

## Retraction

# Retracted: A Hybrid Model for Assessing the Performance of Medical Tourism: Integration of Bayesian BWM and Grey PROMETHEE-AL

### Journal of Function Spaces

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

- (1) Discrepancies in scope
- (2) Discrepancies in the description of the research reported
- (3) Discrepancies between the availability of data and the research described
- (4) Inappropriate citations
- (5) Incoherent, meaningless and/or irrelevant content included in the article
- (6) Peer-review manipulation

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

### References

- [1] C.-C. Yang, C.-C. Shen, T.-Y. Mao, H.-W. Lo, and C.-J. Pai, "A Hybrid Model for Assessing the Performance of Medical Tourism: Integration of Bayesian BWM and Grey PROMETHEE-AL," *Journal of Function Spaces*, vol. 2022, Article ID 5745499, 15 pages, 2022.

## Research Article

# A Hybrid Model for Assessing the Performance of Medical Tourism: Integration of Bayesian BWM and Grey PROMETHEE-AL

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Medical tourism (MT) is the activity of traveling domestically or abroad to receive medical services. The scope of medical treatments covers dentistry, surgery, antiaging procedures, preventive medicine, and even some health-related treatments (meditation, physiotherapy, psychotherapy, addiction treatment, psychiatry, etc.). Due to the global boom in MT, governments are actively promoting MT packages to capture this huge business opportunity. However, what are the key factors that make MT development successful or unsuccessful? How can the performance of current MT operators be evaluated? And, how can the performance of underperforming operators be improved? This paper addresses these questions by proposing a MT assessment framework that summarizes the potential key factors of MT. In addition, this study proposes a model that integrates the Bayesian Best-Worst Method (Bayesian BWM) and grey Preference Ranking Organization Method for Enrichment Evaluations based on Aspiration Level (grey PROMETHEE-AL) to assess the performance of assessed MT operators. The Bayesian BWM not only aggregates the judgments of multiple experts but also generates a set of objective group criteria weights. Besides, the modified PROMETHEE incorporates the grey theory and aspiration level concept to increase the usefulness of the original PROMETHEE. The results of the analysis show that the two most critical criteria for MT are “the operators have cloud computing systems to analyze the travelers’ sensor data in real-time and accurately to provide customized medical services” and “multilingualism and communication skills of medical travel-related personnel.” Poor performers in the travel industry can be improved by prioritizing the criteria in order of importance. The management implications of this study can be used as a basis for performance evaluation by operators and government health care organizations.

## 1. Introduction

Medical tourism (MT) is an emerging trend in the tourism industry, which has grown rapidly and become increasingly institutionalized in recent years [1]. MT refers to people traveling abroad to obtain medical care. This means that the patients who are unable to receive better treatment in less

developed countries go to medical centers in developed countries for treatment [2, 3]. The concept of MT is based on the economic activity of integrating the services provided by tourism and medical institutions. MT is already one of the most competitive industries in the world. Healthcare has been successfully packaged and marketed to cross-border consumers. In addition, the services offered by this industry

enable patients to receive quality healthcare at a lower cost and in a shorter waiting time for treatment [4]. The most common types of MT are for surgical procedures (e.g., plastic surgery), or similar treatments, in addition to dental- or fertility-related travel. Patients with rare diseases may also travel to countries with more advanced treatment techniques. MT is now available for almost all types of health care conditions, including psychiatry, alternative medicine, rehabilitation, and even funeral services.

According to a large amount of literature review [1–7], MT is a novel form of tourism, and it has become one of the fastest-growing international businesses in the tourism industry for developing countries. Medical tourism has been emerging as a particularly lucrative sector, potential tourist market, and global phenomenon in health care. Especially under the raging COVID-19 epidemic, as many countries lack medical resources, people seek medical services through medical tourism [8, 9].

Although there have been many attempts to develop MT in many countries, medical technology and tourism services have become the most important obstacles to overcome. Nilashi et al. [10] mentioned that the Malaysian MT industry still needs significant improvements in the performance of MT services to become a hub for international tourism and medical services. In addition, medical technology, tourism environment, management organization, and human factors all have a profound impact on the success or failure of MT development. However, what are the key factors for success or failure in MT development? How can the performance of current MT operators be identified? And, what can be done to improve the performance of underperforming operators?

To discuss the above issues, a MCDM model is proposed and four main dimensions, including information and technology, internal organizational management, external environmental impact, and health care services and resources, are aggregated, which can be subdivided into 17 criteria. In terms of methodology, the integration of Bayesian Best-Worst Method (Bayesian BWM) and grey Preference Ranking Organization Method for Enrichment Evaluations based on Aspiration Level (grey PROMETHEE-AL) model is proposed in this paper to determine the final performance of the assessed objects, and then rank them and suggest improvements. Bayesian BWM is a statistical probability model that aggregates the opinions of multiple experts [11], significantly improving the problem of the original BWM where each expert's data had to be calculated individually. The Bayesian BWM is used in the study to determine the group weights of four dimensions and 17 criteria. On the other hand, this study improves the PROMETHEE-AL method proposed by Ahmadi et al. [12], which does not take into account the problem of information uncertainty. We combine the grey theory with PROMETHEE-AL in which all assessed objects are expressed as semantic variables. Grey PROMETHEE-AL can calculate the net flow values of all assessed objects, i.e., an index of their performance. This study pioneers the use of the Bayesian BWM-grey PROMETHEE-AL model to discuss the development performance of MT. The sensitivity analysis and models comparison show that the model is applicable and reliable in the tourism medical issues.

The specific contributions and features of this study are summarized as follows:

- (i) This study proposes a novel performance assessment framework for MT, where all criteria are well defined and supported by the literature.
- (ii) Bayesian BWM is used to obtain the group weights of the criteria; Bayesian BWM overcomes the shortcomings of Analytic Hierarchy Process (AHP) and BWM by significantly reducing the number of pairwise comparisons of criteria and integrating the subjective opinions of multiple experts with a statistical probability scale [13].
- (iii) Grey PROMETHEE-AL is used to calculate the development performance of the assessed objects. Compared with other MCDM methods (e.g., Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), ViseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), Weighted Aggregated Sum Product Assessment (WASPAS), and Complex Proportional Assessment (COPRAS)), PROMETHEE uses a more rigorous two-by-two comparison of the assessed objects to obtain the final net flows (PROMETHEE's ranking index) [14]. In addition, the introduction of the grey theory can reflect the uncertainty of the experts in the assessment.
- (iv) We use sensitivity analysis to show the importance of criteria weight determination, meaning that the ranking results of the assessed objects change depending on the weights.
- (v) The proposed assessment framework and analytical model can be applied to other performance evaluation questions. The model can be used for analysis by simply adapting the criteria to the circumstances of the case.
- (vi) From the study, it is possible to identify which criteria are underperforming in the existing assessed objects and to prioritize improvements towards criteria with higher weights.

The remaining sections of the study are organized as follows. Section 2 describes the proposed framework for MT assessment, containing a description of the criteria definition and a review of the literature. Section 3 shows the proposed integrated MCDM model to detail the steps of Bayesian BWM and grey PROMETHEE-AL. Section 4 uses real data from the MT industry in Taiwan as a demonstration case of the method. In Section 5, sensitivity analysis, model comparison, and management implications are discussed. Finally, conclusions and future research directions are given.

## 2. Establishment of the MT Assessment Framework

MT is an emerging form of tourism and is one of the fastest-growing international businesses in many developing countries [10]. MT is a forward-looking industry that

combines high-quality medical services with tourism and has recently received increasing attention [15]. This study establishes the criteria for evaluating sustainable MT based on relevant academic literature on MT [16–26] and discussion with experts in the tourism and hospitality industries to assess the critical success factors of MT. After several rounds of discussions with the experts, we finally selected 17 criteria that are most relevant to Taiwan's MT. These criteria are divided into 4 dimensions based on Nilashi et al.'s study [10]. First of all, it involves the integration of hardware implementation and information flow.

The main framework consists of four dimensions, namely, information and technology ( $D_1$ ), internal organization management ( $D_2$ ), external environmental impact ( $D_3$ ), and services and health care resources ( $D_4$ ). Each dimension is divided into a number of criteria, and a total of 17 assessment criteria are used to form the assessment framework, as shown in Table 1. The purpose of this study is to “assess the importance of critical factors for the success of MT” and “assess the development performance of existing MT operators.”

With the rapid development of information technology and the Internet, MT has become a global trend in healthcare services, and the demand for low-cost medical services is increasing [16]. Many countries have the advantage of advanced equipment and superior medical technology, which in turn attracts many foreign tourists to receive medical services.  $D_1$  is a necessary condition for the development of MT and its criteria include  $C_{11}$ ,  $C_{12}$ ,  $C_{13}$ , and  $C_{14}$ .  $C_{11}$  refers to the establishment of medical information systems in the tourism and hotel industry through effective information technology, and the provision of a consultation platform for tourists to seek medical treatment.  $C_{12}$  refers to the fact that the Internet has become an integral part of hospital accessibility [17]. The Internet is an important foundation and core of the Internet of Things (IoT), which is connected to the Internet through various wired and wireless networks to deliver accurate information and integrate sensors to track the status of travelers and monitor the safety of their environment in real time [18].  $C_{13}$  refers to hospitals with international standard treatment centers with certified physicians and advanced technology [19], such as telemedicine and clinics, to support travelers [20].  $C_{14}$  refers to the current evolution of technology, which is moving towards 5G, and 5G cloud technology will play an important role in health, medical travel, security, and social life applications through the cloud, where wearable sensors are expected to be used to monitor and analyze traveler status and provide personalized care [21].

Quality management encompasses commitment from the highest management level, and from a management-level perspective, effective organizational capabilities of managers is an essential element of the quality improvement structure of health care organizations.  $D_2$  is one of the factors valued in the development of health tourism, and its criteria include  $C_{21}$ ,  $C_{22}$ ,  $C_{23}$ , and  $C_{24}$ . The practice area of health tourism management and development includes sustainability [22].  $C_{21}$  refers to the establishment of internal management processes to implement sustainable management.  $C_{22}$  refers

to the development of appropriate policies and regulations to stimulate investment and reduce the financial, operational, and other risks involved. Tourism resources and healthcare infrastructure play an important role in promoting the health tourism industry [16].  $C_{23}$  is the most basic assessment and refers to the use of advanced equipment, the provision of comprehensive care and prevention, the establishment of a national accreditation mechanism for health systems, and the international accreditation of hospitals with international standards of care to provide high-quality health services. Collaboration with strategic alliances of international medical organizations to obtain information and experience on MT in various countries ( $C_{24}$ ) is an essential part of this assessment.

Millions of travelers worldwide travel for medical purposes each year, and their primary motivations can be broadly categorized as seeking better quality care, lower cost of services, and faster access to medical services, all of which are influenced by macro policy issues [23].  $D_3$  includes  $C_{31}$ ,  $C_{32}$ ,  $C_{33}$ ,  $C_{34}$ , and  $C_{35}$ . When travelers benefit from better private medical services and the most advanced medical devices, it may lead to a double standard in the health care system, thus making better medical services available to travelers with better affordability and creating health disparities [23].  $C_{31}$  suggests that the government should pay more attention to the trade-off between its policies and the health of its citizens in the development of MT policies. The U.S. health care system is considered the most expensive in the world, and as a result, more and more Americans are becoming medical tourists seeking cheaper medical care [24].  $C_{32}$  refers to the goal of making NHI and malpractice insurance available to the entire population.  $C_{33}$  refers to the priority given to hospitals to provide better services to visitors who can bring more benefits to the hospital and who pay through non-NHI funds, i.e., nonnational visitors pay their fees [23].  $C_{34}$  refers to the understanding of the impact of hospitality on medical tourists [25], where the hotel has the advantage of providing services that are tailored to the needs of tourists, and if tourists give higher ratings, there is a good chance that the industry will attract investors. If medical factors are intrinsic to MT for tourists, tourism factors are environmental conditions that constitute the choice of destination for MT. Travel factors include the fact that the destination country is well developed in terms of transportation, shopping, and accommodation [19].  $C_{35}$  refers to the fact that more convenient transportation will attract more travelers to choose their itineraries.

Providers of healthcare services should adopt international service standards. Factors such as quality of service, medical expertise, and hospital hardware and equipment affect the motivation of medical travelers. The decision to seek care locally or abroad is based on the level of care provided [19].  $D_4$  includes  $C_{41}$ ,  $C_{42}$ ,  $C_{43}$ , and  $C_{44}$ .  $C_{41}$  refers to the provision of multilingual accommodation, treatment appointments, and follow-up services with medically knowledgeable interpreters and coordinators to assist travelers [15], and the need for destinations to meet travelers' needs in terms of communication.  $C_{42}$  refers to the cooperation with hotel operators in the tourism industry to

TABLE 1: The MT assessment framework proposed in this study.

Dimension	Criteria
Information and technology ( $D_1$ )	Tourism and hotel operators have a complete medical information system and consultation platform ( $C_{11}$ )
	Combination of wearable sensing devices and the Internet of things (IoT) to track travelers' physical and mental status and monitor the safety of the surrounding environment at any time ( $C_{12}$ )
	Provision of advanced medical technology and support, such as telemedicine and retail clinics, etc. ( $C_{13}$ )
	The operators have cloud computing systems to analyze the travelers' sensor data in real-time and to accurately provide customized medical services ( $C_{14}$ )
Internal organization management ( $D_2$ )	Management's support for MT and commitment to sustainable practices in corporate healthcare policy ( $C_{21}$ )
	Financial capability of the company, including profitability, operations, debt service, and risk tolerance ( $C_{22}$ )
	Provision of medical infrastructure ( $C_{23}$ )
External environmental impact ( $D_3$ )	Strategic alliances with international medical organizations to gain information and experience in travel medicine in various countries ( $C_{24}$ )
	The government's attitude and policy fairness towards travel medicine ( $C_{31}$ )
	National health care policy, including health care system and insurance services ( $C_{32}$ )
	Health care policy for nonnationals ( $C_{33}$ )
Services and health care resources ( $D_4$ )	The advantages and opportunities of tourism or hotel operators are enough to attract investors to invest in more favorable resources ( $C_{34}$ )
	Travel arrangements for travelers ( $C_{35}$ )
	Multilingualism and communication skills of medical travel-related personnel ( $C_{41}$ )
	Quality of services and safety facilities provided by the hotel ( $C_{42}$ )
	Professional medical care for travel itineraries, including treatment of illness, physical examination, rehabilitation follow-up, and recuperation care ( $C_{43}$ )
	Training operators with long-term medical education, hospital internship, and specialized examinations to ensure the professional quality of travel medical care ( $C_{44}$ )

provide real-time online response and care, comfortable resting places, and shuttle service to the airport to meet travelers' needs. According to the survey, the most satisfactory nonmedical services for ambulatory travelers to hospitals are those that provide information on travelers' conditions, treatment, and self-care [15].  $C_{43}$  is one of the factors that travelers value when visiting a destination for MT. The sustainability criteria to be considered in choosing a MT destination include enhancing the business capacity of the staff to serve the travelers and hiring experienced and well-trained staff [26].  $C_{44}$ , factors that influence travelers' choice of medical destination include the availability of doctors with training and special expertise to provide a more complete range of specialist services.

### 3. Proposed Hybrid Model: Integration of Bayesian BWM and Modified Grey PROMETHEE-AL

This section presents the proposed hybrid model that applies Bayesian BWM to determine the weights of the criteria and uses modified grey PROMETHEE-AL to calculate the performance of the assessed objects.

Bayesian BWM was proposed by Mohammadi and Rezaei [11], which improves the multiexpert integration problem of the original BWM approach. In the past, the original BWM processed data from multiple experts by averaging the results of each expert's analysis to produce a final set of weights. Bayesian BWM constructs a statistical probability model from the perspective of decision science

and deduces the integration opinions of multiple experts from the probability distribution to assign the most appropriate group weights to the criteria. Many studies on weighting issues have been discussed using Bayesian BWM, e.g., occupational health, safety, and environmental risk assessment [27], safety analysis of process systems [28], and airport resilience mensuration [14].

On the other hand, this study improves the PROMETHEE-AL method proposed by Ahmadi et al. [12]. Many previous studies did not take into account the concept of aspiration level and only found "relatively good ideal solutions among the existing assessed objects as a reference point," ignoring the difference with the real benchmark solution (aspiration level). This means "picking a relatively good apple out of a basket of bad apples." Therefore, they incorporated the concept of aspiration level in PROMETHEE to know explicitly how far from the aspiration level each assessed object was. Unfortunately, their study did not take into account the problem of information uncertainty. In the present study, we combine the grey theory in PROMETHEE-AL, and all assessed objects are expressed in terms of semantic variables. In addition, we use the results of the criteria weights generated by Bayesian BWM as one of the input parameters of grey PROMETHEE-AL to reflect the relative importance of each criterion. Detailed computational procedures and concepts of Bayesian BWM and modified grey PROMETHEE-AL are described in the following two subsections.

*3.1. Bayesian BWM.* Bayesian BWM has the same input data as the original BWM, which is designed to reduce the problem of the excessive number of pairwise comparisons of

AHPs. Assuming that there are  $n$  ( $j = 1, 2, \dots, n$ ) criteria in the assessment system, AHP needs to perform  $n(n-1)/2$  pairwise comparisons, while BWM only needs  $2n-3$  pairwise comparisons. Because the number of pairwise comparisons is significantly reduced, the logical/consistent results of BWM are better than those of AHP. In recent years, BWM has become popular in the field of multicriteria decision-making, where the information obtained is constructed into two structured vectors through expert interviews.

Since each expert may have different ideas and opinions, the resulting two vectors of information will have different meanings (when the experts choose different best and worst criteria). The general form of the MCDM weight vector is  $w_j = (w_1, w_2, \dots, w_n)$ , and it is required that the sum of the weights is 1 (i.e.,  $\sum_{j=1}^n w_j = 1$ ) and the weights must be greater than or equal to 0 (e.g.,  $w_j \geq 0$ ) [29]. The statistical probability model of Bayesian BWM is constructed following the above MCDM requirements, and the implementation process is described in the following steps [11]:

*Step 1.* Construct a framework of assessment criteria in line with the development trend of MT

Through literature review and expert discussion,  $n$  criteria ( $C_j, j = 1, 2, \dots, n$ ) that are identified as influential/important for the development of MT are summarized. These criteria can be assigned to several dimensions to form a hierarchical assessment framework.

*Step 2.* Select the most important criterion and compare it with other criteria

From the criteria identified in Step 1, the most important criterion is selected as the basis for comparison, and then the experts assess the relative importance of the best criterion to other criteria (on a scale of 1 to 9), and the resulting best-to-others vector (BO vector) is

$$A_{Bj} = (a_{B1}, a_{B2}, \dots, a_{Bn}). \quad (1)$$

where the symbol “subscript  $B$ ” indicates the most important criterion. Here,  $a_{BB}$  and  $a_{jj}$  are required to be 1 (the self-importance of the criteria is equal).

*Step 3.* Similar to Step 2, select the least significant criterion and compare the other criteria to the least significant criterion

This step differs from Step 2 in that we compare the others-to-worst vector (OW vector) to the least significant standard, resulting in

$$A_{jW} = (a_{1W}, a_{2W}, \dots, a_{nW})^T. \quad (2)$$

where the symbol “subscript  $W$ ” indicates the least important criterion. Similarly,  $a_{WW} = 1$  is also required.

*Step 4.* Calculate the group optimal weights for the criteria

*Step 4.1.* Parameter setting and construction of its probability distribution

Each criterion  $C_j$  has its corresponding weight, let it be  $w_j$ , and the weight vector is  $w = (w_1, w_2, \dots, w_n)$ . Assume that the criterion  $C_j$  is a random event, and  $w_j$  can be considered as the probability of  $C_j$  occurring. By such a statistical probability concept, BO and OW vectors ( $A_{Bj}$  and  $A_{jW}$ ) are probability models of the multinomial distribution. Undoubtedly, the contents of both vectors are positive integers, so the probability mass density function of  $A_{jW}$  is

$$P(A_{jW}|w) = \frac{(\sum_{j=1}^n a_{jW})!}{\prod_{j=1}^n a_{jW}!} \prod_{j=1}^n w_j^{a_{jW}}. \quad (3)$$

As defined in the multinomial distribution, the probability ( $w_j$ ) of  $C_j$  is the number of occurrences proportional to the total number of experiments, as

$$w_j \propto \frac{a_{jW}}{\sum_{j=1}^n a_{jW}}, \quad \forall j = 1, 2, \dots, n. \quad (4)$$

In addition, the probability ( $w_W$ ) of  $C_W$  can be written as

$$w_W \propto \frac{a_{WW}}{\sum_{j=1}^n a_{jW}} = \frac{1}{\sum_{j=1}^n a_{jW}}. \quad (5)$$

Therefore, the integration of  $w_j$  and  $w_W$  leads to equation (6), as

$$\frac{w_j}{w_W} \propto a_{jW}, \quad \forall j = 1, 2, \dots, n. \quad (6)$$

However, the concept generated by the BO vector is different from that of the OW vector. A larger element  $a_{Bj}$  in the BO vector means a smaller corresponding  $w_j$ ; on the contrary, a larger element  $a_{jW}$  in the BO vector means a larger corresponding  $w_j$ . Obviously, the elements of  $A_{Bj}$  should be converted to weights in the inverse relationship, as follows:

$$A_{Bj} \sim \text{multinomial}\left(\frac{1}{w_j}\right), \quad (7)$$

$$\frac{1}{w_j} \propto \frac{a_{Bj}}{\sum_{j=1}^n a_{Bj}}, \quad \forall j = 1, 2, \dots, n. \quad (8)$$

The probability ( $w_B$ ) of  $C_B$  can be written as

$$\frac{1}{w_B} \propto \frac{a_{BB}}{\sum_{j=1}^n a_{Bj}} = \frac{1}{\sum_{j=1}^n a_{Bj}} \Rightarrow \frac{w_B}{w_j} \propto a_{Bj}, \quad \forall j = 1, 2, \dots, n. \quad (9)$$

To satisfy the requirement that the sum of the weights is 1 and each weight is greater than or equal to 0, here, the model is constructed using the Dirichlet probability distribution as in equation (10). Equation (10) can be interpreted as the prior probability distribution of the weight vector  $w$ , where  $\alpha$  is set to 1. Then, the Bayesian estimation is performed based on the weight vector  $w$  of the Dirichlet distribution, and the model of the

posterior probability distribution is shown in equation (11), which can provide an accurate optimal approximation.

$$\text{Dir}(w|\alpha) = \frac{1}{B(\alpha)} \prod_{j=1}^n w_j^{\alpha_j-1}, \quad (10)$$

where  $\alpha$  is the vector parameter.

$$\mu_j = \frac{\alpha_{post,t_j} - 1}{\sum_{j=1}^n \alpha_{post,t_j} - n} = \frac{1 + a_{jW} - 1}{\sum_{j=1}^n (a_{jW} + 1) - n} = \frac{a_{jW}}{\sum_{j=1}^n a_{jW}}, \quad (11)$$

where  $\alpha_{post} = \alpha + A_W = 1 + A_W$  and  $A_W = (a_{jW}) = (a_{1W}, a_{2W}, \dots, a_{nW})$ .

*Step 4.2. Construction of the joint probability distribution*

In this study, there are  $k$  experts involved in decision-making,  $k = 1, 2, \dots, K$ . Then, the optimal weight vector

of individual experts can be denoted as  $w^k$  and the integrated group weight vector is denoted as  $w^{agg}$ . In addition,  $A_B^{1:K}$  and  $A_W^{1:K}$  are denoted as BO and OW vectors of expert 1 to expert  $k$ , respectively. The joint probability distribution of group decisions as follows:

$$P(w^{agg}, w^{1:K} | A_B^{1:K}, A_W^{1:K}). \quad (12)$$

*Step 4.3. Bayesian hierarchical model development and computation*

The input data are the individual optimal weight vectors  $w^k$  from the experts. The Bayesian hierarchical model is based on an iterative approach to continuously derive the optimal group weights  $w^{agg}$ . And,  $w^{agg}$  is generated when each  $w^k$  is input. Here, it can be determined that  $w^k$  is assumed to be independent, and the joint probability of the Bayesian model is equation (13). Further derivation of equation (13) yields equation (14).

$$P(w^{agg}, w^{1:K} | A_B^{1:K}, A_W^{1:K}) \propto P(A_B^{1:K}, A_W^{1:K} | w^{agg}, w^{1:K}) P(w^{agg}, w^{1:K}), \quad (13)$$

$$P(A_B^{1:K}, A_W^{1:K} | w^{agg}, w^{1:K}) P(w^{agg}, w^{1:K}) = P(w^{agg}) \prod_{k=1}^K P(A_W^k | w^k) P(A_B^k | w^k) P(w^k | w^{agg}). \quad (14)$$

A Dirichlet distribution can be constructed for  $w^k$  under  $w^{agg}$  conditions, as follows:

$$w^k | w^{agg} \sim \text{Dir}(\gamma \times w^{agg}), \quad \forall k = 1, 2, \dots, K, \quad (15)$$

where  $\gamma$  is a nonnegative parameter. As can be seen from the Dirichlet distribution presented in equation (15),  $w^k$  approximates  $w^{agg}$  to the mean of the probability distribution (the parameter  $\gamma$  determines the degree of approximation). Finally,  $w^{agg}$  obeys the Dirichlet distribution, with the parameter  $\alpha$  set to 1.

$$w^{agg} \sim \text{Dir}(\alpha). \quad (16)$$

The probability distributions of these parameters have been constructed, including  $w_j, w_W, w_B, w^k$ , and  $w^{agg}$ . Finally, Markov Chain Monte Carlo (MCMC) is used to simulate the posterior probability distributions of  $w^{agg}$  many times, and the optimal criterion group weights can be inferred.

*Step 4.4. Ranking Confidence test*

After determining the optimal group weights of the criteria through Bayesian BWM, a ranking confidence test must be performed.

The ranking confidence test provides an understanding of the consistency of all experts' assessment of the importance of the criteria. Therefore, Credal Ranking is used to examine the confidence in the ranking of its criteria. For

example, for two criteria  $C_i$  and  $C_j$ , the probability that  $C_i$  is more important than  $C_j$  is

$$P(c_i > c_j) = \int I(w_i^{agg} > w_j^{agg}) P(w^{agg}). \quad (17)$$

The posterior probability of  $w^{agg}$  is  $P(w^{agg})$ . In addition,  $I$  is a conditional parameter, and  $I$  is 1 when  $w_i^{agg} - w_j^{agg} > 0$  is true. Furthermore, when there are  $Q$  samples, the probability that  $C_i$  is more important than  $C_j$  is

$$P(c_i > c_j) = \frac{1}{Q} \sum_{q=1}^Q I(w_i^{agg_q} > w_j^{agg_q}), \quad (18)$$

$$P(c_j > c_i) = \frac{1}{Q} \sum_{q=1}^Q I(w_j^{agg_q} > w_i^{agg_q}).$$

Here,  $P(c_i > c_j) + P(c_j > c_i) = 1$ .

*3.2. Grey PROMETHEE-AL.* The PROMETHEE technique must perform multiple comparisons (pairwise comparisons of assessed objects) to obtain the final integration score (net flow). Compared to other MCDM methods, PROMETHEE is a more rigorous but also more complex procedure. Ahmadi et al. [12] proposed a novel PROMETHEE-AL to improve the traditional PROMETHEE technique. Their study emphasizes the importance of not just picking a relatively good apple from a basket of apples, but finding a benchmark solution as the aspiration level. In this way, it is

possible to know how far all the assessed objects fall short of the benchmark. However, their study did not take into account the problem of information uncertainty and ambiguity in the complex assessment environment. Therefore, this paper adds the grey theory to the PROMETHEE-AL technique to optimize the PROMETHEE-AL technique, which we refer to as the grey PROMETHEE-AL. PROMETHEE-AL can be summarized in the following steps:

*Step 1.* Build the initial decision matrix

The experts measure the performance of the assessed objects according to the established assessment criteria, assuming that there are  $j$  criteria and  $i$  assessed objects in the assessment system, where  $j = 1, 2, \dots, n$ ;  $i = 1, 2, \dots, m$ . The experts judge the performance of the assessed objects and assign an assessment scale from VP (very poor performance) to  $E$  (excellent performance), as shown in Table 2, with higher scores indicating better performance. Here, we have 12 experts discussing the initial decision values of all the assessed objects, which can be obtained from the initial decision matrix  $A$ , as shown in the following equation:

$$\otimes A = \begin{bmatrix} \otimes a_{11} & \otimes a_{12} & \cdots & \otimes a_{1n} \\ \otimes a_{21} & \otimes a_{22} & \cdots & \otimes a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \otimes a_{m1} & \otimes a_{m2} & \cdots & \otimes a_{mn} \end{bmatrix}_{m \times n}, \quad (19)$$

where  $\otimes A = [\otimes a_{ij}]_{m \times n}$  and  $\otimes a_{ij} = [a_{ij}^{lower}, a_{ij}^{upper}]$ .

*Step 2.* Determine the aspiration and worst levels of each criterion

In the past, positive and negative ideals were developed based on the maximum and minimum values of the performance of the assessed objects, as in equations (20) and (21). The ranking of the assessed objects can be obtained through this approach, but not the real existing room for improvement. Therefore, in this paper, the maximum value ( $E$ , [4, 5]) and the minimum value (VP, [0, 0]) of the assessment scale are set as aspiration and worst levels, as in equations (22) and (23), respectively. In the algorithm of PROMETHEE, not only are the aspiration and worst levels used as the basis for normalization but also the two levels are treated as assessed objects. In this way, it can be determined as to how far each of the assessed objects are from the aspiration level, and then effective improvement measures can be developed. Here, we consider the aspiration level and the worst level as two assessed objects.

Positive ideal:

$$a_i^* = \max_i \otimes a_{ij} | i = 1, 2, \dots, m; j = 1, 2, \dots, n. \quad (20)$$

Negative ideal:

$$a_i^- = \min_i \otimes a_{ij} | i = 1, 2, \dots, m; j = 1, 2, \dots, n. \quad (21)$$

TABLE 2: Linguistic variables and grey numbers of grey PROMETHEE-AL.

Linguistic variables	Crisp numbers	Grey numbers
Very poor (VP)	0	[0, 0]
Poor (P)	1	[0, 1]
Medium (M)	2	[1, 2]
Good (G)	3	[2, 3]
Very good (VG)	4	[3, 4]
Excellent (E)	5	[4, 5]

With the introduction of the concept of aspiration level into PROMETHEE technology, the positive and negative ideals change from equations (20) and (21) to equations (22) and (23), respectively.

The aspiration levels:

$$\otimes a_j^{asprie} = (\otimes a_1^{asprie}, \otimes a_2^{asprie}, \dots, \otimes a_n^{asprie}). \quad (22)$$

The worst levels:

$$\otimes a_j^{worst} = (\otimes a_1^{worst}, \otimes a_2^{worst}, \dots, \otimes a_n^{worst}). \quad (23)$$

*Step 3.* Calculate the normalized decision matrix

PROMETHEE has six basic preference functions. This study uses the Type V preference function ‘‘Criterion with Linear Preference and Indifference Area’’ as the formula for normalization (called Degree of Preference for All Alternatives for Each Criterion in PROMETHEE terminology). Through normalization, the range of all assessment values can be converged between 0 and 1, and the units of the criteria can be unified. Equation (24) is the normalized decision matrix, and the normalized formula used is equation (25).

$$\otimes F = \begin{bmatrix} \otimes f_{11} & \otimes f_{12} & \cdots & \otimes f_{1n} \\ \otimes f_{21} & \otimes f_{22} & \cdots & \otimes f_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \otimes f_{m1} & \otimes f_{m2} & \cdots & \otimes f_{mn} \end{bmatrix}_{m \times n}, \quad (24)$$

where  $\otimes F = [\otimes f_{ij}]_{m \times n}$  and  $\otimes f_{ij} = [f_{ij}^{lower}, f_{ij}^{upper}]$

$$\otimes f_{ij} = \frac{\otimes a_{ij}}{\otimes a_j^{asprie}}. \quad (25)$$

*Step 4.* Compute the preference function of the assessed objects under each criterion

We define a preference function  $\otimes S_j(u, v)$  to indicate the degree of superiority of the assessed object  $u$  over the assessed object  $v$  under the criterion  $j$ , as shown in equation (26).

$$\otimes S_j(u, v) = \begin{cases} 0, & \otimes f_{uj} - \otimes f_{vj} \leq \otimes f_j^{worst}, \\ \otimes f_{uj} - \otimes f_{vj}, & \otimes f_j^{worst} < \otimes f_{uj} - \otimes f_{vj} \leq \otimes f_j^{asprie}, \\ 1, & \text{otherwise.} \end{cases} \quad (26)$$



In this step, we de-greay  $\otimes S_j(u, v)$  (i.e.,  $(S_j(u, v)^{lower} + \otimes S_j(u, v)^{upper})/2$ ) to obtain  $S_j(u, v)$ .

*Step 5.* Generate multicriteria preference index for each alternative

Since the assessment criteria are numerous and not equally important, this step combines the optimal weights  $w_j$  of Bayesian BWM with the preference function  $S_j(u, v)$  obtained in Step 4 to obtain the multicriteria preference index  $\pi(u, v)$ , where index  $\pi(u, v)$  indicates the degree of dominance of the assessed object  $u$  over the assessed object  $v$  in the overall performance, as shown in equation (27).

$$\pi(u, v) = \sum_{j=1}^n w_j \pi_j(u, v). \quad (27)$$

*Step 6.* Obtain the net flow for all assessed objects

How well all the assessed objects perform can be distinguished based on the multi-criteria preference index. We can calculate three flows of assessed objects to rank them, including leaving flow  $\theta^+(u)$ , entering flow  $\theta^-(u)$ , and net flow  $\theta(u)$ , which are denoted by equations (28)–(30), respectively.

The leaving flow:

$$\theta^+(u) = \sum_{v=1}^z \pi(u, v), \quad (28)$$

The entering flow:

$$\theta^-(u) = \sum_{v=1}^z \pi(v, u), \quad (29)$$

The net flow:

$$\theta(u) = \theta^+(u) - \theta^-(u), \quad (30)$$

where  $z$  denotes the total number of times the assessed object  $u$  compares with the assessed object  $v$ . Suppose there are 3 assessed objects, then  $z$  is 2 ( $n - 1$ ) times. The greater the net flow of the assessed object, the better the assessed object outperforms the others.

## 4. Empirical Example

*4.1. Problem Description.* With the rise in the awareness of medical care, people are traveling to hot spring areas to get water and soak in hot springs to relieve their physical and mental stress, intending to promote health, mental health, and recovery. Gradually, people are combining medical services with tourism to make it more concrete, and this development has become the prototype of the MT market. In addition to the abovementioned changes in people's health needs, some countries have been driven by inadequate medical services, long waiting times for medical treatment, expensive medical services, or insurance coverage for overseas medical treatment, which have prompted many people with medical needs to choose an overseas medical

service system that offers high-quality medical services at low medical costs. Overseas medical treatment can also be combined with some travel to meet the cultural experience of a country. This trend of MT has become the economic lifeblood of many countries and has led to the development of the MT industry in the Asia-Pacific region.

In Taiwan, many travel industry operators have recognized the huge business opportunities that MT offers and are working with medical institutions to develop integrated MT solutions. The Taiwanese government has also promoted a number of measures to sharpen the competitive edge of the tourism industry, including relaxing advertising and marketing restrictions for medical institutions, providing guidance to domestic medical institutions on international medical quality certification, upgrading international service capabilities, and adjusting regulations for foreigners traveling to Taiwan for medical services. In recent years, the travel industry is optimistic about the development of MT in Taiwan. The industry agrees that the development of MT can not only bring substantial industrial benefits to Taiwan but also achieve the function of international marketing. However, there are many challenges facing the development of MT, mainly including budgeting, legal sources and regulations, and poor promotion.

We surveyed seven MT companies in Taiwan. This study developed a framework for assessing tourism health care to evaluate the performance of the industry and provide recommendations for improvement. A team of 12 experts from the tourism industry, the tourism board, and the health care sector was invited to participate in the study, and the backgrounds and work experiences of the team members are presented in Table 3. These experts have considerable influence on the development of MT in Taiwan. They have operated several MT itineraries for many years. The seven companies are located in the northern and central parts of Taiwan, and they have specific customer groups and diverse travel plans. Therefore, a complete assessment model is needed to measure their MT development performance, and to formulate appropriate improvement strategies in order to obtain better and professional medical services. The performance scores of the seven MT companies were jointly assessed by the expert team.

The proposed model requires two forms of data survey, namely, Bayesian BWM questionnaire and performance questionnaire. During the interview, the researcher explained to the experts in detail how to fill in the two questionnaires. The time for each expert interview is limited to four hours, and there are four breaks during the process to avoid expert fatigue and erroneous judgments. Each expert's interview location and time are different, so the opinions of each expert will not affect others. After all the questionnaires filled out by experts have confirmed that the content is correct, we can perform Bayesian BWM and Grey PROMETHEE-AL calculations.

*4.2. Applying the Bayesian BWM to Determine the Criteria Weights.* After the expert team learned about the BWM questionnaire filling process in the round table meeting, the

TABLE 3: Background information of 12 experts.

Experts	Category	Degree	Years of working experience
No. 1	Operator	Master	More than 20
No. 2	Operator	Bachelor	13
No. 3	Operator	Master	15
No. 4	Operator	Master	15
No. 5	Operator	Bachelor	More than 20
No. 6	Operator	Master	16
No. 7	Tourism bureau	Master	18
No. 8	Tourism bureau	Bachelor	More than 20
No. 9	Tourism bureau	Bachelor	8
No. 10	Medical institution	Bachelor	More than 20
No. 11	Medical institution	Ph.D.	10
No. 12	Medical institution	Master	7

experts separately assessed the importance of the criteria. Taking dimensions as an example, each expert selected the most important and least important criterion, and compared them with other criteria in pairs. The results of the answers are shown in Table 4. The data in Table 4 can be directly calculated by the Bayesian BWM algorithm (MATLAB software) provided by Mohammadi and Rezaei [11] to calculate the optimal group weight of the criterion, as shown in Table 5. In the dimension part, the weight value of  $D_4$  is the highest, which is 0.291. The criteria under each dimension are  $C_{14}$ ,  $C_{21}$ ,  $C_{34}$ , and  $C_{41}$ , which are the most important. If a comprehensive assessment framework is considered, the top five criteria for ranking are  $C_{14}$ ,  $C_{41}$ ,  $C_{43}$ ,  $C_{44}$ , and  $C_{13}$ .

Compared with the original BWM, the assessment data of 12 experts do not need to perform BWM calculations separately, but only need to be input into the MATLAB program to estimate the optimal group weight. In addition, in order to check that the analysis results of Bayesian BWM are in line with the expectations of 12 experts, a ranking confidence test is performed here. Similarly, taking dimensions as an example, the ranking confidence matrix is shown in Table 6. For example, the confidence that  $D_1$  is more important than  $D_2$  is 91.12%, which means that  $D_1$  has a 90% probability of ranking higher than  $D_2$ . Conversely, the confidence that  $D_2$  is more important than  $D_1$  is 8.89% (100%–91.12%). In addition, Bayesian BWM also provides the optimal individual weights for each expert. When the experts' judgment consensus is higher, the generated individual weight gaps are smaller, as shown in Figure 1.

**4.3. Using the PROMETHEE-AL to Calculate the Performance of the Assessed Objects.** Twelve experts jointly assessed the performance of each assessed object under each criterion, as shown in Table 7. For example,  $A_1$  performs as Poor (P) in  $C_{11}$ , and so on, up to the last criterion  $C_{44}$ . Table 8 shows the leaving flow and the entering flow of the assessed objects, with the better performing assessed objects having a higher leaving flow and a lower entering flow. It is worth mentioning that since we consider the aspiration level and the worst level as the assessed objects, it is obvious that the aspiration level will have the largest leaving flow and, conversely, the worst level will have the largest entering flow.

Table 9 shows the results of the grey PROMETHEE-AL analysis, where we can see the net flow of each assessed object and its rank. The best MT development performance is  $A_6$ , which has the highest net flow of 0.887. Here, assessed objects with negative net flows are in the relatively poor group. If they want to make significant improvements, they can first develop improvement strategies for the criteria with higher weights. The results of the grey PROMETHEE-AL are further presented graphically in Figure 2. Although  $A_6$  is the best among the existing MT industry, there is still a significant gap between them and the aspiration level. On the other hand,  $A_1$  and  $A_5$  are relatively underperforming companies that need to re-examine their current capabilities to develop into MT-oriented travel agencies.

## 5. Results and Discussion

To understand whether the weights of the criteria are sensitive to the proposed mixture model, we performed nine sensitivity analyses to observe the differences in the ranking of the assessed objects. The results of the Bayesian BWM showed that  $D_4$  was the most important dimension. Therefore, nine analyses were performed for  $D_4$  from 0.1 to 0.9, and the weights of the other dimensions were adjusted in the same proportion as the criteria. The sum of the weights for each sensitivity performed is required to be 1, as shown in Table 10. The results of the sensitivity analysis can be presented in Table 11 and Figure 3. There is no systematic pattern in the overall ranking of the assessed objects when the  $D_4$  weight is changed from 0.1 to 0.4. That is, the change in weight does affect the overall ranking results. Therefore, the process of using Bayesian BWM to determine the weights of the criteria is necessary.

In this paper, we compare the original PROMETHEE-AL with the proposed grey PROMETHEE-AL. Table 12 presents the net flow and ranking results. The original PROMETHEE-AL does not take into account the uncertainty of the experts in the assessment. In contrast, the grey PROMETHEE-AL is more complex, but it reflects the ambiguity of information and the analysis results are more objective.

The top five criteria in order of importance are  $C_{14}$ ,  $C_{41}$ ,  $C_{43}$ ,  $C_{44}$ , and  $C_{13}$ . This echoes the concepts advocated in past

TABLE 4: Taking dimensions as an example: BO and OW vectors of 12 experts (OW vectors have been transposed).

Expert	Vector	$D_1$	$D_2$	$D_3$	$D_4$
Expert 1	BO vector	1	3	2	1
	OW vector	3	1	2	3
Expert 2	BO vector	1	1	1	4
	OW vector	4	4	4	1
Expert 3	BO vector	1	3	1	2
	OW vector	3	1	3	2
Expert 4	BO vector	1	2	3	2
	OW vector	1	2	1	2
Expert 5	BO vector	1	3	2	1
	OW vector	3	1	2	3
Expert 6	BO vector	1	3	2	1
	OW vector	3	1	2	3
Expert 7	BO vector	5	3	1	2
	OW vector	1	2	5	3
Expert 8	BO vector	2	2	3	1
	OW vector	2	2	1	3
Expert 9	BO vector	2	2	3	1
	OW vector	2	2	1	3
Expert 10	BO vector	5	2	3	1
	OW vector	1	3	2	5
Expert 11	BO vector	1	1	2	1
	OW vector	2	2	1	2
Expert 12	BO vector	1	5	2	3
	OW vector	5	1	3	2

TABLE 5: Weights of dimensions and criteria.

Dimension	Local weight	Rank	Criteria	Local weight	Rank	Global weight	Rank
$D_1$	0.270	2	$C_{11}$	0.259	3	0.070	6
			$C_{12}$	0.160	4	0.043	16
			$C_{13}$	0.264	2	0.071	5
			$C_{14}$	0.317	1	0.086	1
$D_2$	0.200	4	$C_{21}$	0.271	1	0.054	9
			$C_{22}$	0.245	3	0.049	12
			$C_{23}$	0.232	4	0.046	13
			$C_{24}$	0.252	2	0.050	10
$D_3$	0.239	3	$C_{31}$	0.171	5	0.041	17
			$C_{32}$	0.209	2	0.050	11
			$C_{33}$	0.182	4	0.043	15
			$C_{34}$	0.251	1	0.060	7
			$C_{35}$	0.187	3	0.045	14
$D_4$	0.291	1	$C_{41}$	0.286	1	0.083	2
			$C_{42}$	0.194	4	0.056	8
			$C_{43}$	0.261	2	0.076	3
			$C_{44}$	0.260	3	0.075	4

TABLE 6: Confidence in the ranking of dimensions.

	$D_1$ (%)	$D_2$ (%)	$D_3$ (%)	$D_4$ (%)
$D_1$	—	91.12	71.49	36.74
$D_2$	8.89	—	21.67	4.76
$D_3$	28.51	78.32	—	18.29
$D_4$	63.26	95.24	81.71	—

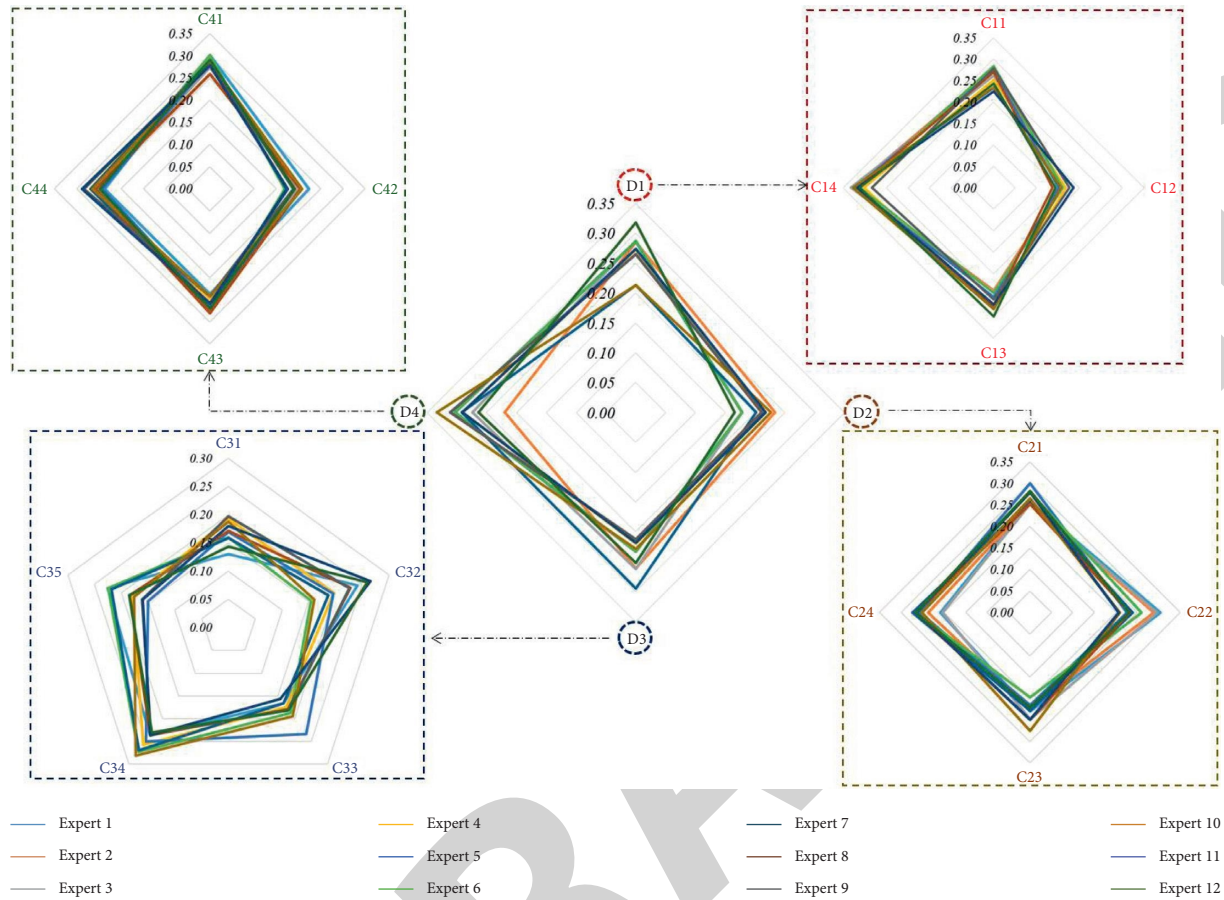


FIGURE 1: The consensus of the importance of the nine experts' assessment of the dimensions.

TABLE 7: Performance assessment of the assessed objects under each criterion.

	C <sub>11</sub>	C <sub>12</sub>	C <sub>13</sub>	C <sub>14</sub>	C <sub>21</sub>	C <sub>22</sub>	C <sub>23</sub>	C <sub>24</sub>	C <sub>31</sub>	C <sub>32</sub>	C <sub>33</sub>	C <sub>34</sub>	C <sub>35</sub>	C <sub>41</sub>	C <sub>42</sub>	C <sub>43</sub>	C <sub>44</sub>
A <sub>1</sub>	P	VP	VP	VP	G	G	P	P	P	E	P	P	E	P	P	G	P
A <sub>2</sub>	G	G	M	M	G	E	P	G	G	G	G	G	E	VG	VG	VG	G
A <sub>3</sub>	M	G	G	G	G	VG	G	G	G	VG	G	G	G	VG	G	G	G
A <sub>4</sub>	M	M	M	G	E	E	M	M	M	E	M	G	E	G	E	G	M
A <sub>5</sub>	M	P	M	P	P	M	P	P	M	G	M	E	G	G	G	G	M
A <sub>6</sub>	M	M	G	G	G	G	M	G	G	VG	VG	G	VG	VG	VG	G	VG
A <sub>7</sub>	M	M	G	G	G	G	VG	VG	VG	VG	G	G	VG	G	VG	G	M
Aspiration	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E	E
Worst	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP	VP

TABLE 8: Entering flows and leaving flows of the assessed objects.

	A1	A2	A3	A4	A5	A6	A7	Aspiration	Worst	Leaving flow
A <sub>1</sub>	—	0.022	0.031	0.000	0.078	0.021	0.021	0.000	0.246	0.420
A <sub>2</sub>	0.361	—	0.077	0.108	0.266	0.075	0.110	0.000	0.584	1.582
A <sub>3</sub>	0.361	0.067	—	0.102	0.257	0.031	0.056	0.000	0.575	1.451
A <sub>4</sub>	0.320	0.089	0.092	—	0.247	0.080	0.080	0.000	0.565	1.474
A <sub>5</sub>	0.151	0.000	0.000	0.000	—	0.000	0.000	0.000	0.318	0.469
A <sub>6</sub>	0.369	0.084	0.049	0.109	0.275	—	0.062	0.000	0.593	1.542
A <sub>7</sub>	0.348	0.098	0.054	0.088	0.254	0.041	—	0.000	0.572	1.456
Aspiration	0.754	0.416	0.425	0.435	0.682	0.407	0.428	—	1.000	4.546
Worst	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	—	0.000
Entering flow	2.664	0.777	0.728	0.842	2.060	0.656	0.758	0.000	4.454	

TABLE 9: Results of Grey PROMETHEE-AL analysis.

	A1	A2	A3	A4	A5	A6	A7	Aspiration	Worst
Leaving flow	0.420	1.582	1.451	1.474	0.469	1.542	1.456	4.546	0.000
Entering flow	2.664	0.777	0.728	0.842	2.060	0.656	0.758	0.000	4.454
Net flow	-2.244	0.805	0.723	0.632	-1.591	0.887	0.698	4.546	-4.454
Ranking	7	2	3	5	6	1	4		

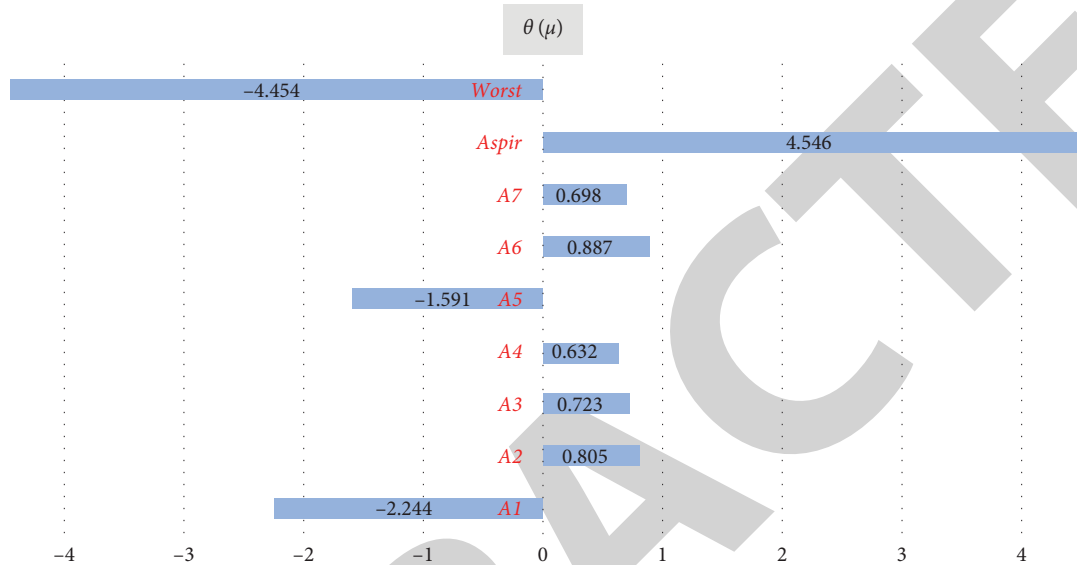


FIGURE 2: The difference between the 7 assessed objects and the aspiration level.

TABLE 10: Weight assignments for performing nine sensitivity analyses.

Dimension	$D_1$	$D_2$	$D_3$	$D_4$
Bayesian BWM	0.2704	0.2004	0.2386	0.2906
Run 1	0.3430	0.2543	0.3027	0.1
Run 2	0.3049	0.2260	0.2691	0.2
Run 3	0.2668	0.1978	0.2354	0.3
Run 4	0.2287	0.1695	0.2018	0.4
Run 5	0.1906	0.1413	0.1682	0.5
Run 6	0.1525	0.1130	0.1345	0.6
Run 7	0.1143	0.0848	0.1009	0.7
Run 8	0.0762	0.0565	0.0673	0.8
Run 9	0.0381	0.0283	0.0336	0.9

literature [30–33]. For example, travel operators should build a complete cloud computing system so that they can analyze travelers’ data from sensors in real time to provide customized medical services. In addition, MT personnel should be multilingual, so that the scope of services can be expanded to more developing countries. In the course of travel itineraries, personalized medical professionals are also needed to assist in the treatment of illnesses, physiological examinations,

rehabilitation tracking, and recuperation care. In terms of education and training, companies should train operators with long-term medical education, hospital internships, and specialized examinations to ensure the professional quality of travel medicine. Finally, companies should collaborate with medical institutions to achieve cross-sector alliances to provide more advanced medical technology and support, such as telemedicine and retail clinics.

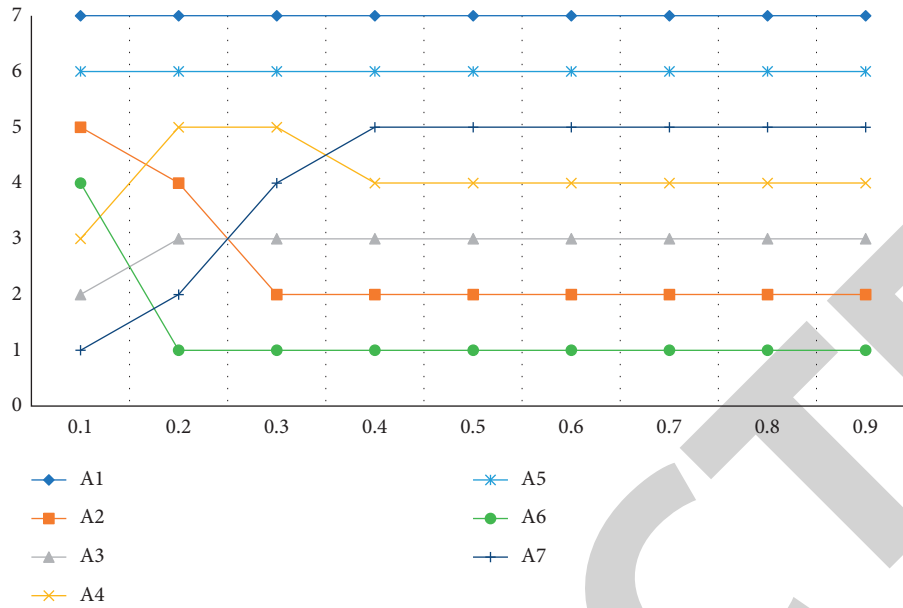


FIGURE 3: Broken line graph of the assessed objects in the sensitivity analysis.

TABLE 11: Ranking results of assessed objects after nine sensitivity analyses.

	Run 1 0.1	Run 2 0.2	Run 3 0.3	Run 4 0.4	Run 5 0.5	Run 6 0.6	Run 7 0.7	Run 8 0.8	Run 9 0.9
A1	7	7	7	7	7	7	7	7	7
A2	5	4	2	2	2	2	2	2	2
A3	2	3	3	3	3	3	3	3	3
A4	3	5	5	4	4	4	4	4	4
A5	6	6	6	6	6	6	6	6	6
A6	4	1	1	1	1	1	1	1	1
A7	1	2	4	5	5	5	5	5	5

TABLE 12: Comparison of grey PROMETHEE-AL and PROMETHEE-AL.

		A1	A2	A3	A4	A5	A6	A7
Grey PROMETHEE-AL	Net flow	-2.244	0.805	0.723	0.632	-1.591	0.887	0.698
	Ranking	7	2	3	5	6	1	4
Original PROMETHEE-AL	Net flow	-2.010	0.609	0.736	0.710	-1.062	0.702	0.878
	Ranking	7	5	2	3	6	4	1

### 6. Conclusions and Further Work

Many countries are committed to integrating medical technology and tourism services to provide MT planning and itineraries. However, medical technology, tourism environment, management organization, and human factors all have a profound impact on the success or failure of MT development. What are the criteria for evaluating MT, what models are suitable for evaluating the assessed objects, and how to improve the MT industry with poor performance, are the areas of research focus of this paper. We proposed a hybrid model that integrates the Bayesian BWM and the grey PROMETHEE-AL to determine the weight of the criteria, calculates the final performance of the assessed objects, and then ranks them. Based on the analysis results,

we suggest that the MT industry must pay attention to the following indexes: (i) the operators have cloud computing systems ( $C_{14}$ ); (ii) multilingualism and communication skills of medical travel-related personnel ( $C_{41}$ ); (iii) professional medical care for travel itineraries ( $C_{43}$ ); (iv) training operators with long-term medical education, hospital internship, and specialized examinations ( $C_{44}$ ); and provision of advanced medical technology and support ( $C_{13}$ ). In terms of the assessed objects, A2, A3, A4, A6, and A7 are relatively well-developed companies in MT, but they still need continuous improvement to reach the aspiration level. On the other hand, A1 and A5 are underperforming assessed objects, because they are rated as P (poor) in many criteria. Therefore, in addition to improving the top five important criteria, they should also improve the criteria for rating P.

This study pioneers the application of the Bayesian BWM-grey PROMETHEE-AL model to discuss the development performance of MT. While most prior studies applied statistics and qualitative researches (e.g., structural equation modeling (SEM) [34], grounded theory approach [4], and social cognition models [35]) to evaluate the development performance of MT, we provide an alternative tool to explore the performance evaluation of MT. The performance evaluation issues herein comprise a MCDM problem with many tangible and intangible factors. There have been many documents confirming that the MCDM methods are effective in dealing with multi-conflict/constraint criteria decision-making problems [36, 37], and our research also echoes this statement.

In the future, tourism industry developers who develop MT can review their company's development performance based on our proposed framework. In terms of methodology, as long as decision-making problems involving performance assessment are involved, our model can be used to solve decision-making problems. Academic researchers can also use our model as a basis for improvement and to incorporate other fuzzy theories into the model.

One limitation of this paper is that the results are based on a single assessment model (integration of Bayesian BWM and grey PROMETHEE-AL). Therefore, the findings are sensitive to the models' assumptions for the assessed objects' MT assessment. Another limitation relates to the decision framework. Each dimension can have several criteria for deep and accurate analysis and assessment. We suggest that future researchers can adjust the assessment criteria according to the local tourism development status.

## Abbreviations

Acronym:	Nomenclature
MT:	Medical tourism
Bayesian BWM:	Bayesian best-worst method
Grey PROMETHEE-AL:	Grey preference ranking organization method for enrichment evaluations based on aspiration level
AHP:	Analytic hierarchy process
MCDM:	Multiple criteria decision-making
TOPSIS:	Technique for order preference by similarity to ideal solution
VIKOR:	VIseKriterijumska Optimizacija I Kompromisno Resenje
WASPAS:	Weighted aggregated sum product assessment
COPRAS:	Complex proportional assessment
IoT:	Internet of things
BO:	Best-to-others
OW:	Others-to-worst.

## Data Availability

All data generated or analyzed during the study are included in this published article.

## Conflicts of Interest

The authors declare no conflicts of interest.

## Authors' Contributions

C.-C.Y. conceptualized the study; H.-W.L. and C.-C.S. were in charge of methodology; T.-Y. M. was responsible for the investigation for the study; H.-W.L. and C.-J.P. prepared the original draft; C.-C.Y. and H.-W.L. were involved in reviewing and editing; all authors have read and agreed to the published version of the manuscript.

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