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USING FUZZY DELPHI METHODS TO DEVELOP INDICES FOR EVALUATING NATURAL AND CULTURAL SCENIC ECOLOGICAL AREAS

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Abstract. *No comprehensive or clear criteria have been defined for planning and evaluating natural and cultural scenic ecological areas in Taiwan. This study was conducted to develop dedicated indices for planning and evaluating these areas and to stress the importance of the indices. The lands reserved for indigenous people in Taiwan were used as the scope of this study. Fuzzy evaluations were performed on the basis of expert panel perceptions by substituting conventionally used crisp values with the concept of membership function. The fuzzy Delphi method was employed to select appropriate evaluation dimensions and indices. The research results were used to develop key evaluation dimensions, and index reliability was ensured using the fuzzy semantic feedback provided by expert panel decisions as a basis. Four evaluation dimensions, namely the environmental, economic, sociocultural, and policy dimensions, and 22 secondary evaluation indices and characteristics were obtained. The evaluation indices developed in this study can serve as a reference for planning natural and cultural scenic ecological areas in the future.*
Keywords: Fuzzy Delphi method, Indigenous tribe, Natural and cultural scenic ecological area

1. **Introduction.** Natural and cultural scenic ecological areas in Taiwan are defined as unique natural monuments that cannot be artificially reconstructed, ecological environments of fauna or flora that require strict protection, or special ecological or cultural reserves demonstrated by crucial prehistoric relics. These reserves include: reserves for aboriginal people, restricted mountainous zones, wildlife preservation areas, resource preservation areas for aquatic products, natural reserves, historical sites, special monuments and ecological preservation areas in national parks. No comprehensive or clear criteria have been defined for planning and evaluating the natural and cultural scenic ecological areas in Taiwan. The lack of such criteria is related to the unavailability of environmental resource data and lack of basic local research in remote areas. Therefore, an easy-to-operate and simple plan evaluation model was developed by examining the environmental, economic, sociocultural, and policy dimensions. The model was intended to promote nature conservation and the sustainability of tourism and recreation. The literature review in Section 2 explains the process of sustainable touring evaluations to construct the planning indicators and criteria in natural and cultural scenic ecological areas.

Through a literature review, Section 2 organizes the process for evaluating sustainable tourism development, addresses the establishment of evaluation indices and criteria for planning natural and cultural scenic ecological areas, and explains and describes the characteristics of these indices and criteria. The establishment of the evaluation mode is described in detail in Sections 3 and 4 followed by the conclusions of this study in Section 5.

2. **Literature Review.** In November 1983, the United Nations established the World Commission on Environment and Development according to the United Nations, the basic agenda of this organization is sustainability and the organization is responsible for formulating an agenda for global changes. In April 1987, this commission submitted "Our Common Future" [1], a report that was based on 4 years of research, to the United Nations General Assembly, officially proposing the concept of sustainability, "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." In summary, the purpose of sustainable development is to promote harmonious relationships among humans and between humans and nature. Tourism is a type of interaction between human society and the natural environment. The question is how to achieve sustainable development in tourism and create a harmonious relationship between humans and the environment during tourist activities. Consequently, sustainable tourism was proposed.

2.1. **Procedures and indices for evaluating sustainable tourism.** In recent years, information management systems have become a trend [2]. Ko argued that developing the science of sustainable tourism and establishing objective evaluation methods are the crucial features of sustainable development in 2005. If sustainable development is assumed to be the primary goal of modern tourism, then the tourism industry must be able to measure the influence of its performance on local areas [3]. Brink et al. indicated that no systematic sustainability evaluation methods have been applied to the tourism industry [4].

2.2. **Evaluation criteria and explanations and characteristics of the criteria.** Four evaluation dimensions, namely the environmental, economic, sociocultural, and policy dimensions, and 22 evaluation indices were identified from the summarized results of journal papers, theses and dissertations, and technical reports and regulations. The indices were used as the items on the fuzzy Delphi expert questionnaire, and explanations and characteristics of the indices are shown in Table 1.

3. **Methods.** This study features a mixed research design using qualitative and quantitative research methods. A literature review was conducted, and data were collected using the following research methods: participant observation, interviews, focus groups, participatory workshops, and case studies. Research methods, qualitative descriptive measurements, and mathematical and statistical analyses have been applied extensively in recent studies. By contrast, quantitative methods, which focus on long-term measurements and experimental analyses, have been rarely used. Multiple-criteria decision making is a method that decision makers can employ to review a limited number of feasible solutions, rank the solutions on the basis of the property characteristics of the solutions, and subsequently evaluate all the solutions and select a solution that satisfies the expectations of the decision makers [5].

3.1. **Fuzzy Delphi method.** The fuzzy Delphi method was developed according to the conventional Delphi method, in which the consensus values of expert opinions are only average values. An unknown function relationship exists in expert consensus, and this relationship can yield different function relationships according to varying consensus functions such as geometric means, maximum means, minimum means, harmonic means,

Table 1. Evaluation dimensions and indices

Evaluation dimensions	Indices
Environmental	C1-1 Biodiversity
	C1-2 Landscape diversity
	C1-3 Uniqueness of weather and water
	C1-4 Uniqueness of historical sites and culture
	C1-5 Tourism resources
	C1-6 Environmental sensitivity
Economic	C2-1 Economic values of activities
	C2-2 Local industrial patterns
	C2-3 Facility service quality
	C2-4 Human resources dedicated to tourism
	C2-5 Consumer market
	C2-6 Visibility
Sociocultural	C3-1 Resident support
	C3-2 Educational functions
	C3-3 Social impact
	C3-4 Intangible cultural assets of local communities
	C3-5 Community feedback
	C3-6 Innovation capacity of local communities
Policy	C4-1 Location protection policies
	C4-2 Development plans
	C4-3 Limitations on use
	C4-4 Quantity and quality of public facilities

and arithmetic means. Fuzzy Delphi Method was proposed by Ishikawa et al. [6], and it was derived from the traditional Delphi technique and fuzzy set theory. Noorderhaben indicated that applying the Fuzzy Delphi Method to group decision can solve the fuzziness of common understanding of expert opinions [7]. As for the selection of fuzzy membership functions, previous researches were usually based on triangular fuzzy number, trapezoidal fuzzy number and Gaussian fuzzy number. Using the evaluation values yielded from expert questionnaires develops triangular fuzzy functions. Specifically, the minimum value (LR_i) and maximum value (UR_i) are the two end points of a triangular fuzzy function and the medium value (MR_i) is the most possible score representing expert's views, as shown in Figure 1.

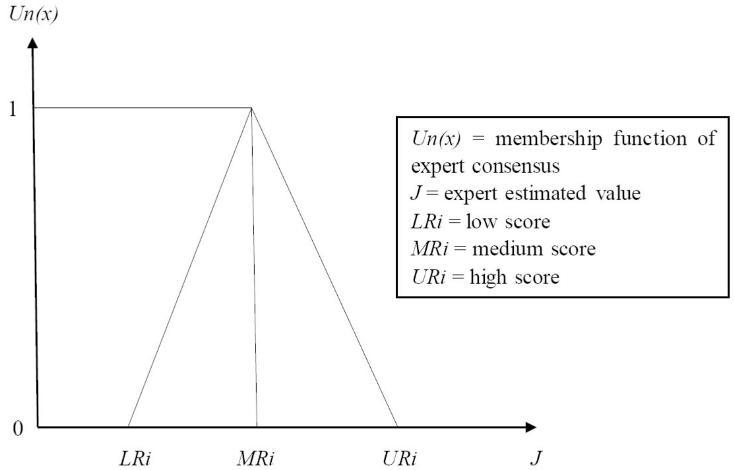

Figure 1. Triangular-type membership functions

3.2. **Advantages of the fuzzy Delphi method.** Compared with the use of the conventional Delphi method, using fuzzy Delphi method enables a survey to be conducted more quickly with minimal resources, clearly explains expert suggestions without distorting them, distinctly expresses the semantic structure of each prediction term, accounts for fuzziness that is inevitable during a survey process, and processes multi-layer, multi-attribute, and multi-option decision-making problems because of its simple calculation procedure. The Delphi method is deemed as an approach involving group communication process and is applicable to nearly every human activity [8]. The Delphi method is widely used in various types of research, among which performance assessment and management as well as planning commonly employ this method.

4. **Results and Analyses.** A total of 26 experts and scholars were invited to assess the primary evaluation dimensions and indices examined during decision making. Specifically, seven experts served in the public sector, primarily in departments overseeing affairs for authorities at the county or township levels; eight experts served in relevant industries and were primarily local opinion leaders, tourism business owners, or staff members overseeing affairs at planning units. In addition, five experts were master's and doctoral students researching tourism, environmental landscapes, and regional development and six scholars were also invited who were familiar with tourism, environmental landscapes, regional development, and measurement methods. The 26 experts and scholars had some understanding of the research topics. Table 2 displays the results of the fuzzy membership function defined by the expert panel.

In the design of the fuzzy Delphi expert questionnaire, five semantic levels were provided for the experts to evaluate the importance of the evaluation dimensions and indices.

Table 2. Fuzzy membership function as defined by the expert panel

Group type	Code	Extremely important			Important			Neutral			Unimportant			Extremely unimportant		
		LR_i	MR_i	UR_i	LR_i	MR_i	UR_i	LR_i	MR_i	UR_i	LR_i	MR_i	UR_i	LR_i	MR_i	UR_i
Public sector	P-01	6	8	9	5	6	7	3	4	5	2	3	4	1	1	2
	P-02	7	8	9	5	6	7	3	4	5	2	3	4	1	2	3
	P-03	7	8	9	6	7	7	5	6	6	4	5	6	3	4	4
	P-04	8	8	9	5	5	6	3	3	4	2	2	3	1	1	2
	P-05	5	7	9	5	6	7	4	5	6	2	3	4	1	2	3
	P-06	8	9	9	6	7	7	4	5	5	2	3	3	1	1	1
	P-07	8	8	9	6	7	8	4	5	6	2	3	4	1	2	3
Industries	I-01	7	8	8	4	5	6	2	2	3	1	2	2	1	1	2
	I-02	7	8	9	6	7	8	4	5	6	2	3	4	1	2	3
	I-03	8	8	9	6	6	8	3	4	5	2	2	3	1	1	2
	I-04	6	7	9	5	6	7	4	5	6	3	4	5	1	2	3
	I-05	6	7	9	5	6	7	5	5	5	2	3	4	1	2	3
	I-06	7	7	9	6	7	8	4	5	6	3	4	5	1	1	2
	I-07	8	9	9	6	7	8	4	5	6	2	3	4	1	2	3
	I-08	7	9	9	6	8	8	3	5	6	1	2	3	1	2	3
Research institutes	R-01	5	7	9	4	6	8	3	5	7	2	3	4	1	2	3
	R-02	8	8	9	6	7	8	4	5	6	3	3	4	1	2	3
	R-03	8	9	9	6	7	8	3	5	5	3	4	4	1	2	3
	R-04	9	9	9	7	8	8	4	4	5	2	2	3	1	1	1
	R-05	8	8	9	6	7	8	4	5	6	3	4	4	1	1	2
Academic institutes	A-01	7	8	9	5	6	7	4	5	6	2	3	4	1	2	3
	A-02	6	8	9	5	6	7	3	4	5	2	3	4	1	2	3
	A-03	7	8	9	5	6	7	4	5	6	2	3	4	1	2	3
	A-04	7	8	9	5	6	7	4	5	5	3	3	4	1	1	2
	A-05	7	8	9	6	7	8	4	5	6	3	4	5	1	2	3
	A-06	7	8	9	6	7	8	3	5	7	2	3	4	1	2	3

Regarding the rating, the experts differed in their definitions of importance. The experts were allowed to rate the evaluation criteria according to their opinions by using scores of 1 to 9 points (low, medium, and high scores) with each score corresponding to one of the semantic levels. This rating system was employed to represent the fuzzy membership function, and the scores at each of the semantic levels could overlap.

In this manner, the raters were allowed to determine the importance of the criteria by using a 9-point scale, thereby enabling the research results to more accurately reflect reality. The interviewed experts and scholars provided their definitions of the importance of the evaluation criteria in writing before using the five semantic levels to rate the importance of the criteria. The fuzziness of expert common understanding could be solved using the fuzzy theory and evaluated on a more flexible scale. The efficiency and quality of questionnaires could be improved. Thus, more objective evaluation factors could be screened through the statistical results [8]. To defuzzify the importance of the overall evaluation indices, the level of importance that the experts awarded to each index was converted to a fuzzy score, as displayed in Table 3. Subsequently, equations were employed to integrate the fuzzy scores from the experts and the results were calculated. By comparing expert questionnaire dimensions and assessment criteria and calculating the geometric mean, the values of multiple experts are integrated under the same dimension or assessment criteria. The equation is provided in (1):

$$UR_i = \sqrt[k]{\prod_{j=1}^{k} UR_{ij}} \qquad LR_i = \sqrt[k]{\prod_{j=1}^{k} LR_{ij}} \qquad MR_i = \sqrt[k]{\prod_{j=1}^{k} MR_{ij}} \tag{1}$$

where k represents the number of experts.

UR_{ij} represents the maximum value of the evaluation of the j^{th} expert corresponding to the i^{th} index.

LR_{ij} represents the minimum value of the evaluation of the j^{th} expert corresponding to the i^{th} index.

Table 3. Summary of defuzzified importance of the overall evaluation indices

Dimension	Code	Evaluation indices and importance	LR_i	MR_i	UR_i	BNP	Ranking	Overall ranking
Environmental	C1-1	Biodiversity	6.73	7.65	8.54	7.64	1	1
	C1-2	Landscape diversity	5.46	6.50	7.46	6.47	4	11
	C1-3	Uniqueness of weather and water	4.96	5.85	6.85	5.88	6	19
	C1-4	Uniqueness of historical sites and culture	5.81	6.73	7.62	6.72	3	5
	C1-5	Tourism resources	5.12	6.00	6.85	5.99	5	18
	C1-6	Environmental sensitivity	6.54	7.38	8.31	7.41	2	3
Economic	C2-1	Economic values of activities	5.15	6.15	7.04	6.12	3	17
	C2-2	Local industrial patterns	5.42	6.38	7.31	6.37	2	15
	C2-3	Facility service quality	4.85	5.81	6.77	5.81	4	20
	C2-4	Human resources dedicated to tourism	5.46	6.38	7.35	6.40	1	14
	C2-5	Consumer market	4.62	5.69	6.58	5.63	5	21
	C2-6	Visibility	4.46	5.38	6.31	5.38	6	22
Sociocultural	C3-1	Resident support	6.50	7.54	8.46	7.50	1	2
	C3-2	Educational functions	5.69	6.62	7.46	6.59	3	8
	C3-3	Social impact	5.27	6.27	7.27	6.27	6	16
	C3-4	Intangible cultural assets	5.81	6.65	7.69	6.72	2	5
	C3-5	Community feedback	5.46	6.54	7.46	6.49	5	10
	C3-6	Innovation capacity of local communities	5.58	6.54	7.50	6.54	4	9
Policy	C4-1	Location protection policies	5.81	6.65	7.54	6.67	2	7
	C4-2	Development plans	6.08	7.04	8.00	7.04	1	4
	C4-3	Limitations on use	5.50	6.42	7.46	6.46	3	12
	C4-4	Quantity and quality of public facilities	5.46	6.46	7.42	6.45	4	13

MR_{ij} represents the medium value of the evaluation of the j^{th} expert corresponding to the i^{th} index.

The fuzzy numbers were converted to best nonfuzzy performance values ($BNPs$) by using the centroid method to enable solution ranking. The equation is provided in (2):

$$BNP = \left[\left(U\tilde{R}_l - L\tilde{R}_l\right) + \left(M\tilde{R}_l - L\tilde{R}_l\right)\right] \div 3 + L\tilde{R}_l, \quad \forall i \tag{2}$$

where i represents the codes of the criteria; $L\tilde{R}_l$ represents the geometrical average of the low scores that the expert panel awarded to the weight of solution criterion i; $M\tilde{R}_l$ represents the means of the medium scores that the expert panel awarded to the weight of solution criterion i; $U\tilde{R}_l$ represents the means of the high scores that the expert panel awarded to the weight of solution criterion i.

For example, "C1-1 Biodiversity" under the environmental dimension is calculated as follows:

$$BNP = [(8.54 - 6.73) + (7.65 - 6.73)] \div 3 + 6.73 = 7.64$$

After the results obtained using the fuzzy Delphi method were defuzzified, the means of the scores were calculated, indicating the importance of the indices. In this manner, the fuzzy comparison matrices were obtained, and the scores were compiled (Table 3). Under the environmental dimension, the evaluation index with the highest importance score was biodiversity (the highest mean was 7.64), followed by environmental sensitivity and the uniqueness of historical sites and culture; the indices with the lowest importance values were weather and water uniqueness (the lowest mean was 5.88), followed by tourism resources. The overall evaluation of the expert panel demonstrated that the average importance values of the indices under the economic dimension were the lowest among the four dimensions, indicating that, compared with the other three dimensions, the economic dimension was the least significant dimension among the evaluations performed for selecting and planning natural and cultural scenic ecological areas.

Among the indices under the economic dimension, human resources dedicated to tourism exhibited the highest average importance values (the highest mean was 6.40), followed by local industrial patterns and the economic values of activities; visibility exhibited the lowest importance values (the lowest mean was 5.38), followed by the consumer market. Moreover, among the indices under the sociocultural dimension, resident support exhibited the highest average importance values (the highest mean was 7.50), followed by intangible cultural assets and educational functions; social impact exhibited the lowest importance values (the lowest mean was 6.27), followed by community feedback. Finally, among the indices under the policy dimension, development plans exhibited the highest average importance values (the highest mean was 7.04), followed by location protection policies and limitations on use; quantity and quality of public facilities exhibited the lowest importance values (the lowest mean was 6.45).

5. **Conclusions.** This study applied the concept of membership functions in replace of the conventional crisp value method and used the fuzzy Delphi method to analyze semantic feedback obtained from expert panel decisions. Through the fuzzy evaluations of the expert panel, a fuzzy theory featuring scales of fuzzy semantics was implemented to reduce subjective differences and favoritism resulting from fuzzy semantics in the expert panel decisions. Consequently, humanized decisions can be formulated to identify and assess problems related to research decisions, enabling the overall evaluation result to closely resemble the actual outcome. The indices developed in this study for evaluating natural and cultural scenic ecological areas can be divided into four dimensions, namely the environmental, economic, sociocultural, and policy dimensions, and 22 secondary evaluation indices and characteristics. The results of this study can serve as a reference for government decision-makers or subsequent studies to analyze the weights of relevant

criteria and factors for developing evaluation scales. The evaluation indices developed in this study can serve as a reference for planning natural and cultural scenic ecological areas in the future.

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