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THE APPLICATION OF AHP IN EVALUATING GONDOLA CONSTRUCTION PROJECT

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Abstract. *Gondolas are a transportation and tourism vehicle that are environmentally friendly, convenient, and inexpensive. This study used the Wufeng Township Gondola as a case study. The Analytic Hierarchy Process was applied to evaluating a gondola construction project. In examining the Wufeng Township Gondola project, the study used an expert questionnaire to determine the evaluation factors and weights and pair-wise comparisons to obtain the scores and priorities of each alternative. This study was constructed on the framework of the evaluation hierarchy and analysis model. The case study results demonstrated the feasibility of the research method, allowing the study's conclusions to serve as a reference to authorities evaluating gondola construction projects.*
Keywords: Analytic Hierarchy Process (AHP), Gondola, Pair-wise comparison, Project evaluation

1. **Introduction.** The core value of low-carbon tourism is to provide a high-quality tourism experience that ensures low carbon emissions and decreases pollution in association with transportation, accommodations, sightseeing, shopping, and entertainment. The use of low-carbon evaluation indexes for tourist attractions can encourage widespread low-carbon tourism [1]. Compared with road development, gondola lifts are environmentally friendly, convenient, and economical. Assessing gondola construction is complex and comprises numerous factors such as construction technology, geology, market conditions, financing, land acquisition, environmental impact, and traffic. Cost control is a critical factor in construction projects; improving the level of cost management should be carefully considered [2].

The evaluation framework must incorporate diverse assessment factors that are weighted according to individual case differences. This study used the construction of the Wufeng Township Gondola as a case study and adopted the Analytic Hierarchy Process (AHP) to evaluate assessments of the gondola construction. In this paper, Section 2 presents the literature review, which establishes the assessment dimensions and indicators by using case examples, research reports, and expert opinions; Section 3 describes the AHP method; Section 4 explains how expert questionnaire surveys were administered to determine the weights of the dimensions and indicators for evaluation. Subsequently, potential construction schemes for the Wufeng Township Gondola project were ranked according to preference after conducting paired comparisons of the assessment indicators and analyzing the scheme scores. The results of this study can be used to verify the feasibility of this assessment method and may serve as a reference in feasibility assessments of gondola construction projects for relevant government departments in Taiwan. And Section 6 makes the conclusions.

2. Literature Review.

Most studies on gondola construction in Taiwan have adopted the AHP as an assessment method but have substantially differed regarding assessment dimensions and index contents. Therefore, in this study, information regarding assessment factors was collected through a literature review, expert interviews, and a questionnaire survey before establishing an AHP [3]. Moreover, most of these studies have rated possible schemes and assessment indices directly rather than proposing assessment considerations for domestic gondola construction cases that promote public participation. However, assessing indices is complex and difficult to accomplish directly. Thus, this study proposed a revision to the method for evaluating the hierarchical structure and used paired comparisons to establish a revised evaluation mode.

3. Methods.

Policy makers at all levels of decision making in organizations use multiple criteria to analyze their complex problems. Multicriteria thinking is used formally to facilitate their decision making. The well-known hierarchical, multicriteria decision-making mechanism, the AHP, is a practical tool for decision makers facing such prioritization problems.

3.1. Analytic Hierarchy Process.

The AHP has been applied to diverse situations [4], including the development of transport system strategies [5-7]. This study advances the current AHP literature [8,9] by addressing the need for prioritizing numerous alternatives with substantial heterogeneity. Multicriteria decision analysis is an effective method for handling complex decision making by clarifying the advantages and disadvantages of the available options under uncertain conditions [10]. These methods have been utilized extensively in the broader areas of environmental science management and stakeholder involvement [11]. AHP has many obvious advantages such as simplifying complex decision-making problems by decomposing them into hierarchies and being accessible to lay people. Therefore, this paper discusses the validity of AHP for evaluating the sustainability of gondola construction projects. Making a decision in an organized manner entails generating priorities and decomposing the decision into steps.

3.2. AHP procedure.

3.2.1. *Decision problem.* The system in which the problems are situated should be enlarged until all of the crucial factors influencing the problems are included. At this stage, a planning group is established to define the problem scope.

3.2.2. *Actors.* A decision group consisting of specialists is established based on the domains and complexity of the problems involved in the decision, with 5-15 specialists in the group. This step can be eliminated when only a single decision must be made. During the group decision making, feasible plans and schemes are assigned different weightings because specialists have various preferences. Consequently, the preferences of the specialists must be integrated. This study used two methods for integrating the specialists' preferences: the pool-first and pool-last methods. The pool-first method employs the geometric mean and the majority decision method, whereas the pool-last method employs the arithmetic mean.

3.2.3. *Hierarchical framework.* At this stage, the problem is formed, with its definition, elements, and hierarchy being defined. Every element in the hierarchy framework is defined, and the hierarchical relationships within the problems and among the elements are determined. Levels in the hierarchical framework are considered to be influenced only by the levels above them; moreover, every element is considered independent. Satisfying these conditions is necessary for achieving superior consistency.

3.2.4. *Questionnaire survey and paired-comparison matrix.* All assessment criteria of the same level were evaluated using paired comparisons based on an assessment of the elements from the level above them and rated using a scale from 1 to 9 (Table 1). This evaluation process enabled acquiring the paired-comparison matrix A. If n factors are compared, $n(n-1)/2$ times the paired comparisons must be conducted. Because of the reciprocal property of paired comparisons, if the ratio between element i and j is a_{ij}, then the ratio between element j and i is $1/a_{ij}$. Similarly, the lower triangular matrix of the paired-comparison matrix A is the reciprocal of the upper triangular matrix, as shown in (1):

$$A = [a_{ij}] = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \cdots & \cdots & & \cdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} = \begin{bmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \cdots & \cdots & & \cdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{bmatrix} \tag{1}$$

where w_i represents the element weight of i, $i = 1, 2, \ldots, n$, a_{ij} represents the relative importance ratio between two elements, $i = 1, 2, \ldots, n$, and $j = 1, 2, \ldots, n$.

Table 1. The fundamental scale of absolute numbers

Intensity of importance	Definition	Explanation
1	Equal importance of i and j	Two activities contribute equally to the objective.
3	Moderate importance of i over j	Experience and judgment slightly favor one activity over another.
5	Strong importance of i over j	Experience and judgment strongly favor one activity over another.
7	Very strong importance of i over j	An activity is favored very strongly over another; its dominance is demonstrated in practice.
9	Extreme importance of i over j	The evidence favoring one activity over another is of the highest possible order of affirmation.
2, 4, 6, 8	For compromise between the above values	Sometimes one needs to interpolate a compromise judgment numerically because there is no good word to describe it.

Reference: T. L. Saaty [12]

3.2.5. *Eigenvalue and eigenvector calculations.* After acquiring the paired-comparison matrix, the eigenvalue of the numerical analysis is employed to determine the eigenvector and priority vector. The results are used to obtain the weights of elements at every level. To calculate the eigenvector, the geometric mean of the row vectors was normalized, as proposed by Saaty (1980). The geometric mean was obtained by multiplying elements in every row and then normalizing the value, as expressed in (2):

$$W_i = \frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{\frac{1}{n}}}, \quad i, j = 1, 2, \ldots, n \tag{2}$$

A new eigenvector W_i' is attained by multiplying the paired-comparison matrix A with the obtained eigenvector W_i; $\lambda_{\max}$ is obtained by dividing every vector of W_i' by the corresponding original vector W_i and then calculating the arithmetic mean of every obtained value, as expressed in (3):

$$\lambda_{\max} = \frac{1}{n}\left(\frac{W_1'}{W_1} + \frac{W_2'}{W_2} + \cdots + \frac{W_n'}{W_n}\right) \tag{3}$$

3.2.6. *Consistency test.* In this step, a consistency test is conducted to determine the consistency index ($C.I.$). The paired-comparison matrix, based on the decision makers' responses, is examined to determine whether it is a consistent matrix. An unsatisfactory consistency level indicates that the relatedness of the level elements in a matrix is problematic; this problem can be ascribed to the assessment based on the decision makers' judgments or to the testing of the hierarchy framework as a whole. Saaty suggested that the most satisfactory $C.I.$ was < 0.1, with the largest allowable bias being $C.I. < 0.2$. If the $C.I.$ falls within these numbers, consistency is ensured, as expressed in (4):

$$C.I. = \frac{\lambda_{\max} - n}{n - 1} \tag{4}$$

where $\lambda_{\max}$ represents the maximum eigenvalue in matrix A, and n represents the number of assessment elements. A $C.I.$ of 0 implies that a single criterion is being used, that the decision makers were completely consistent in their assessment of the importance of n elements. A $C.I. > 0$ implies that the decision makers were not consistent in their assessment of the importance of n elements. The consistency ratio ($C.R.$) is calculated as the ratio of the $C.I.$ to the random index ($R.I.$) of a matrix, as expressed in (5):

$$C.R. = \frac{C.I.}{R.I.} \tag{5}$$

A $C.R. < 0.1$ implies satisfactory matrix consistency. The positive reciprocal matrix derived from the 1-9 assessment scale generates different $C.I.$ values in different orders. The ratio of $C.I$ to $R.I$ is $C.R.$, where $R.I.$ is the average random index. In addition, variance in the importance of every level suggests that the consistency of the whole hierarchy framework requires further examination. After the assessment dimension and criteria weight of the specialists are determined to satisfy consistency requirements, this weight can be applied to every scheme in deciding the priority index (PI) of every assessment index. The PI can be obtained by calculating the weight W_i and the score X_{ij} of every scheme i obtained from every index, as shown in (6):

$$PI_i = \sum_{j=1}^{n} W_j * X_{ij} \tag{6}$$

The score X_{ij} that every scheme i obtains from every index is directly rated by the specialists. Because the judgment of every assessment index is complex, this study proposed a paired comparison of the schemes.

The advantage weight of every index was taken as its score, and the calculation method was the same as using the paired-comparison matrix to evaluate the weights, as described previously.

4. Results and Analyses.

4.1. Gondola construction dimension assessment and indicator analysis. Table 2 shows the results of the paired comparisons. To evaluate the eight dimensions and 24 evaluation indicators, 14 experts completed a questionnaire survey: 10 county government supervisors, two township office supervisors, and two supervisors from a construction

Table 2. Gondola construction assessment dimension and indicator analysis results

Feasibility analysis dimensions	Dimension weight	Dimension ranking	Assessment indicators	Assessment indicators weight	Indicators ranking	Comprehensive weight	Comprehensive ranking
E1 Construction technology feasibility	0.137	3	E11 Geological conditions	0.564	1	0.077	3
			E12 Terrain conditions	0.175	2	0.024	20
			E13 Climate conditions	0.146	3	0.020	23
			E14 Gondola system construction and maintenance	0.115	4	0.016	24
E2 Land-acquisition feasibility	0.134	4	E21 Zoning restrictions	0.384	1	0.051	6
			E22 Air rights	0.252	3	0.034	13
			E23 Land acquisition costs	0.364	2	0.049	7
E3 Traffic feasibility	0.083	7	E31 Transportation function	0.355	1	0.029	15
			E32 Road network integrity	0.294	3	0.024	20
			E33 Disaster relief needs	0.351	2	0.029	15
E4 Market feasibility	0.112	6	E41 Demand and growth	0.413	2	0.046	9
			E42 Market competition and investment intentions	0.587	1	0.066	4
E5 Legal feasibility	0.126	5	E51 Public construction	0.247	2	0.031	14
			E52 Economic taxation	0.164	4	0.021	22
			E53 Tourism business activities	0.212	3	0.027	18
			E54 Environmental impact assessment	0.376	1	0.048	8
E6 Social feasibility	0.072	8	E61 Public expectations in the region	0.627	1	0.045	10
			E62 Public-sector policies	0.373	2	0.027	18
E7 Financial feasibility	0.177	1	E71 The scale of investment (cost)	0.203	3	0.036	12
			E72 Return on investment	0.466	1	0.082	2
			E73 Payback period	0.331	2	0.059	5
E8 Environmental feasibility	0.159	2	E81 Effects on the cultural environment	0.184	3	0.029	15
			E82 Effects on the natural environment	0.271	2	0.043	11
			E83 Effects on the ecological environment	0.546	1	0.087	1

consultancy company. After the confidence intervals and composite reliability values were aggregated and calculated, the results showed satisfactory consistency (> 0.1).

4.2. **Feasibility analysis of the Wufeng Township Gondola.** The ranking results (Table 3) indicated that Scheme 5 possessed the highest performance value.

This study used the Wufeng Township Gondola as a case study for performing a feasibility analysis. In general, gondola station locations are assessed first at the initial route-development stage. Other factors are considered for appropriately connecting stations to develop future routes progressively. Analyses regarding resources, demand, and social aspects are conducted according to site survey observations for predicting potential problems. Consequently, five possible gondola routes were proposed: Scheme 1 (Chingchuan-Bailan tribal lands), Scheme 2 (Chingchuan-Sakalo tribal lands), Scheme 3 (Chingchuan-Yunshan tribal lands), Scheme 4 (Chingchuan-Daping Nursery), and Scheme 5 (Chingchuan-Daping Nursery-Guanwu). The 14 experts conducted paired comparisons of the schemes and ranked them using various assessment indicators. Subsequently, the results were used to determine the performance of various schemes according to the indicators and to assign a score for each scheme. The schemes were ranked according to the performance evaluations, from highest to lowest: 5, 4, 3, 2, and 1. The study results were consistent with the scheme preference order in the current Wufeng Township Gondola planning report. In addition, the results indicated that the method used in this study (combining expert questionnaires and AHP) was feasible for appraising the prioritization of the gondola route schemes.

TABLE 3. Appraisal results for the gondola route schemes

Feasibility analysis dimensions	Assessment indicators	Scheme 1	Scheme 2	Scheme 3	Scheme 4	Scheme 5
E1 Construction technology feasibility	E11 Geological conditions	0.108	0.139	0.164	0.227	0.363
	E12 Terrain conditions	0.129	0.123	0.181	0.293	0.274
	E13 Climate conditions	0.194	0.153	0.167	0.260	0.226
	E14 Gondola system construction and maintenance	0.215	0.150	0.173	0.234	0.228
E2 Land-acquisition feasibility	E21 Zoning restrictions	0.145	0.127	0.189	0.271	0.268
	E22 Air rights	0.185	0.126	0.199	0.233	0.258
	E23 Land acquisition costs	0.128	0.158	0.204	0.268	0.241
E3 Traffic feasibility	E31 Transportation function	0.124	0.174	0.207	0.188	0.307
	E32 Road network integrity	0.159	0.173	0.152	0.199	0.317
	E33 Disaster relief needs	0.080	0.197	0.141	0.192	0.391
E4 Market feasibility	E41 Demand and growth	0.147	0.163	0.187	0.211	0.292
	E42 Market competition and investment intentions	0.074	0.161	0.203	0.236	0.326
E5 Legal feasibility	E51 Public construction	0.146	0.171	0.190	0.181	0.311
	E52 Economic taxation	0.216	0.192	0.224	0.216	0.152
	E53 Tourism business activities	0.183	0.166	0.153	0.179	0.320
	E54 Environmental impact assessment	0.167	0.145	0.161	0.238	0.289
E6 Social feasibility	E61 Public expectations in the region	0.074	0.102	0.095	0.209	0.521
	E62 Public-sector policies	0.144	0.128	0.185	0.210	0.333
E7 Financial feasibility	E71 The scale of investment (cost)	0.106	0.102	0.177	0.304	0.311
	E72 Return on investment	0.088	0.066	0.145	0.236	0.465
	E73 Payback period	0.130	0.094	0.162	0.250	0.364
E8 Environmental feasibility	E81 Effects on the cultural environment	0.184	0.162	0.174	0.210	0.269
	E82 Effects on the natural environment	0.174	0.143	0.196	0.229	0.259
	E83 Effects on the ecological environment	0.187	0.145	0.166	0.242	0.259
Priority index, (PI)		0.137	0.138	0.173	0.233	0.320

5. **Conclusions.** This study adopted evaluating gondola construction schemes to establish a hierarchical evaluation framework based on the characteristics of assessing gondola construction in Taiwan. Referencing the "Act for Promotion of Private Participation in Infrastructure Projects" and related feasibility studies, the framework can be practically applied as an assessment framework. In addition, on the basis of the assessment indicators, this study conducted paired comparisons and ranking in considering potential recommendations and calculated the scores of the various schemes. This approach avoids appraisal difficulties caused by directly allocating scores to various schemes using the assessment indicators. The weighting and analysis of the construction dimensions and indicators of the Wufeng Township Gondola case study and its scheme preference analysis yielded the following results. (1) Regarding the AHP results for the gondola construction-assessment dimensions, Financial feasibility (E7) exhibited the highest weight value at 0.177, followed by Environmental feasibility (E8) at 0.519 and Construction technology feasibility (E1) at 0.137. (2) Regarding the AHP results for the gondola-construction assessment indicators, Ecological environment effects (E83) exhibited the highest weight value at 0.087, followed by Return on investment (E72) at 0.082 and Geological conditions (E11) at 0.077. (3) Regarding the gondola-route assessment, Scheme 5 was the most suitable scheme, followed by Schemes 4, 3, 2, and 1. This result was consistent with the scheme preference order in the Wufeng Township Gondola planning report.

The hierarchical evaluation framework proposed by this study can be applied to evaluating gondola construction schemes. Regarding dimension and indicator weighting, this study recommends that expert scholars be selected to determine the weights of dimensions and indicators according to individual case characteristics.

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