic multiplicative number into an intuitionistic fuzzy number, in the form of $[a,b] \subseteq [0,1]$. We can choose the average of $[a,b]$, so the two models are transformed into the same number field. This transformation formula guarantees that our model will not violate the basic assumptions of the BWM.

Table 4. The calculated comparison results of every alternative under each criterion by the expert.

	$(C_1(\alpha),C_1(\beta))$	$(C_2(\alpha),C_2(\beta))$	$(C_3(\alpha),C_3(\beta))$	$(C_4(\alpha),C_4(\beta))$	$(C_w(\alpha),C_w(\beta))$
x_1	(0.071,0.051)	(0.071,0.055)	(0.091,0.064)	(0.084,0.057)	(0.076,0.055)
x_2	(0.258,0.214)	(0.295,0.218)	(0.336,0.259)	(0.276,0.189)	(0.287,0.222)
x_3	(0.671,0.735)	(0.633,0.727)	(0.573,0.677)	(0.640,0.754)	(0.637,0.723)
$\xi^*(C_i)$	0.394	0.860	0.298	0.683	-
$\eta^*(C_i)$	0.041	0.050	0.048	0.050	-

3.3. Some Properties about the Non-Linear BWM for Intuitionistic Relations

1. Violation Degree (VD):

$$VD = \frac{Vd}{2(2n-3)m} \tag{29}$$

where $Vd = \sum_{i=1}^{n}\sum_{j=1}^{n} V_{ij}$ and m is the number of all criteria.

V_{ij} describes the degree of some unreasonable conditions defined in the following:

$$V_{ij} = \begin{cases} 1 & w_i > w_j, \alpha_{ij} < 1, \beta_{ij} > 1 \\ 1 & w_i = w_j, \alpha_{ij} \neq \beta_{ij}, \alpha_{ij} \neq 1, \beta_{ij} \neq 1 \\ 1 & w_i \neq w_j, \alpha_{ij} = \beta_{ij} = 1 \\ 0.5 & w_i > w_j, \alpha_{ij} > 1, \beta_{ij} > 1 \\ 0.5 & w_i > w_j, \alpha_{ij} < 1, \beta_{ij} < 1 \\ 0.5 & w_i = w_j, \alpha_{ij} = \beta_{ij} \neq 1 \\ 0.5 & w_i = w_j, \alpha_{ij} \neq \beta_{ij}, \alpha_{ij} = 1 \, or \, \beta_{ij} = 1 \\ 0.5 & w_i \neq w_j, \alpha_{ij} = 1 \, or \, \beta_{ij} = 1 \\ 0 & otherwise \end{cases} \tag{30}$$

In Example 2, for all cases $VD = 0$, it shows that the calculated weights are good enough under this standard.

2. Deviation degree (DD):

We also calculate the total value of Euclidean distance between w_i/w_j and x_{ij}, by $DD = \frac{Dd}{(2(2n-3))^2 m}$ where:

$$Dd = \sum_{i=1}^{n} D_i = \sum_{i=1}^{n} [(\frac{w_B}{w_i} - \alpha_{Bi})^2 + (\frac{w_i}{w_B} - \beta_{iB})^2 + (\frac{w_i}{w_W} - \alpha_{iW})^2 + (\frac{w_W}{w_i})^2 - \beta_{Wi}] \tag{31}$$

$i = 1, 2, ..., n$ and m is the number of criteria.

The value of DD of Example 2 is $DD = \frac{20.992}{2(2\times3-3)^2\times1)} = 0.292$.

During the group decision making process, we can obtain the violation degree and deviation degree of each decision maker. The higher the values of VD and DD, the better the decision results from the decision maker. Depending on the values, we may consider the decision maker weights further or omit some decision makers' comparisons for their highest values of VD and DD.

4. The Illustrative Study

Tianjin, an economic center in the northern part of China, has constantly focused on the introduction of overseas talents. The relevant government agencies of the city have implemented some policies with regard to problems with respect to the introduction of overseas talents, such as how to evaluate and classify them based on the assessments and how to fairly offer them equitable treatment, which has become the main bottle neck. One important problem is improving assessment systems, including evaluation and classification. Here, we mainly discuss the evaluation part. Test samples are drawn out from the overseas talents who participated in the selection of the Tian Jin Haihe Friendship Award in 2015. To ensure the objectivity of the evaluation process, we omit specific information, such as the names of decision makers and overseas talents. We chose 20 overseas talents who came to the city for working or cooperating via the introduction by the government. With the purpose of making general statements for the 20 overseas talents, we list five criteria to evaluate them. The government assigned a group of three experts to evaluate the alternatives with each criterion.

We evaluated candidates from different aspects, considering some necessary qualities. In the early days, Harvard professor McClelland [48] proposed the concept of competency. He expounded on the relationship between individual and position from the quality and ability aspects. Spreitzer et al. [49] developed the prospector as an evaluation tool, which evaluated the managers' potential to lead national and international enterprises. He researched managers from 21 countries and belonging to six major industries, who came to work in the United States, as multinational professional managers. The results of this research demonstrated the effectiveness of the prospector. Subsequently, more systematic talent evaluation problems were considered by researchers, including some Chinese scholars who did research mostly in the Chinese situation. Luo [50] considered that good internal ability and continuous creative ability were key points for the definition of talent. In addition, the creative achievements obtained by the talents should have a positive impact on the progress of society. Yan and Chen [51] conducted research based on case analysis and came to the conclusion that the marketer's assessment was largely from three aspects, consisting of personality, knowledge and ability. Recently, Xu et al. [52] studied the talent evaluation index in regards to the high-level talents' introduction in DongHu High-tech Zone. They constructed a high-level personnel evaluation index system containing four indexes, consisting of performance, ability, contribution and potential.

In this study, the criteria are sourced from Xu's evaluation system [52], which was used to evaluate high-level talents in China. In addition, we collect advice from a sample of 15 experts, who are good at talent evaluation, in order to extract factors of overseas talents' assessment. This group includes university professors, headhunting company managers, company executives and government review experts. We first explained the problem to these experts, and then, they were given some documents describing the criteria for evaluating overseas talents and a comprehensive list of the characteristics of overseas talents. Finally, after the interviews, we analyzed the information and created the index system of overseas talents' evaluation, which contains basic quality, capacity, contribution, development potential and internationalization, as shown in Table 5.

It is important to notice that internationalization is a key-influencing factor for overseas talents [53]. On the one hand, global perspective refers to international experience and cognition of the world technology market [54]. Someone who has a global perspective may gain an insight into development opportunities, which may come from the differences between countries, such as the business opportunities that come from the technology and application differences between different countries, as well as differences in market demand and supply. On the other hand, overseas talents need to have good cross-cultural adaptability, which can help them to easily tackle the obstacles of cultural differences. Cross-cultural adaptability is a capability that appropriately deals with interactions among people from different countries and cultures [55]. Specifically, overseas talents with good cultural adaptability can identify similarities and differences between the new culture and their own culture and can actively coordinate the cultural conflicts, so that they can integrate into the new culture.

Table 5. Criteria to evaluate overseas talents and their descriptions.

Criteria	Description
Basic quality	Age, physical condition, psychological health status and credit standing.
Capacity	The benefits created for the organization, optimization of industry output and promotion of the industrial and social development.
Contributions	The benefits created for the organization, optimization of industry output and promotion of the industrial and social development.
Development potential	Innovations and innovation ability, enterprise, ability to solve difficulties and resist setback.
Internationalization	Global perspective and cross-cultural adaptability.

After constructing the criteria system, in order to evaluate and classify the chosen 20 overseas talents, we follow the subsequent decision making procedures, depending on the definitions and models from Sections 2 and 3.

Step 1: From Definition 2, decision maker e_t, $t \in \{1,2,3,\}$, gives his/her decision matrix about criteria c_1, $l \in \{1,2,3,4,5\}$ (standing for basic quality, capacity, contribution, development potential and internationalization, respectively).

$$DM_1 = \begin{bmatrix} (1,1) & (1/8,8) & (1/2,1) & (1/3,2) & (1/6,5) \\ (8,1/8) & (1,1) & (8,1/9) & (7,1/9) & (8,1/9) \\ (1,1/2) & (1/9,8) & (1,1) & (1/2,2) & (2,1/3) \\ (2,1/3) & (1/9,7) & (2,1/2) & (1,1) & (2,1/4) \\ (5,1/6) & (1/9,8) & (1/3,2) & (1/4,2) & (1,1) \end{bmatrix} \tag{32}$$

$$DM_2 = \begin{bmatrix} (1,1) & (1/9,8) & (1,1/2) & (2,1/3) & (1,1/2) \\ (8,1/9) & (1,1) & (8,1/9) & (8,1/8) & (7,1/9) \\ (1/2,1) & (1/9,8) & (1,1) & (1/6,5) & (1/2,2) \\ (1/3,2) & (1/8,7) & (5,1/6) & (1,1) & (1/3,1) \\ (1/2,1) & (1/9,8) & (2,1/2) & (2,1/3) & (1,1) \end{bmatrix} \tag{33}$$

$$DM_3 = \begin{bmatrix} (1,1) & (1/9,8) & (1/4,3) & (1/3,2) & (1,1/2) \\ (8,1/9) & (1,1) & (8,1/9) & (8,1/8) & (8,1/9) \\ (3,1/4) & (1/9,8) & (1,1) & (1/2,2) & (2,1/3) \\ (2,1/3) & (1/8,8) & (2,1/3) & (1,1) & (2,1/3) \\ (1/2,1) & (1/9,8) & (1/3,2) & (1/3,2) & (1,1) \end{bmatrix} \tag{34}$$

Calculate the consistency degree of each expert's decision matrix, and then, by Equation (11), we obtain the weight values for every expert: $w_1 = 0.39$, $w_2 = 0.34$, $w_3 = 0.27$; by Equation (12) to the weight vector of the criteria $(0.14, 0.36, 0.15, 0.19, 0.16)'$.

Step 2: After the decision group enters data into the decision matrices, applying the same method with Example 2, we obtain the weighted ranking results, shown in Figures 1 and 2.

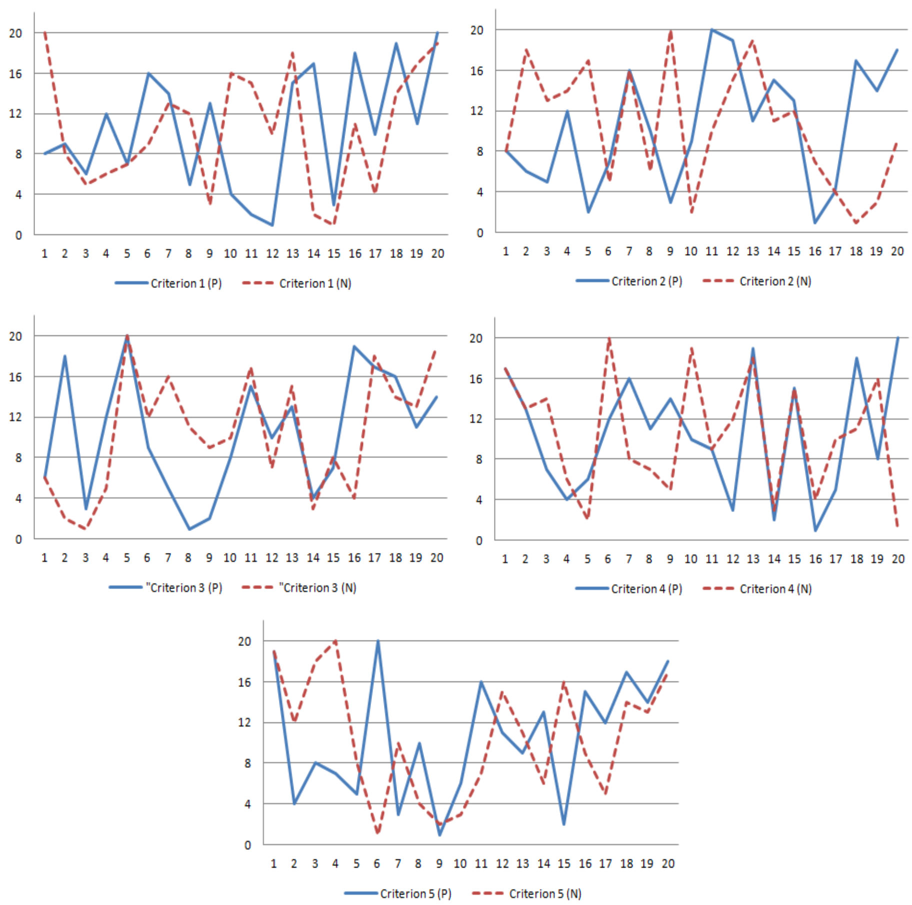

Figure 1. Ranking results of all alternatives by the experts under each criterion.

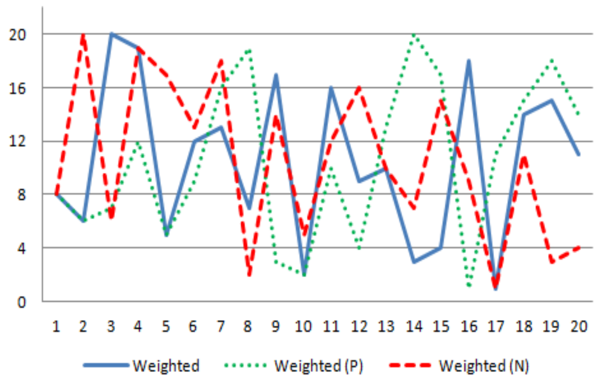

Figure 2. Comparison results of the weighted result by the experts.

Figure 1 shows the rankings of all of the alternatives given by DMs in two aspects: the positive one (indicated by a blue solid line) and the negative one (shown by a red dashed line). The weighted results calculated by the experts are summarized in Figure 2, where the abscissa stands for the ranking number of its alternative located on the ordinate. Each alternative's ranking number can be read from the figures. Overall, ranking results are different between the positive and negative aspects from all of the figures. This intuitive conclusion indicates that it is meaningful to introduce the intuitionistic preference relations. Figure 1 tells us that the best and worst alternatives with different criteria are different, illustrating that the criteria are recognizable for comparing the alternatives. This is useful for evaluating overseas talents from different aspects. More specifically, under Criterion 1 (basic quality), Alternative 8 is the best one in the positive aspect, and Alternative 20 is the worst one; Alternative 20 is the best one in the negative aspect, and Alternative 19 is the worst one. Taking the weights of the criteria and decision maker into consideration, we get the weights for all alternatives in the positive aspect, shown in the Figure 2 with a green dotted line; the weights for all alternatives in the negative aspect, shown in Figure 2 with a read dashed line; the 20 alternatives can be partitioned into three classes with respect to the average weight, shown in Figure 2 with a blue solid line: the first class contains alternatives x_8,x_6,x_{20},x_{19},x_5,x_{12}; the second class contains alternative x_{13},x_7,x_{17},x_2,x_{16},x_9,x_{10}; the third class contains alternative x_3,x_4,x_{18},x_1,x_{14},x_{15},x_{11}. For each class, the government would offer them different treatments. As a key management method, the category divides objects into several categories or various types, in order to achieve the target of more intensive and more efficient management. Therefore, based on the category results, the relevant department can distinguish between different levels of foreign talents and offer various management and services in terms of green card applications, entry and exit control, child education, personal income tax relief, and so on.

Table 6 shows us the consistency degree of each criterion by every DM, such as element (0.4121,0.0409) from Table 6 that stands for positive consistency, which is 0.4121, and the negative one is 0.0409, with respect to decision maker e_3, who has the smallest consistency value in two angles with criterion C_1. The consistency degree is a very important reference standard, for low consistency may bring about the wrong decisions. Besides, the violation degree and deviation degree are also considerable. From Equation (29) and Equation (30), for each expert e_t, $t = 1,2,3$, their violation degrees and deviation degrees can also be obtained as follows: $VD_1 = \frac{158}{2\times(2\times20-3)\times12} = 0.1779$, $VD_2 = \frac{187}{2\times(2\times20-3)\times12} = 0.2106$, $VD_3 = \frac{205}{2\times(2\times20-3)\times12} = 0.2309$; $DDe_1 = \frac{1995.86}{2(2\times20-3)^2\times12)} = 0.0607$, $DDe_2 = \frac{2123.45}{2(2\times20-3)^2\times12)} = 0.0646$, $DDe_3 = \frac{2364.18}{2(2\times20-3)^2\times12)} = 0.0720$. As reference standards, these calculations present the different deviations from different decision makers, which are convenient for analyzing the decision result more comprehensively.

Table 6. The consistency degree of each criterion by the expert.

	C_1	C_2	C_3	C_4	C_5	**Weighted**
DM_1	(0.4722,0.0557)	(0.4963,0.0704)	(0.5274,0.0725)	(0.5954,0.0704)	(0.4963,0.0593)	(0.5164,0.0699)
DM_2	(0.5274,0.0781)	(0.4906,0.0887)	(0.4041,0.0784)	(0.5730,0.0648)	(0.4861,0.0595)	(0.4977,0.0765)
DM_3	(0.4121,0.0409)	(0.4079,0.0789)	(0.4121,0.0550)	(0.4068,0.5274)	(0.5274,0.0601)	(0.4280,0.0624)

5. Conclusions and Further Research

This article studies the evaluation and classification of overseas talents in a Chinese context. We construct an evaluation-criteria system and propose a novel decision making methodology to rank the alternatives. These developments contribute to overseas talent management in China. Moreover, they provide valuable references for overseas talent management by the Chinese Government and in other developing countries. The advantages and limitations of the case discussed in this paper are now analyzed, in regard to the proposed methodology, human resources practices system and overseas talents' evaluating method's effectiveness, compared to the other methods for multi-criteria group decision making problems.

Advantages:

(a) The proposed method contains two parts: one is about calculating the weights of criteria and decision makers; the other one is about ranking the alternatives based on the obtained weights. We introduce the fuzz-based geometric index matrix to calculate the consistency degree of decision makers, whose weights can be obtained. Additionally, the criteria's weights are given subsequently. The importance of decision makers' weights is obvious, which can also be shown in Example 1. Based on the original BWM, we develop it into the intuitionistic preference relation's environment and construct a non-linear BWM. Then, the decision process can be more effective than the other pairwise-based decision making method.

(b) This paper studies the overseas talents' evaluation and classification problem of China. After summarizing the published related references and analyzing the Chinese context, we construct a criteria table for evaluation. Then, we apply the proposed method to rank 20 overseas talents and classify them. According to the specificity of human resource evaluation, we add the comparison of non-preferred degree by introducing the intuitionistic preference relation. This extension is more suitable for human's decision making psychology, leading to the decision making process being closer to reality. Additionally, it also can decrease the subjective influence on the decision results. Research studies on the overseas talents of China are rare, and the published papers do not consider the situation as extensively as this paper dose. Therefore, this paper is meaningful for the human resources practices system.

(c) We transform the talents evaluation problem into a Multi-Criteria Group Decision Making (MCGDM) problem, and solve it through a combination MCGDM methodology. For this proposed methodology, we develop the related methods to make them more effective. Example 1 can show the importance of considering geometry consistency degree, rather than paying more attention to calculating the missing elements in the reference of [44]. The illustrative study demonstrates the applicable of the proposed model. We also give two properties to measure whether the decisions are within the reasonable range. That ensures the effectiveness and reasonableness of our methodology.

Limitations:

(a) The proposed method is based on intuitionistic preference relations. However, in some more complicated conditions, this tool may still be insufficient to describe decision makers' hesitation degree. Decision making of alternatives with incomplete information is not a focus in this paper. As the decision problem in reality becomes gradually more complicated, it is unavoidable to deal with the complex problems that decision making results may be incomplete.

(b) The method is suitable for the overseas talent evaluation and classification problem, whose number of criteria and alternatives is moderate. Compared with the general pairwise comparison methods, we improve the practicability by introducing BWM. However, faced with large numbers of alternatives, our method may have heavy workloads and high cost.
(c) During the step of calculating criteria and decision makers' weights, we consider the geometry consistency degree. The consistency of BWM with intuitionistic preference relations has not been considered in this paper. This consistency degree may bring uncertain influence on the ranking results.

To conclude this paper, we make suggestions for further research. Firstly, as the pairwise comparison has been developed to the interval intuitionistic preference relations, we hope our methodology can also be extended to this extent. Meanwhile, problems in regard to missing elements of the decision matrix could be explored. Secondly, we could consider how to measure the consistency degree of the BWM for intuitionistic preference relations. Additionally, we may give each decision maker a second weight, making the decision results more reasonable. Thirdly, the overseas talents' evaluation and classification system is discussed in the Chinese context in this paper. The proposed methodology may be extended to other fields in further research, such as talent recruitment, investment decision making and supplier selection.

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