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# Combining Grey Relation and TOPSIS Concepts for Selecting an Expatriate Host Country

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**Abstract**—As international corporate activities increase, their staffing involves more strategic concerns. However, foreign assignments have many differences, and dissatisfaction with the host country is a known cause of expatriate failure. From the point of view of an expatriate candidate, the decision of whether to take an expatriate assignment can be regarded as a FMCDM (fuzzy multiple criteria decision making) problem. This paper describes a fuzzy AHP (fuzzy analytic hierarchy process) to determine the weighting of subjective judgments. Using the Sugeno integral for $\lambda$-fuzzy measure, and using the nonadditive fuzzy integral technique to evaluate the synthetic utility values of the alternatives and the fuzzy weights, then the best host country alternative can be derived with the grey relation model. The authors further combine the grey relation model based on the concepts of TOPSIS (technique for order preference by similarity to ideal solution) to evaluate and select the best alternative. A real case of expatriate assignment decision-making was used to demonstrate that the grey relation model combined with the ideas of TOPSIS results in a satisfactory and effective evaluation. © 2005 Elsevier Ltd. All rights reserved.

**Keywords**—Expatriate assignments, Fuzzy AHP, Grey relation model, Nonadditive fuzzy integral, TOPSIS.

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# 1. INTRODUCTION

Firms expand internationally for a variety of reasons, including access to markets, more abundant and/or less expensive resources, readily available labor supply, lower transportation costs, financial incentives, etc. However, firms adopting global strategies to their extend international markets often encounter problems in staffing and maintaining foreign operations with competent employees, which makes international human resource planning increasingly important. Thus, international firms make efforts to find the right people for overseas assignments and induce them to remain there for the duration of their assignments. With the dramatic growth of the international business sector, the number of individuals working for business concerns outside their native country has increased greatly. However, foreign assignments have great differences, and employee dissatisfaction with the host country is a major known cause of expatriate failure. These failures, whether by premature termination or poor adjustment, can cause employees to refuse international assignments, which can affect human resource planning and global strategies, as well as adding to reduced international control and coordination.

Past research has generally focused on the problem of expatriate selection. In this paper, we review and summarize research on factors associated with employee's willingness to accept expatriate assignments. This study of the employee relocation decision-making processes could help organizations reduce the number of employees who reject relocations or are dissatisfied after relocation [1]. Multinational corporations can benefit from international human resource management if we can better understand what criteria are important to the expatriate candidates and how they decide whether or not to accept the expatriate assignments. In addition, it may also assist organizations to enhance employee adjustment and overseas performance, as well as improving the success rate of expatriate assignments. Successful expatriates achieve both personal growth and corporate objectives, thus creating win-win situations for the employees and the business.

Based on the study of Borstorff *et al.* [2], factors associated with employee willingness to take expatriate assignments can be divided into four aspects:

(1) employee personal characteristics;
(2) employee job and relocation attitudes;
(3) spouse characteristics and attitudes toward relocation; and
(4) organization relocation support activities.

Mendenhall and Oddou [3] recommend a multidimensional approach to the selection of expatriate managers, linking behavioral tendencies to likely overseas performance. Technical skills, family situation, relational skills, and motivational state all play crucial roles in effective cross-cultural adjustment. In addition, the job characteristics of expatriate assignment as presented by Hackman and Oldham [4] relate to organizational commitment, job satisfaction, and job involvement, and these in turn influence employees' propensity to resign [5–8]. Hutchison *et al.* [9] further indicate that employees' perceived support from their organization is related to their beliefs regarding the extent to which their organizations value their contributions and care about their welfare. This increases the employee's affective attachment to the organization and the expectation that greater effort toward meeting organizational goals will be rewarded.

After reviewing the literature, we conclude that there are six distinct aspects, which influence whether the expatriate candidates take the expatriate assignments:

(1) personal factors;
(2) competencies;
(3) job characteristics;
(4) family factors;
(5) environmental factors;
(6) organization relocation support activities.

Because of the lack of information, the future states of the systems might not be known completely. Decision-making problems in real world systems are very often uncertain or vague. This type of uncertainty has long been handled appropriately by probability theory and statistics. However, in our daily life, people often employ natural language to express thinking and subjective perception; and in these natural languages the meaning of words is often vague. Although the meaning of a word might be well defined, when using the word as a label for a set, the boundaries within which objects do or do not belong to the set become fuzzy or vague. Furthermore, human judgment of events may be significantly different based on individuals' subjective perception or personality, even using the same words. Thus, fuzzy numbers are introduced to appropriately express linguistic variables.

This paper describes a fuzzy AHP (analytic hierarchy process) used to determine the weighting of subjective judgments from the views of expatriate candidates. From these perceived judgments, this article addresses how the expatriate candidates select the ideal host country and offers guidelines for managers concerned with expatriate assignment and success. A successful expatriate will achieve both personal growth and corporate objectives. Through this article, we demonstrate that the grey relation based on the concepts of TOPSIS (technique for order preference by similarity to ideal solution) to solve the multiple criteria decision making problem for selecting the expatriate host country is a good means of evaluation, and it appears to be more appropriate.

The remainder of this paper is organized as follows. The concept of fuzzy hierarchical evaluation with grey relation model based on the ideas of TOPSIS is introduced in Section 2. The combination model of grey relation model with TOPSIS concepts of fuzzy hierarchical evaluation for selecting the expatriate host country is proposed in Section 3. Then, in Section 4, an illustrative example applying the FMCDM methods from Section 3 for potential expatriate candidates in a Taiwanese multinational corporation (MNC) is presented, after which we discuss and show how the grey relation model based on the ideas of TOPSIS methods in this paper is effective. Finally, conclusions are presented in Section 5.

## 2. CONCEPTS OF THE FUZZY HIERARCHICAL EVALUATION

Saaty [10,11] developed AHP (analytic hierarchy process), which is a widely popular technique employed to model subjective decision-making processes based on multiple attributes. Application of AHP in MCDM environments involves defining a common hierarchy of criteria, specifying pairwise comparisons by members of the group, and aggregating those pairwise comparisons for the entire group. Saaty used the principal eigenvector of the comparison matrix to find the relative weights among the criteria of the hierarchy systems. Here, we employ Buckley's [12] method to fuzzify hierarchical analysis by allowing fuzzy numbers for the pairwise comparisons, and find the fuzzy weights and fuzzy performance. In this section, we briefly review concepts of fuzzy hierarchical evaluation with a grey relation model and with TOPSIS, and how to combine these two methods.

### 2.1. Fuzzy Number

Fuzzy set theory was originally introduced by Zadeh [13]. Subsequently, after Bellman and Zadeh [14] described the decision-making methods in fuzzy environments, an increasing number of studies have dealt with uncertain fuzzy problems by applying fuzzy set theory. Similarly, this current study includes fuzzy decision-making theory, considering the possible fuzzy subjective judgment of the evaluators in evaluating host country alternatives.

A fuzzy number $\tilde{A}$ is a fuzzy subset of a real number, and its membership function is $\mu_{\tilde{A}}(x) : R \to [0,1]$, where $x$ represents the criteria, and is described by the following characteristics [15]:

(1) $\mu_{\tilde{A}}(x)$ is a continuous mapping from $R$ to the closed interval $[0,1]$;
(2) $\mu_{\tilde{A}}(x)$ is a convex fuzzy subset;

(3) $\mu_{\tilde{A}}(x)$ is the normalization of a fuzzy subset, which means that there exists a number $x_0$ such that $\mu_{\tilde{A}}(x_0) = 1$.

According to the characteristics of triangular fuzzy numbers (TFN) and the extension principle put forward by Zadeh [16–18], the operational laws of two triangular fuzzy numbers $\tilde{A} = (a_1, a_2, a_3)$ and $\tilde{B} = (b_1, b_2, b_3)$ are as follows.

- Addition of two fuzzy numbers $\oplus$

$$(a_1, a_2, a_3) \oplus (b_1, b_2, b_3) = (a_1 + b_1, a_2 + b_2, a_3 + b_3). \tag{1}$$

- Subtraction of two fuzzy numbers $\ominus$

$$(a_1, a_2, a_3) \ominus (b_1, b_2, b_3) = (a_1 - b_3, a_2 - b_2, a_3 - b_1). \tag{2}$$

- Multiplication of two fuzzy numbers $\otimes$

$$(a_1, a_2, a_3) \otimes (b_1, b_2, b_3) \cong (a_1 b_1, a_2 b_2, a_3 b_3). \tag{3}$$

- Multiplication of any real number $k$ and a fuzzy number $\otimes$

$$k \otimes (a_1, a_2, a_3) = (ka_1, ka_2, ka_3). \tag{4}$$

- Division of two fuzzy numbers $\oslash$

$$(a_1, a_2, a_3) \oslash (b_1, b_2, b_3) \cong \left(\frac{a_1}{b_3}, \frac{a_2}{b_2}, \frac{a_3}{b_1}\right). \tag{5}$$

- Fuzzy inverse

$$(a, b, c)^{-1} = \left(\frac{1}{c}, \frac{1}{b}, \frac{1}{a}\right). \tag{6}$$

## 2.2. Linguistic Variables

When traditional quantification methods are difficult to reasonably express situations that are overtly complex or hard to define situations, the notion of a linguistic variable is necessary [16–18]. The theory of linguistic variables is used to represent imprecision of spatial data and human cognition over the criteria used for the evaluation process. A linguistic variable is a variable whose values are words or sentences in a natural or artificial language, and here we use this kind of expression to compare two evaluation criteria by using the five basic linguistic terms "absolutely important", "very strongly important", "essentially important", "weakly important", and "equally important" with respect to a fuzzy five level scale. The use of linguistic variables is currently widespread and the linguistic effect values of alternatives found in this paper are primarily used to assess the linguistic ratings given by evaluators. In addition, linguistic variables are also used as a way to measure the performance value of each host country as "very dissatisfied", "dissatisfied", "fair", "satisfied", and "very satisfied". This paper employs triangular fuzzy numbers (TFN) to express the fuzzy scale.

## 2.3. Fuzzy Measure and Fuzzy Integral

The assumption that there is no interaction between any two criteria within the same hierarchy in traditional AHP is often not the case since each individual criterion is inevitably correlated to others with different degrees. Sugeno [19] originally introduced the concept of fuzzy measure and fuzzy integral, generalizing the usual definition of a measure by replacing the usual additive property with a weaker requirement, i.e., the monotonicity property with respect to set inclusion. In this section, we give a brief introduction to some notions from the theory of fuzzy measure and fuzzy integral. For a more detailed account, please refer to [20–22], etc.

### 2.3.1. Fuzzy measure

DEFINITION 2.3.1.1. *Let $X$ be a measurable set that is endowed with properties of $\sigma$-algebra, where $\aleph$ is all subsets of $X$. A fuzzy measure $g$ defined on the measurable space $(X, \aleph)$ is a set function $g : \aleph \rightarrow [0,1]$, which satisfies the following properties:*

(1) $g(\phi) = 0$, $g(X) = 1$;
(2) *if* $A \subseteq B$, *then* $g(A) \leq g(B), \forall A, B \in \aleph$.

As in the above definition, $(X, \aleph, g)$ is said to be a fuzzy measure space. Furthermore, as a consequence of the monotonicity condition, we can obtain: $g(A \cup B) \geq \max\{g(A), g(B)\}$, and $g(A \cap B) \leq \min\{g(A), g(B)\}$. In the case of $g(A \cup B) = \max\{g(A), g(B)\}$, the set function $g$ is called a possibility measure [23], and $g$ is called a necessity measure if $g(A \cap B) = \min\{g(A), g(B)\}$.

DEFINITION 2.3.1.2. *Let $(X, \aleph, g)$ be a fuzzy measure space. The Sugeno integral of a fuzzy measure $g : \aleph \rightarrow [0,1]$ with respect to a simple function $h$ is defined by*

$$\int h(x) \circ g(x) = \bigvee_{i=1}^{n} \left(h\left(x_{(i)}\right) \wedge g\left(A_{(i)}\right)\right) = \max_{i} \min\left\{a_i', g\left(A_i'\right)\right\}, \tag{7}$$

*where $h(x_{(i)})$ is a linear combination of a characteristic function such that $A_1 \subset A_2 \subset \cdots \subset A_n$, and $A_i' = \{x \mid h(x) \geq a_i'\}$.*

DEFINITION 2.3.1.3. *Let $(X, \aleph, g)$ be a fuzzy measure space. The Choquet integral of a fuzzy measure $g : \aleph \rightarrow [0,1]$ with respect to a simple function $h$ is defined by*

$$\int h(x) \cdot dg \cong \sum_{i=1}^{n} \left[h(x_i) - h(x_{i-1})\right] \cdot g(A_i) \tag{8}$$

*with the same notations as above, and* $h(x_{(0)}) = 0$.

If there were no interactions among criteria, then no fuzzy integral approach would be needed. However, in reality the criteria often interact with each other to different degrees. Thus, Keeney and Raiffa [24] advocated the use of a multiattribute multiplicative utility function, called the nonadditive multiple criteria evaluation (MCE) technique, to refine situations that do not conform to the assumption of independence between criteria [25–27]. In this paper, we apply Keeney's nonadditive MCE technique using Choquet integrals to derive the fuzzy synthetic utilities of each alternative for the criteria as follows.

Let $g$ be a fuzzy measure defined on a power set $P(x)$, which satisfies Definition 2.3.1.1 as above. The following property is evident:

$$\begin{aligned} &\forall A, B \in P(X), \qquad A \cap B = \phi, \qquad \text{then} \\ &g_\lambda(A \cup B) = g_\lambda(A) + g_\lambda(B) + \lambda g_\lambda(A) g_\lambda(B), \qquad \text{for } -1 \leq \lambda < \infty, \end{aligned} \tag{9}$$

set $X = \{x_1, x_2, \dots, x_n\}$, fuzzy density $g_i = g_\lambda(\{x_i\})$ can be formulated as follows:

$$\begin{aligned} g_\lambda(\{x_1, x_2, \dots, x_n\}) &= \sum_{i=1}^{n} g_i + \lambda \sum_{i_1=1}^{n-1} \sum_{i_2=i_1+1}^{n} g_{i_1} \cdot g_{i_2} + \cdots + \lambda^{n-1} g_1 \cdot g_2 \cdots g_n \\ &= \frac{1}{\lambda} \left| \prod_{i=1}^{n} (1 + \lambda \cdot g_i) - 1 \right|, \qquad \text{for } -1 \leq \lambda < \infty. \end{aligned} \tag{10}$$

For an evaluation case with two criteria, $A$ and $B$, based on the above properties, one of the following three cases will be sustained.

CASE 1. If $\lambda > 0$, then $g_\lambda(A \cup B) > g_\lambda(A) + g_\lambda(B)$, implying that $A$ and $B$ have multiplicative effect.

CASE 2. If $\lambda = 0$, then $g_\lambda(A \cup B) = g_\lambda(A) + g_\lambda(B)$, implying that $A$ and $B$ have additive effect.

CASE 3. If $\lambda < 0$, then $g_\lambda(A \cup B) < g_\lambda(A) + g_\lambda(B)$, implying that $A$ and $B$ have substitutive effect.

Fuzzy measures are often used with fuzzy integrals for aggregating information evaluation.

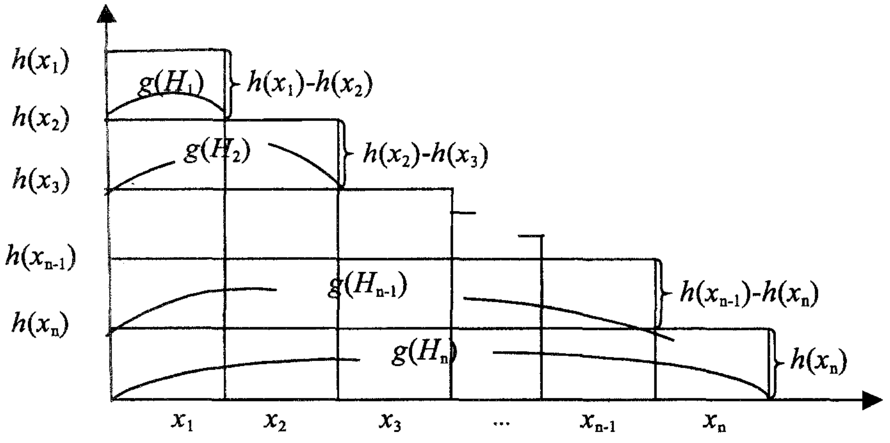

Figure 1. Diagram of nonadditive fuzzy integral.

### 2.3.2. Fuzzy integral

Let $h$ be a measurable set function defined on the fuzzy measurable space $(X, \aleph)$, and suppose that $h(x_1) \geq h(x_2) \geq \cdots \geq h(x_n)$, then the fuzzy integral of fuzzy measure $g(\cdot)$ with respect to $h(\cdot)$ can be defined as follows [28] (see Figure 1):

$$\begin{aligned}\int h \cdot dg &= h(x_n) \cdot g(H_n) + [h(x_{n-1}) - h(x_n)] \cdot g(H_{n-1}) + \cdots + [h(x_1) - h(x_2)] \cdot g(H_1) \\ &= h(x_n) \cdot [g(H_n) - g(H_{n-1})] + h(x_{n-1}) \\ &\quad \cdot [g(H_{n-1}) - g(H_{n-2})] + \cdots + h(x_1) \cdot g(H_1),\end{aligned} \tag{11}$$

where $H_1 = \{x_1\}$, $H_2 = \{x_1, x_2\}, \ldots, H_n = \{x_1, x_2, \ldots, x_n\} = X$. If $\lambda = 0$ and $g_1 = g_2 = \cdots = g_n$, then $h(x_1) \geq h(x_2) \geq \cdots \geq h(x_n)$ is not a necessary condition.

## 2.4. Grey Relation Model for MCDM

Grey theory, proposed by Deng in 1982 [29], similar to fuzzy set theory, is an effective mathematical means to deal with systems analysis characterized by incomplete information. Grey relation refers to the uncertain relations among things, among elements of systems, or among elements and behaviors. The relational analysis in the grey system theory is a kind of quantitative analysis for the evaluation of alternatives. Grey theory is widely applied in fields such as systems analysis, data processing, modeling and prediction, as well as control and decision-making [30–33]. Due to the presence of incomplete information and uncertain relations in a system, it is difficult to analyze it by using ordinary methods. On the other hand, grey system theory presents a grey relation space, and a series of nonfunctional type models are established in this space so as to overcome the obstacles of needing a massive amount of samples in general statistical methods, or the typical distribution and large amount of calculation work. In this section, we briefly review some relevant definitions and the calculation process for the grey relation model.

DEFINITION 2.4.1. *Let $X$ be a decision factor set of grey relations, $x_0 \in X$ the referential sequence, and $x_i \in X$ the comparative sequence; with $x_0(k)$ and $x_i(k)$ representing, respectively, the numerals at point $k$ for $x_0$ and $x_i$. If $\gamma(x_0(k), x_i(k))$ and $\gamma(x_0, x_i)$ are real numbers, and satisfy the following four grey axioms [34], then we call $\gamma(x_0(k), x_i(k))$ the grey relation coefficient of these factors in point $k$, and the grade of grey relation $\gamma(x_0, x_i)$ is the average value of $\gamma(x_0(k), x_i(k))$.*

1. Norm interval

$$0 < \gamma(x_0, x_i) \leq 1, \quad \forall\, k; \qquad \gamma(x_0, x_i) = 1, \quad \text{iff } x_0 = x_i; \qquad \gamma(x_0, x_i) = 0, \quad \text{iff } x_0, x_i \in \phi,$$

where $\phi$ is an empty set.

2. Duality symmetric

$$x, y \in X \Rightarrow \gamma(x,y) = \gamma(y,x), \qquad \text{iff } X = \{x, y\}.$$

3. Wholeness

$$\gamma(x_i, x_j) \overset{\text{often}}{\neq} \gamma(x_j, x_i), \qquad \text{iff } X = \{x_i \mid i = 0, 1, 2, \ldots, n\}, \qquad n > 2.$$

4. Approachability

$$\gamma(x_0(k), x_i(k)) \text{ decreasing along with } |(x_0(k) - x_i(k))| \text{ increasing.}$$

Deng also proposed a mathematical equation, which satisfies the above four axioms of grey relation, and for the grey relation coefficient is expressed as

$$\gamma(x_0(k), x_i(k)) = \frac{\min_i \min_k |x_0(k) - x_i(k)| + \zeta \max_i \max_k |x_0(k) - x_i(k)|}{|x_0(k) - x_i(k)| + \zeta \max_i \max_k |x_0(k) - x_i(k)|}, \tag{12}$$

where $|x_0(k) - x_i(k)| = \Delta_i(k)$, and $\zeta$ is the distinguished coefficient ($\zeta \in [0,1]$).

Definition 2.4.2. *If $\gamma(x_0, x_i)$ satisfies the four grey relation axioms, then $\gamma$ is called the grey relational map.*

Definition 2.4.3. *If $\Gamma$ is the entirety of the grey relational map, $\gamma \in \Gamma$ satisfies the four axioms of grey relation, and $X$ is the factor set of grey relation, then $(X, \Gamma)$ is called as the grey relational space, while $\gamma$ is the specific map for $\Gamma$.*

Definition 2.4.4. *Let $(X, \Gamma)$ be the grey relational space, and if $\gamma(x_0, x_j), \gamma(x_0, x_p), \ldots, \gamma(x_0, x_q)$ satisfy $\gamma(x_0, x_j) > \gamma(x_0, x_p) > \cdots > \gamma(x_0, x_q)$, then we have the grey relational order as $x_j \succ x_p \succ \cdots \succ x_q$.*

The analysis of grey relation is conducted with its basis of developmental trends, so there are not strict requirements for the sample size, the typical distribution of statistics is not at all necessary, and the calculation is rather simple.

## 2.5. TOPSIS for MCDM

Multiple criteria decision-making (MCDM) is used to select a project from several alternatives according to various criteria. The technique for order preference by similarity to ideal solution (TOPSIS) was first developed by Hwang and Yoon [35], based on the concept that the chosen alternative should have the shortest distance from the positive ideal solution (PIS) and the farthest from the negative-ideal solution (NIS) for solving a multiple criteria decision-making problem. Thus, the best alternative should not only have the shortest distance from the positive ideal solution, but also should have the largest distance from the negative ideal solution. In short, the ideal solution is composed of all best values attainable of criteria, whereas the negative ideal solution is made up of all worst values attainable of criteria. The calculation processes of this method are as follows.

1. Normalize the evaluation matrix: the process is to transform different scales and units among various criteria into common measurable units to allow comparisons across the criteria. Assume $x_{ij}$ to be of the evaluation matrix $R$ of alternative $i$ under evaluation criterion $j$ then an element $r_{ij}$ of the normalized evaluation matrix $R$ can calculated by many normalization methods to achieve this objective.
2. Construct the weighted normalized evaluation matrix: we cannot assume that each evaluation criterion is of equal importance because the evaluation criteria have various meanings. There are many methods that can be employed to determine weights [35], such as

the eigenvector method, weighted least square method, entropy method, AHP, as well as linear programming techniques for multidimension of analysis preference (LINMAP). The selection of method depends on the nature of the problems. The weighted normalized evaluation matrix can be calculated by multiplying the normalized evaluation matrix $r_{ij}$ with its associated weight $w_j$ to obtain the result $V = [w_j r_{ij}] = [v_{ij}]$.

3. Determine positive and negative ideal solutions: the positive ideal solution $A^+$ indicates the most preferable alternative, and the negative ideal solution $A^-$ indicates the least preferable alternative.
4. Calculate the separation measure: the separation from the positive and negative ideal for each alternative can be measured by the $n$-criteria Euclidean distance

$$DA_i^+ = \left[\sum_{j=1}^{n} \left(v_{ij} - v_j^+\right)^2\right]^{1/2}, \quad i = 1, 2, \dots, k, \tag{13}$$

$$DA_i^- = \left[\sum_{j=1}^{n} \left(v_{ij} - v_j^-\right)^2\right]^{1/2}, \quad i = 1, 2, \dots, k. \tag{14}$$

5. Calculate the relative closeness to the ideal solution: the relative closeness of the $i^{\text{th}}$ alternative with respect to ideal solution $A^+$ is defined as

$$R_i^+ = \frac{DA_i^-}{DA_i^+ + DA_i^-}, \qquad 0 \le R_i^+ \le 1, \quad i = 1, 2, \dots, K. \tag{15}$$

6. Rank the priority: a set of alternatives then can be preference ranked according to the descending order of $R_i^+$.

## 2.6. Combining Grey Relation and TOPSIS Concepts to Solve MCDM

There exists a certain degree of similarity between the input and operation of grey relation model and the multiple criteria evaluation of TOPSIS [33]. Thus, this paper is based on the concept of TOPSIS in combination with the application of grey relation model in order to do multiple criteria evaluation, and the procedures of calculation are delineated as follows.

1. To establish a normalized evaluation matrix: this step is to transform criteria of different units into unit-free evaluation matrix so as to facilitate comparison as we mentioned earlier.
2. To find the ideal solution and the negative ideal solution: the positive ideal solution $A^+$ indicates the most preferable alternative, and the negative ideal solution $A^-$ indicates the least preferable alternative.
3. To take the ideal solution and negative ideal solution as the referential sequence and each of the alternatives to be the comparative sequence, in order to obtain the grey relation coefficient of each alternative to the ideal $r(A^+(j), A_i(j))$ and the negative ideal $r(A^-(j), A_i(j))$ solution.

$$r\left(A^+(j), A_i(j)\right) = \frac{\min_i \min_j \left|A^+(j) - A_i(j)\right| + \zeta \max_i \max_j \left|A^+(j) - A_i(j)\right|}{\left|A^+(j) - A_i(j)\right| + \zeta \max_i \max_j \left|A^+(j) - A_i(j)\right|}, \tag{16}$$

$$r\left(A^-(j), A_i(j)\right) = \frac{\min_i \min_j \left|A^-(j) - A_i(j)\right| + \zeta \max_i \max_j \left|A^-(j) - A_i(j)\right|}{\left|A^-(j) - A_i(j)\right| + \zeta \max_i \max_j \left|A^-(j) - A_i(j)\right|}. \tag{17}$$

4. To determine the grade of grey relation of each alternative to the ideal and the negative

ideal solutions, and its calculation equations are as follows:

$$r\left(A^{+}, A_i\right) = \sum_{j=1}^{n} w_j r\left(A^{+}(j), A_i(j)\right), \tag{18}$$

$$r\left(A^{-}, A_i\right) = \sum_{j=1}^{n} w_j r\left(A^{-}(j), A_i(j)\right), \tag{19}$$

$$\sum_{j=1}^{n} w_j = 1. \tag{20}$$

5. To find the relative closeness $C_i$ of distance that an alternative is close to the ideal solution, which is defined as follows:

$$C_i = \frac{r\left(A^{+}, A_i\right)}{r\left(A^{-}, A_i\right)}. \tag{21}$$

6. To rank the priority: the order of alternative is ranked according to the value of relative closeness to each of the alternatives, and a greater value of $C_i$ indicates a higher priority of the alternative.

The difference of this method from conventional TOPSIS lies in its introduction of the definition of grey relation coefficient of grey relation model to replace the definition of general distance. Meanwhile, the definition of conventional grey relation is revised so as to reflect the impact of decision-making theory for the preference of criteria weight. As a result, a compromise satisfactory solution can be found, so the grade relation of each alternative to the ideal solution and negative ideal solution can also be considered, while maintaining the objectivity in regard to the indication of ups and downs of alternatives.

## 3. COMBINING GREY RELATION MODEL WITH TOPSIS CONCEPTS OF FUZZY HIERARCHICAL EVALUATION TO SELECT AN EXPATRIATE HOST COUNTRY

Since expatriate assignments have many differences and dissatisfaction with the host country is a major known cause of expatriate failure, thus, better understanding of how expatriate candidates evaluate and select an ideal host country is very helpful for international human resource management. In this paper, we review and summarize research on factors associated with employees' willingness to take expatriate assignments, and then build a hierarchical framework for evaluators to make decisions on expatriate assignments. This effort could assist those organizations, enhance employee adjustment, and overseas performance, as well as and improving the success rate of expatriate assignments.

### 3.1. Building a Hierarchical Framework for Selecting the Expatriate Assignments Evaluation Criteria

First of all, we establish a hierarchical system of expatriate assignment for analysis and evaluation through literature review, as shown in Figure 2. Phase 1 indicates our successful expatriate goal. Second, in Phase 2, we consider six aspects for achieving our goal including:

(1) employee personal factors;
(2) employee competencies;
(3) job characteristics;
(4) family factors;
(5) environmental factors; and
(6) organization relocation support activities.

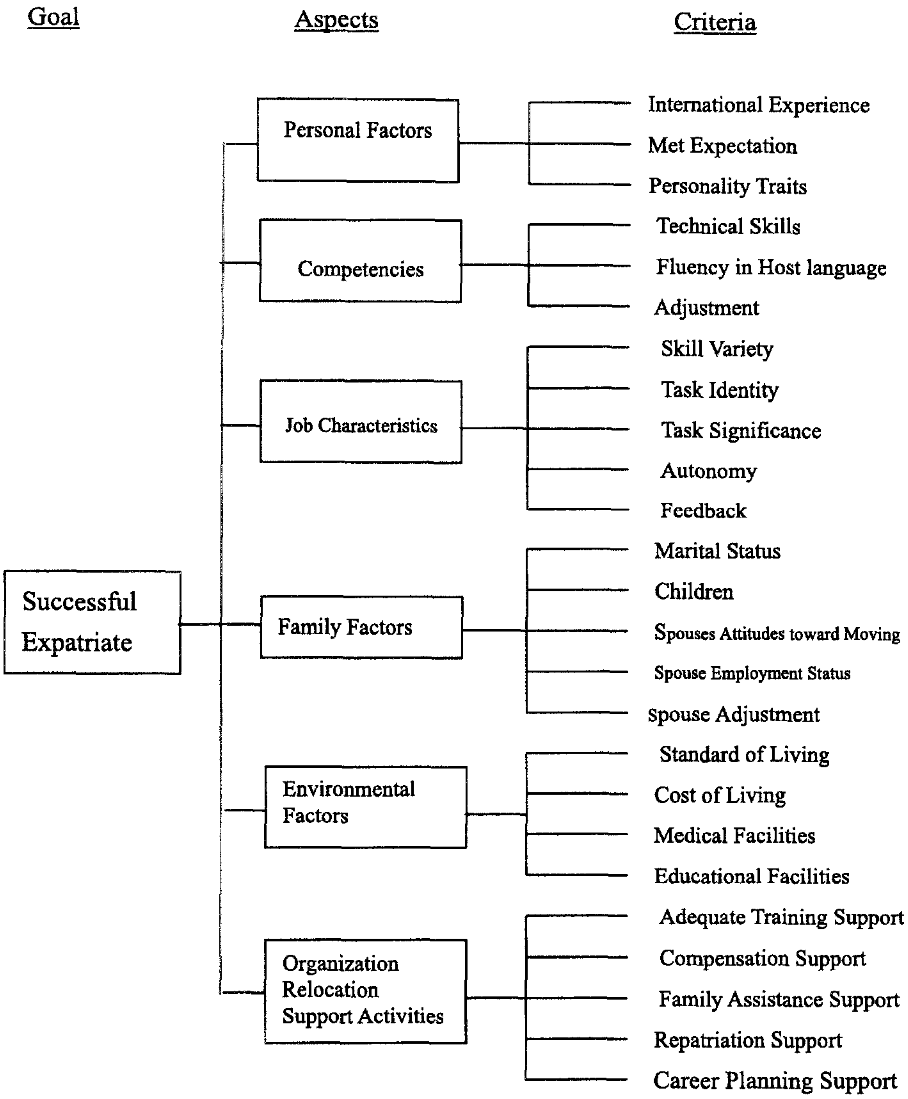

Figure 2. Fuzzy MCDM hierarchical framework for expatriate assignment evaluation criteria.

Third, we consider three criteria in employee personal factors, three criteria in employee competencies, five criteria in job characteristics, five criteria in family factors, four criteria in environmental factors, and five criteria in organization relocation support activities with respect to our consideration aspects that are selected and evaluated as listed in Phase 3. All considered criteria are measured by evaluators, consisting of individuals with different viewpoints. The definitions of relevant criteria are listed in Table 1.

### 3.2. Determination of Evaluation Criteria Weights

As we mentioned earlier, we cannot assume that each evaluation criterion is of equal importance. To resolve this issue, there are many methods that can be employed to determine weights [35], including the eigenvector method, weighted least square method, entropy method and AHP, as well as linear programming techniques for multidimensions of analysis preference (LINMAP). Here, we employed the AHP method to derive the weights of the evaluation criteria. The procedure for AHP can be summarized in four steps, as follows.

STEP 1. Set up the hierarchical system by decomposing the problem into a hierarchy of interrelated elements.

STEP 2. Generate input data consisting of comparative judgments regarding decision elements.

Table 1. Definitions of evaluation criteria for expatriate assignments.

| Evaluation Criteria | Description |
|---|---|
| Personal Factors | |
| International Experience | • Previous international assignments |
| Met Expectations | • Whether the work environment and the physical environment met with the expatriate candidate's expectations |
| Personality Traits | • Flexibility, willingness to learn, openness, sense of humor, adaptability, ability to handle ambiguity and interest in others, all of which are helpful characteristics working abroad |
| Competencies | |
| Technical Skills | • Skills need for the expatriate assignment task |
| Fluency in Host Language | • Fluency in the language of the host country |
| Adjustment | • Relational ability, cultural sensitivity and ability to handle stress in the host country |
| Job Characteristics | |
| Skill Variety | • Degree to which a job requires a variety of activities so that an employee can use a number of different skills and talents |
| Task Identity | • The extent to which employees do an entire or whole piece of work and can identify with the results of their efforts |
| Task Significance | • Degree to which a job has a substantial impact on the lives or work of other people |
| Autonomy | • Extent to which employees have a say in scheduling their work and freedom to do what they want on the job |
| Feedback | • Feedback assesses the degree to which employees receive information as they are working that reveals how well they are performing on the job |
| Family Factors | |
| Marital Status | • Single or married |
| Children | • Children living with parents |
| Spouses Attitudes toward Moving | • Spouses' motivation to make an international relocation and their attitude to this move |
| Spouse Employment Status | • The degree of involvement that spouses have with their work |
| Spouse Adjustment | • Adjustment capabilities of the spouses who relocate with the expatriate candidates |
| Environmental Factors | |
| Standard of Living | • Standard of living in the host country |
| Cost of Living | • Cost of living in the host country |
| Medical Facilities | • Completeness of medical facilities in the host country |
| Educational Facilities | • Completeness of educational facilities in the host country |
| Organization Relocation Support Activities | |
| Adequate Training Support | • Adequate training for expatriate assignments, which includes adequate lead time, training support, and mentor support |
| Compensation Support | • Based on national cultural characteristics of the host country, a multinational corporation should permit accurate assessment of appropriate types of compensation packages to motivate expatriate managers |
| Family Assistance Support | • Organization facilitates cultural adjustment through support in the area of housing, education, and spouse job-search assistance |
| Repatriation Support | • Transition from the foreign country back into the home country and home organization |
| Career Planning Support | • Developing an integrated career development strategy for expatriate employees |

STEP 3. Synthesize the judgments and estimate the relative weight.

STEP 4. Determine the aggregate relative weights of the decision elements to arrive at a set of ratings for the decision alternatives.

### 3.3. Obtaining the Fuzzy Weights for the Hierarchy Process

The evaluated priority of a specified criterion is often uncertainly affected by the criteria of other criteria, so it is not easy for evaluators to construct a perfect AHP hierarchy with no interaction among criteria in a given level. This means that we should consider the uncertain interaction effects due to other criteria when computing the weight of a specified criterion. Furthermore, an evaluator always perceives the weight with his/her own subjective evaluation; therefore, an exact or precise weight for a specified criterion is not given. This leads to the use of the fuzzy weights of criteria.

Buckley [12] initially investigated fuzzy weights and fuzzy utility for the AHP technique, extending it by the geometric mean method to derive the fuzzy weights. In [11], if $A = [a_{ij}]$ is a positive reciprocal matrix, then the geometric mean of each row, $r_i$, can be calculated as $r_i = (\prod_{j=1}^{n} a_{ij})^{1/n}$. Here, Saaty defined $\lambda_{\max}$ as the largest eigenvalue of $A$, and the weights $w_i$ as the components of the normalized eigenvector corresponding to $\lambda_{\max}$, where $w_i = r_i/(r_1 + \cdots + r_n)$.

Buckley [12] considered a fuzzy positive reciprocal matrix $\tilde{A} = [\tilde{a}_{ij}]$, extending the geometric mean technique to define the fuzzy geometric mean of each row $\tilde{r}_i$ and fuzzy weight $\tilde{w}_i$ corresponding to each criterion as follows:

$$\tilde{r}_i = \left(\tilde{a}_{i1} \otimes \cdots \otimes \tilde{a}_{in}\right)^{1/n}; \qquad \tilde{w}_i = \tilde{r}_i \otimes \left(\tilde{r}_1 \oplus \cdots \oplus \tilde{r}_n\right)^{-1}. \tag{22}$$

### 3.4. Driving the Synthetic Utility Values

The evaluators choose a performance value for each alternative based on their subjective judgments. In this paper, we aggregate the anticipated performance values by the geometric mean method. Furthermore, we utilize the nonadditive fuzzy integral to find the synthetic utilities of each alternative after considering the criteria that are not necessarily mutually independent.

The result of the fuzzy synthetic decision reached by each alternative is a fuzzy number. Therefore, in the nonfuzzy ranking method it is necessary for fuzzy numbers to be employed during the comparison of the alternatives. In previous works, the procedure of defuzzification has been to locate the best nonfuzzy performance (BNP) value. Defuzzified fuzzy ranking methods generally include the three kinds of methods, mean of maximal (MOM), center of area (COA), and $\alpha$-cut [36–38]. Adopting the COA method to determine the BNP is a simple and practical method; there is no need to introduce the preferences of any evaluators. According to the value of BNP, the evaluation values of each host country can then proceed. The BNP value of the triangular fuzzy number $(LR_i, MR_i, UR_i)$ can be found as follows:

$$\mathrm{BNP}_i = \frac{[(UR_i - LR_i) + (MR_i - LR_i)]}{3} + LR_i, \qquad \forall i. \tag{23}$$

### 3.5. Outranking the Host Country Alternatives

Based on the concepts of TOPSIS and the norm interval axiom of grey relation, the synthetic utilities of host country alternatives are compared. In addition, we use the weights from fuzzy hierarchical analysis and nonadditive fuzzy integrals to find the synthetic utilities within the same aspect because in reality the evaluation criterion inevitably interacts with other criteria to different degrees. Finally, we compute the grade of grey relation based on the concepts of TOPSIS to rank the order of preference of alternatives.

# 4. ILLUSTRATIVE EXAMPLE: EXPATRIATE HOST COUNTRY SELECTION FOR THE TANG-TUNG COMPANY

In this section, we take expatriate host country selection evaluation for the Tang-Tung Company as an illustrative example to demonstrate that the grey relation model combines with the concepts of TOPSIS to provide good evaluations and appears to be more appropriate than other methods, especially when the criteria interact each other to different degrees in a fuzzy environment. Tang-Tang Company, which is based in Taiwan, and the products it provides globally are mainly in the area of computer displays, information appliances, home appliances, power, and energy. Five subsections are included in this section:

(1) problem descriptions,
(2) determining of evaluation criteria weights,
(3) determining the performance matrix,
(4) calculating the nonadditive fuzzy synthetic utilities and the grade of grey relation based on TOPSIS, and
(5) discussions.

## 4.1. Problem Descriptions

Because staffing and maintaining foreign operations with competent employees is important to international firms, the expatriate selection process becomes a focus of research. However, cases of expatriate failure often make expatriate candidates refuse to take assignments. Thus, the understandings of how expatriate candidates evaluate the related factors in this fuzzy decision-making environment becomes important. If we can understand what criteria the expatriate candidates emphasize and how they select the ideal host country, that will help successful placement of expatriates.

## 4.2. Determining of Evaluation Criteria Weights

First, we establish the hierarchical framework for expatriate assignment evaluation criteria shown in Figure 1, which is evaluated in terms of six aspects:

(1) employee personal factors;
(2) employee competencies;
(3) job characteristics;

(4) family factors;
(5) environmental factors;
(6) organization relocation support activities, with 25 criteria selected.

Second, 24 participants were initially screened to verify that they have previous expatriate experience or have potential opportunities to take expatriate assignments. We integrated their subjective judgments to develop the fuzzy criteria weights with respect to aspects by using the fuzzy geometric mean method as equation (22) above. Selection of ten host countries for the expatriate alternatives set was based on Tang-Tung Company's global operation scope, as follows: Mainland China, Japan, Southeast Asia, U.S., Mexico, England, Europe, Canada, Singapore, and Korea. We then derive the final fuzzy weights and nonfuzzy BNP values corresponding to each criterion, as shown in Table 2.

## 4.3. Determining the Performance Matrix

The evaluators can define their own individual range for the linguistic variables employed in this paper based on their subjective judgments within a fuzzy scale to determine the performance value of each alternative. However, under future uncertainties, the anticipated performance values

Table 2. Criteria weights for selecting expatriate host country.

| Aspects and Criteria | Weights | Total Weights |
|---|---|---|
| Personal Factors | 0.241 (0.164, 0.232, 0.327) | |
| International Experience | 0.406 (0.289, 0.392, 0.537) | 0.105 (0.048, 0.091, 0.176) [1] |
| Met Expectation | 0.345 (0.229, 0.330, 0.475) | 0.090 (0.038, 0.077, 0.155) [2] |
| Personality | 0.285 (0.202, 0.278, 0.376) | 0.074 (0.033, 0.065, 0.123) [5] |
| Competence | 0.197 (0.130, 0.188, 0.274) | |
| Technical Skills | 0.366 (0.261, 0.355, 0.483) | 0.078 (0.034, 0.067, 0.132) [3] |
| Fluency in Host Language | 0.346 (0.235, 0.333, 0.471) | 0.074 (0.030, 0.063, 0.129) [4] |
| Adjustment | 0.322 (0.229, 0.312, 0.424) | 0.068 (0.030, 0.059, 0.116) [6] |
| Job Characteristics | 0.201 (0.137, 0.192, 0.273) | |
| Skill Variety | 0.305 (0.211, 0.293, 0.411) | 0.066 (0.029, 0.056, 0.112) [7] |
| Task Identity | 0.238 (0.158, 0.230, 0.327) | 0.052 (0.022, 0.044, 0.089) [8] |
| Task Significance | 0.200 (0.134, 0.192, 0.274) | 0.043 (0.018, 0.037, 0.075) [12] |
| Autonomy | 0.168 (0.112, 0.160, 0.233) | 0.037 (0.015, 0.031, 0.064) [14] |
| Feedback | 0.130 (0.089, 0.126, 0.174) | 0.028 (0.012, 0.024, 0.047) [20] |
| Family Factors | 0.141 (0.096, 0.136, 0.191) | |
| Marital Status | 0.171 (0.116, 0.161, 0.235) | 0.026 (0.011, 0.022, 0.045) [22] |
| Children | 0.125 (0.083, 0.117, 0.173) | 0.019 (0.008, 0.016, 0.033) [25] |
| Spouse Attitudes toward Moving | 0.198 (0.136, 0.190, 0.267) | 0.030 (0.013, 0.026, 0.051) [18] |
| Spouse Employment Status | 0.318 (0.210, 0.308, 0.437) | 0.048 (0.020, 0.042, 0.083) [9] |
| Spouse Adjustment | 0.231 (0.155, 0.224, 0.313) | 0.035 (0.015, 0.031, 0.060) [16] |
| Environmental Factors | 0.145 (0.095, 0.139, 0.202) | |
| Standard of Living | 0.239 (0.166, 0.226, 0.325) | 0.038 (0.016, 0.031, 0.066) [13] |
| Cost of Living | 0.286 (0.200, 0.279, 0.379) | 0.045 (0.019, 0.039, 0.076) [10] |
| Medical Facilities | 0.232 (0.164, 0.222, 0.310) | 0.036 (0.016, 0.031, 0.062) [15] |
| Educational Facilities | 0.279 (0.191, 0.274, 0.373) | 0.044 (0.018, 0.038, 0.075) [11] |
| Organizational Relocation Support Activities | 0.117 (0.080, 0.113, 0.159) | |
| Adequate Training Support | 0.190 (0.129, 0.180, 0.261) | 0.024 (0.010, 0.020, 0.042) [23] |
| Compensation Support | 0.168 (0.111, 0.159, 0.234) | 0.021 (0.009, 0.018, 0.037) [24] |
| Family Assistance Support | 0.208 (0.135, 0.198, 0.291) | 0.026 (0.011, 0.022, 0.046) [21] |
| Repatriation Support | 0.256 (0.168, 0.246, 0.354) | 0.032 (0.013, 0.028, 0.056) [17] |
| Career Planning Support | 0.224 (0.150, 0.217, 0.304) | 0.028 (0.012, 0.024, 0.048) [19] |

The figures denote the defuzzified weights by using BNP, parentheses ( ) denote the fuzzy numbers, and brackets [ ] denote the order of importance (weight) of each criterion/objective.

of unquantifiable criteria cannot be specified with qualitative numerical data in a qualitative evaluation pertaining to the possible achievement value of each alternative.

Let $\tilde{h}_{ij}^k$ represent the fuzzy performance score by the $k^{\text{th}}$ evaluator under the $i^{\text{th}}$ alternative with respect to the $j^{\text{th}}$ criterion. Since the perception of each evaluator varies according to individual experience and knowledge, and the definitions of linguistic variables also vary, we employ the fuzzy geometric mean method to integrate the fuzzy performance score $\tilde{h}_{ij}$ for $m$ evaluators. This is

$$\tilde{h}_{ij} = \left(\tilde{h}_{ij}^1 \otimes \cdots \otimes \tilde{h}_{ij}^m\right)^{1/m}. \qquad (24)$$

Furthermore, we employ the COA defuzzification procedure to compute the BNP values of fuzzy performance score $\tilde{h}_{ij}$. The fuzzy performance scores of host country with respect to criteria and the BNP values are shown in Table 3.

Table 3. Evaluation results of expatriate assignments host country.

| | China | Japan | Southeast Asia | U.S. | Mexico | England | Europe | Canada | Singapore | Korea |
|---|---|---|---|---|---|---|---|---|---|---|
| International Experience | 4.528 (1) | 4.032 (3) | 3.304 (5) | 4.262 (2) | 2.980 (9) | 3.169 (8) | 3.189 (7) | 2.938 (10) | 3.519 (4) | 3.227 (6) |
| Met Expectation | 5.768 (4) | 6.215 (1) | 3.532 (10) | 5.787 (3) | 4.209 (8) | 5.672 (5) | 5.459 (6) | 5.259 (7) | 5.877 (2) | 4.094 (9) |
| Personality | 5.009 (2) | 5.051 (1) | 3.760 (8) | 4.857 (3) | 3.316 (10) | 4.434 (5) | 4.236 (7) | 4.409 (6) | 4.840 (4) | 3.594 (9) |
| Technical Skills | 5.542 (1) | 5.340 (3) | 4.063 (10) | 4.776 (4) | 4.066 (9) | 4.632 (5) | 4.244 (8) | 4.366 (7) | 5.387 (2) | 4.393 (6) |
| Fluency in Host Language | 6.136 (1) | 3.451 (7) | 3.347 (8) | 4.802 (3) | 2.903 (9) | 4.504 (4) | 3.464 (6) | 4.418 (5) | 5.325 (2) | 2.276 (10) |
| Adjustment | 5.162 (1) | 4.863 (2) | 4.354 (7) | 4.551 (4) | 3.837 (10) | 4.477 (5) | 4.334 (8) | 4.436 (6) | 4.821 (3) | 4.172 (9) |
| Skill Variety | 4.531 (2) | 4.671 (1) | 3.908 (8) | 4.482 (3) | 3.854 (10) | 4.096 (5) | 4.077 (7) | 3.860 (9) | 4.394 (4) | 4.087 (6) |
| Task Identity | 3.425 (4) | 3.687 (1) | 2.811 (10) | 3.668 (2) | 3.124 (9) | 3.387 (6) | 3.439 (3) | 3.183 (7) | 3.416 (5) | 3.155 (8) |
| Task Significance | 3.152 (2) | 3.080 (3) | 2.585 (10) | 3.288 (1) | 2.788 (8) | 2.868 (5) | 2.860 (6) | 2.810 (7) | 2.879 (4) | 2.697 (9) |
| Autonomy | 2.627 (1) | 2.464 (4) | 2.411 (6) | 2.568 (3) | 2.275 (10) | 2.410 (7) | 2.443 (5) | 2.368 (8) | 2.573 (2) | 2.316 (9) |
| Feedback | 1.903 (3) | 1.931 (2) | 1.680 (10) | 1.960 (1) | 1.696 (9) | 1.872 (4) | 1.853 (5) | 1.746 (7) | 1.821 (6) | 1.728 (8) |
| Marital Status | 1.466 (1) | 1.407 (2) | 1.242 (8) | 1.338 (4) | 1.220 (9) | 1.294 (7) | 1.315 (5) | 1.295 (6) | 1.368 (3) | 1.215 (10) |
| Children | 0.550 (8) | 0.616 (3) | 0.529 (10) | 0.580 (7) | 0.537 (9) | 0.591 (4) | 0.591 (4) | 0.591 (4) | 0.644 (1) | 0.616 (2) |
| Spouse Attitudes toward Moving | 2.185 (2) | 2.234 (1) | 1.859 (9) | 2.140 (3) | 1.749 (10) | 1.906 (7) | 1.933 (6) | 1.957 (5) | 2.100 (4) | 1.883 (8) |
| Spouse Employment Status | 2.751 (8) | 2.841 (2) | 2.841 (2) | 2.905 (1) | 2.841 (2) | 2.751 (8) | 2.751 (8) | 2.841 (2) | 2.811 (6) | 2.811 (6) |
| Spouse Adjustment | 2.568 (1) | 2.421 (3) | 2.321 (9) | 2.376 (4) | 2.304 (10) | 2.330 (7) | 2.330 (7) | 2.374 (5) | 2.438 (2) | 2.334 (6) |
| Standard of Living | 1.990 (9) | 3.217 (1) | 1.865 (10) | 3.143 (2) | 2.026 (8) | 3.071 (4) | 3.088 (3) | 2.927 (6) | 2.949 (5) | 2.273 (7) |
| Cost of Living | 2.595 (1) | 0.694 (10) | 2.408 (2) | 0.982 (8) | 2.009 (3) | 0.942 (9) | 0.990 (7) | 1.162 (6) | 1.534 (5) | 1.697 (4) |
| Medical Facilities | 1.609(10) | 2.957 (1) | 1.786 (9) | 2.939 (4) | 2.156 (8) | 2.956 (2) | 2.940 (3) | 2.877 (6) | 2.877 (5) | 2.615 (7) |
| Educational Facilities | 2.371 (8) | 3.295 (3) | 2.048 (10) | 3.408 (1) | 2.365 (9) | 3.214 (5) | 3.387 (2) | 3.234 (4) | 3.212 (6) | 2.777 (7) |
| Adequate Training Support | 1.596 (5) | 1.677 (1) | 1.361 (10) | 1.623 (3) | 1.417 (9) | 1.614 (4) | 1.639 (2) | 1.591 (6) | 1.578 (7) | 1.494 (8) |
| Compensation support | 1.386 (2) | 1.443 (1) | 1.317 (7) | 1.323 (5) | 1.315 (8) | 1.334 (4) | 1.319 (6) | 1.303 (9) | 1.341 (3) | 1.303 (10) |
| Family Assistance Support | 1.678 (3) | 1.708 (1) | 1.480 (10) | 1.653 (5) | 1.558 (9) | 1.643 (6) | 1.667 (4) | 1.643 (6) | 1.704 (2) | 1.630 (8) |
| Repatriation Support | 2.025 (8) | 2.237 (3) | 1.880 (10) | 2.280 (1) | 1.998 (9) | 2.250 (2) | 2.211 (4) | 2.173 (5) | 2.155 (6) | 2.149 (7) |
| Career Planning Support | 1.727 (8) | 1.954 (2) | 1.704 (9) | 1.956 (1) | 1.561 (10) | 1.942 (3) | 1.917 (4) | 1.866 (5) | 1.814 (6) | 1.791 (7) |
| Total | 74.278(1) | 73.484 (3) | 60.396 (9) | 73.647 (2) | 60.106 (10) | 69.360 (5) | 67.677 (6) | 67.629 (7) | 73.376 (4) | 62.326 (8) |

The figures denote the defuzzified performance value (effect-value) by using BNP, and parentheses ( ) denote the order of performance value (effect-value) of each criterion/objective.

Table 4. The grade of grey relation based on TOPSIS with different $\lambda$ values.

| $\lambda$ | −0.5 | | 0 | | 0.5 | | 1 | | 3 | | 5 | | 10 | | 40 | | $100^+$ | | TOPSIS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| China | 0.592 | 3 | 0.608 | 3 | 0.590 | 1 | 0.605 | 1 | 0.601 | 1 | 0.599 | 1 | 0.601 | 1 | 0.614 | 1 | 0.616 | 1 | 0.728 | 2 |
| Japan | 0.593 | 1 | 0.617 | 1 | 0.575 | 3 | 0.602 | 3 | 0.584 | 4 | 0.572 | 4 | 0.557 | 4 | 0.545 | 4 | 0.537 | 4 | 0.589 | 4 |
| SE Asia | 0.379 | 10 | 0.351 | 9 | 0.386 | 10 | 0.359 | 10 | 0.369 | 10 | 0.376 | 10 | 0.388 | 9 | 0.418 | 9 | 0.431 | 9 | 0.290 | 8 |
| U.S. | 0.592 | 2 | 0.612 | 2 | 0.584 | 2 | 0.602 | 2 | 0.591 | 2 | 0.583 | 2 | 0.575 | 3 | 0.570 | 3 | 0.565 | 3 | 0.673 | 3 |
| Mexico | 0.381 | 9 | 0.350 | 10 | 0.388 | 9 | 0.359 | 9 | 0.370 | 9 | 0.377 | 9 | 0.388 | 10 | 0.415 | 10 | 0.425 | 10 | 0.247 | 10 |
| England | 0.521 | 5 | 0.520 | 5 | 0.511 | 5 | 0.512 | 5 | 0.503 | 5 | 0.496 | 5 | 0.489 | 5 | 0.486 | 5 | 0.482 | 6 | 0.565 | 5 |
| Europe | 0.513 | 6 | 0.511 | 6 | 0.503 | 6 | 0.505 | 6 | 0.497 | 6 | 0.492 | 6 | 0.487 | 6 | 0.486 | 6 | 0.483 | 5 | 0.469 | 7 |
| Canada | 0.494 | 7 | 0.494 | 7 | 0.488 | 7 | 0.488 | 7 | 0.482 | 7 | 0.478 | 7 | 0.473 | 7 | 0.473 | 7 | 0.470 | 7 | 0.517 | 6 |
| Singapore | 0.576 | 4 | 0.593 | 4 | 0.573 | 4 | 0.590 | 4 | 0.584 | 3 | 0.581 | 3 | 0.578 | 2 | 0.579 | 2 | 0.576 | 2 | 0.728 | 1 |
| Korea | 0.415 | 8 | 0.401 | 8 | 0.415 | 8 | 0.404 | 8 | 0.410 | 8 | 0.412 | 8 | 0.418 | 8 | 0.436 | 8 | 0.441 | 8 | 0.265 | 9 |

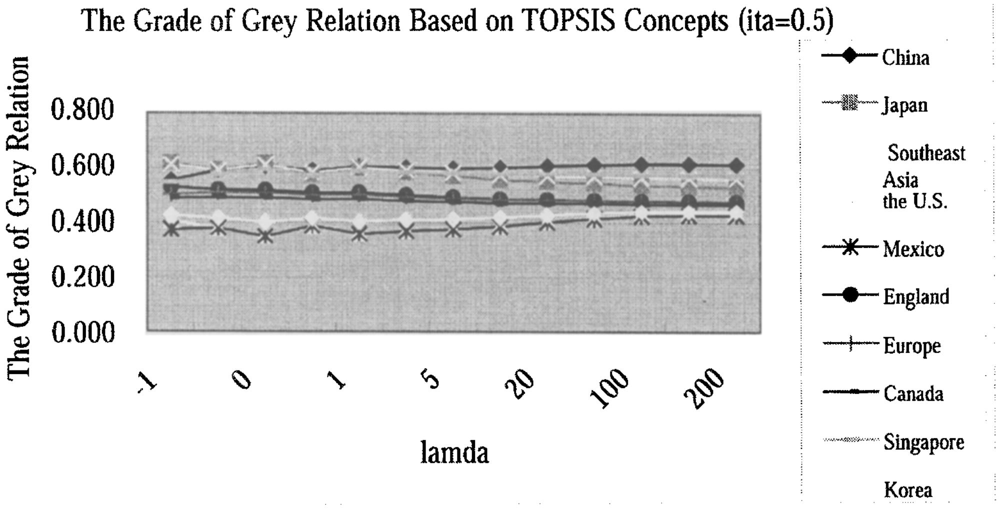

Figure 3. The grade of grey relation based on TOPSIS.

## 4.4. Calculating the Nonadditive Fuzzy Synthetic Utilities and the Grade of Grey Relation Based on TOPSIS

Because the criteria often interact with each other to different degrees, we use the nonadditive fuzzy integral technique to find the synthetic utilities of each alternative within the same aspect. Furthermore, based on the TOPSIS concepts, the coefficient of grey relation of each alternative to the ideal and negative ideal solution is computed by equations (16) and (17) with respect to alternatives. On the other hand, there is mutual independence between aspects, and the measurement is an additive case. Thus, we utilize the additive aggregate method to obtain the grade of grey relation by equations (18)–(20). Finally, we use equation (21) to rank the order of the host country alternatives following the grade of grey relation.

## 4.5. Discussions

In Section 2.3.1, we introduced the $\lambda$ values representing the properties of substitution between criteria, where $\lambda$ values are defined on interval $[-1, \infty)$. In general, picking up the distinguished coefficient $\zeta = 0.5$, we can then find the variation of the grade of grey relation for different $\lambda$ given. For each host country alternative, the grade of grey relations based on the concepts of TOPSIS with different $\lambda$ values is shown in Table 4 and Figure 3.

Where $\lambda < 0$, there is substitutive effect. For example, setting $\lambda = -0.5$ and defining $A \succ B$ means that $A$ outranks $B$, then we rank the grade of grey relation based on TOPSIS concepts, as follows: Japan $\succ$ U.S. $\succ$ China $\succ$ Singapore $\succ$ England $\succ$ Europe $\succ$ Canada $\succ$ Korea $\succ$ Mexico $\succ$ Southeast Asia. In addition, when $\lambda = 0$, there is an additive effect, and we rank the grade of grey relation based on TOPSIS concepts, as follows: Japan $\succ$ U.S. $\succ$ China $\succ$ Singapore $\succ$ England $\succ$ Europe $\succ$ Canada $\succ$ Korea $\succ$ Southeast Asia $\succ$ Mexico. Furthermore, when $\lambda > 0$, there are multiplicative effect cases. For instance, setting $\lambda = 10$, then we have the different outranking the grade of grey relation, as follows: China $\succ$ Singapore $\succ$ U.S. $\succ$ Japan $\succ$ England $\succ$ Europe $\succ$ Canada $\succ$ Korea $\succ$ Southeast Asia $\succ$ Mexico. We can segment the host country alternatives into three groups from the above observations of the grade of grey relations based on TOPSIS concepts, with the first group consisting of {China, Japan, U.S., Singapore}, the second group consisting of {England, Europe, Canada}, and the third group consisting of {Southeast Asia, Mexico, Korea}.

Though TOPSIS technique is easy to use for finding the "ideal" solution, which is composed of all best criteria values attainable, and the "negative-ideal" solution composed of all worst criteria value attainable by using the (weighted) Euclidean distance, however, this technique does not consider the interaction among the criteria, and there is only one preference order (see Table 4).

The results above are based on the overall preferences of the evaluators and we can apply this method to individual evaluators according to their own preferences to select their ideal expatriate host countries.

## 5. CONCLUSIONS

With the dramatic growth of the international business sector, the number of individuals working for business concerns outside their native country has increased greatly. However, foreign assignments have many differences, and dissatisfaction with the host country is a known cause of expatriate failure. Thus, better understanding of how expatriate candidates evaluate the related factors in a fuzzy decision-making environment and select the ideal host country based on their own subjective judgment is increasingly important.

This paper uses a fuzzy analytic hierarchy process to determine the weighting of subjective judgments and fuzzy integral to derive the performance values of each host country alternative. Based on TOPSIS, this paper further combines the grey relation model of grey system to implement FMCDM in order to understand how evaluators select an expatriate host country. We can segment the host country alternatives into three groups with the first group consisting of {China, Japan, U.S., Singapore}, the second group consisting of {England, Europe, Canada}, and the third group consisting of {Southeast Asia, Mexico, Korea}. Satisfactory results are found through the illustrative example.

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