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A Study of Priority Evaluation and Resource Allocation for Revitalization of Cultural Heritages in the Urban Development

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***Abstract*—**Proper maintenance and preservation of significant cultural heritages or historic buildings is necessary. It can not only enhance environmental benefits and a sense of community, but also preserve a city's history and people's memory. It allows the next generation to be able to get a glimpse of our past, and achieve the goal of sustainable preserved cultural assets. However, the management of maintenance work has not been appropriate for many designated heritages or historic buildings so far. The planning and implementation of the reuse has yet to have a breakthrough specification. It leads the heritages to a mere formality of being "reserved", instead of the real meaning of "conservation". For the restoration and preservation of cultural heritages study issues, it is very important due to the consideration of historical significance, symbolism, and economic benefits effects. However, the decision makers such as the officials from public sector they often encounter which heritage should be prioritized to be restored first under the available limited budgets. Only very few techniques are available today to determine the appropriately restoration priorities for the diverse historical heritages, perhaps because of a lack of systematized decision-making aids been proposed before. In the past, the discussions of management and maintenance towards cultural assets were limited to the selection of reuse alternatives instead of the allocation of resources. In view of this, this research will adopt some integrated research methods to solve the existing problems that decision-makers might encounter when allocating resources in the management and maintenance of heritages and historic buildings.

The purpose of this study is to develop a sustainable decision making model for local governments to resolve these problems. We propose an alternative decision support model to prioritize restoration needs within the limited budgets. The model is constructed based on fuzzy Delphi, fuzzy analysis network process (FANP) and goal programming (GP) methods. In order to avoid misallocate resources; this research proposes a precise procedure that can take multi-stakeholders views, limited costs and resources into consideration. Also, the combination of many factors and goals has been taken into account to find the highest priority and feasible solution results. To illustrate the approach we propose in this research, seven cultural heritages in Taipei city as one example has been used as an empirical study, and the results are in depth analyzed to explain the application of our proposed approach.

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I. Introduction

THE revitalization of Taiwan's cultural heritages evaluation and selection are concerned with the allocation of scarce organizational resources. The evaluation and selection problems are multi-criteria decision-making problems. Numerous methodologies for project and research-and-development project selection have been developed and reported in the last two decades. Thus, a decision-making model is important for selecting an optimal solution from the proposed project alternatives.

Although the cultural heritages project alternatives provide new opportunities and benefits, some additional costs and risks are inevitable. Therefore, before adopting new strategies, the benefits, opportunities, costs, and risks (BOCR) of these alternatives must be evaluated. Such an evaluation results in complex decision-making problems, depending on the number of groups that contribute to and are eventually influenced by the decision. The involvement of these groups in the decision making process should improve the decision quality by reflecting their standpoints on the problem. In this study, we adopted a fuzzy ANP to solve a real-world, multi-criteria selection problem based on the following motivations: ANP has a systematic approach to set priorities and trade off among goals and criteria; criteria weights or priorities established by ANP are based on using a ratio scale created by human judgment instead of arbitrary scales; ANP can measure all tangible and intangible criteria in the model; ANP is a relatively simple, intuitive approach that can be accepted by managers and other decision-makers; ANP can easily be used to solve multi-criteria decision-making problems involving multi-actors or group decision-making with multi-actors; and, finally, ANP enables better communication, which leads to a clearer understanding and consensus among the actors so that they will be more likely to commit to the selected alternative [1], [2].

Mathematical programming is essentially static optimization; it consists of different models such as linear programming, goal programming, dynamic programming, and game theory [3]. Goal Programming (GP) [4] is designed to deal with problems involving multiple conflicting objectives. However, to overcome the drawback of GP, decision makers must specify their goals and priorities beforehand. Problem formulation makes a big difference in the decision maker's judgments. Therefore, a systematic procedure is needed to determine the following factors in constructing the GP model through group discussion: (1) objectives, (2) desired level of attainment for each objective, (3) degree of interdependent relationships, and (4) penalty weights for overachievement or underachievement of each goal.

The techniques previously proposed for the cultural heritages project are useful, but their application is restricted because only independent projects and evaluation criteria were considered. Considering the project's interdependent properties saves costs and adds benefits. There are, in fact, numerous clearly interdependent cases to be considered in real-world subset selection problems. In other words, when undertaking projects such as this, many of the various resources from the different revitalization are shared. For example, parts of shop drawings used by design consultants, building departments, and owners can be reused, which provides a substantial savings in developmental costs [5].

We suggest a methodology for solving the project's selection problems, one in which the projects in hand and the evaluation criteria are interdependent. To reflect interdependent properties with multiple criteria, we used an analytic network process (ANP) [6] model and zero-one goal programming (ZOGP) [7] by group expert interview was used. More specifically, we combined FANP and ZOGP models to aid our selection.

II. Review of Project Selection Problem

InAn advantage of the AHP over other MCDM is the former's ability to incorporate tangible as well as intangible criteria, especially where the subjective evaluations of different individuals are important for decision-making [8]. As a general form of AHP, ANP allows for more complex interrelationships between decision levels and attributes [9]-[11]. ANP incorporates dependencies and feedback using a multilevel (or hierarchical) decision network that can adequately model dependence (or interdependence) relations between components, represent and analyze interactions, and synthesize their mutual effects using a single logical procedure [12]. Even though AHP has been applied to a wide variety of decision problems successfully for almost three decades, ANP is still only a promising approach with a limited number of applications and publications describing its use [13]-[15].

Many real-world problems have interdependent criteria and candidate projects [6]. Research and development within one organization are interrelated with other areas of the organization. The interdependencies of the revitalization of the cultural heritages projects can be classified into three main types [16], [17]: resource, benefit, and technical interdependencies. Resource interdependencies arise because hardware and software resources are shared with various revitalization of cultural heritages projects such that the implementation of two or more related projects requires fewer resources than when implemented separately. For example, if shop drawings developed for one project are used in another project, then the total drawing resources required by the second project are accordingly reduced. Beneficial interdependencies occur when the total benefits to the organization derived from implementing two related projects increase due to their synergistic effect [18]. Finally, when the development of a revitalization strategy for the cultural heritages project necessitates the development of a related project, it creates a technical interdependence. By selecting interdependent projects, valuable revitalization can be shared by the projects, thus reducing the total resource expenditure. Recently, Sanathanam and Kyparisis [19] proposed a nonlinear programming model that considers interdependencies and suggested using a project interdependence model for solving problems. This model, however, does not solve problems with multiple or evaluation criteria. In addition, for project evaluation, an expert group discussion should be considered because it is dangerous for only one or two decision makers to determine the criteria or the degree of interdependence for a project. In reality, it is more appropriate to consider multiple criteria in the case of the interdependent cultural heritages project selection problems. No previous study using both multiple criteria and interdependence for the cultural heritages project has been reported yet. In the present study, we considered interdependent project selection using multiple criteria.

Previously research by Saaty developed a matrix manipulation approach for solving a network with dependent criteria alternatives. Lee and Kim [20] used the Saaty's ANP approach within a ZOGP model to suggest an information system project selection methodology, which considered interdependencies among evaluation criteria and candidate projects. Karsak et al. [14] also dealt with product planning in QFD by using a combined ANP and GP approach. Meade and Presley [21] similarly used ANP to support the selection of projects in an R&D environment. Although several methods have been proposed to help organizations make good project selection decisions, no previous study has reported on problem-solving methodology that takes both multiple criteria and interdependence into account for the cultural heritages revitalization project selection. Thus, not only was selection with multiple criteria through group discussions by high-ranking officials of the cultural heritages public sector as well as consultant companies considered, but the important evaluation criteria using the fuzzy Delphi method [22] were also screened in collecting the experts' opinions. For one individual to determine these criteria and the degree of their relative importance can be dangerous.

Finally, in order to solve optimization problems, many researchers use a mathematical model, such as goal programming, dynamic programming, Linear 0-1 programming, etc. [7], [23], [24]. Many previous methodologies are assumed to be independent of criteria or candidate projects.

III. Goal Programming Using the Fuzzy Delphi Method and Analytic Network Process Approach to Analyze the Revitalization of the Cultural Heritages Selection Project

The proposed integrated model for selecting the best revitalization for the cultural heritages project candidate alternatives is based on a fuzzy Delphi method (FDM) and analytic network process (ANP) qualitative evaluation of the strategies. The crisp results (weights of alternatives) were incorporated in a zero-one goal programming (ZOGP) formulation for the final decision-making. Fig. 1 shows the implementing procedure divided into three phases: phase 1: FDM; phase 2: FANP; and phase 3: ZOGP.

Fig. 1 also shows a stepwise representation of the algorithm for the proposed methodology evaluating and utilizing the metrics for project selection.

An early FDM pilot study was done by [22], after which Kaufmann and Gupta [25] proposed another more complete FDM procedure. In the present study's procedure, the FDM was used by asking the participants to give a three-point estimate (pessimistic, moderate, and optimistic values). Triangular fuzzy numbers (TFNs) were then formed and their mean was computed.

FANP can be a valuable aid for decision making that involves both tangible and intangible attributes associated with the model under study. The main reason for choosing FANP as our methodology was its ability to offer solutions in a complex multi-criteria decision environment.

In the evaluation stage, the project alternatives are evaluated according to 4 major criteria that are involved in the control hierarchies: benefits, opportunities, cost, and risks (BOCR). With FANP, it is recognized that there is feedback between the elements at different levels of the hierarchy, and also between elements at the same level, so the decision elements are organized into networks of clusters and nodes. FANP deals systematically with all kinds of feedback and interactions (inner and outer dependence). When elements are linked only to elements in another cluster, the model shows only outer dependence. When elements are linked only to elements in their own cluster, the model shows only inner dependence. Feedback captures the complex effects of interplay in human society.

The process for solving the interdependent cultural heritages revitalization project selection is summarized as follows.

(1) To consider interdependence, the first step is to identify the multiple criteria that merit consideration and then draw a relation which shows the degree of interdependence between the criteria.

(2) Next is to determine the degree of impact or influence between the criteria or alternatives. When comparing the alternatives for each criterion, the decision maker will respond to questions such as: "In comparing alternatives A and B on the basis of cost reduction, which alternative is preferred?"

(3) When there is interdependence, one answers the following kind of question in making the pairwise comparisons: "Given an alternative and an evaluation criterion, which of the two alternatives influences the given alternatives more with respect to the criterion, and how much more than another alternative?"

(4) The responses are presented numerically, scaled using Saaty's proposed 1-9 scale [26], [6] with reciprocals, in a project comparison matrix.

(5) The final step is to determine the overall prioritization of these revitalization strategy alternatives.

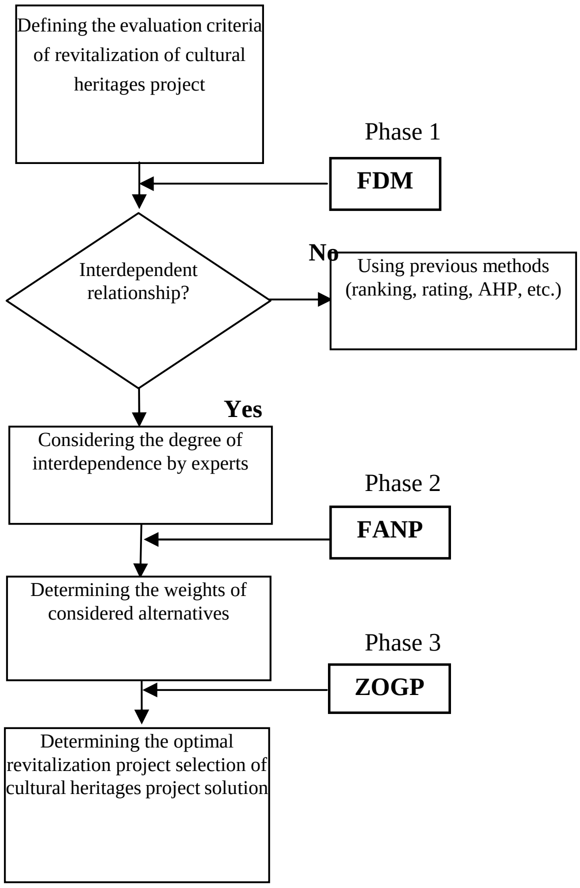


Fig. 1 An overview of the proposed model

The information obtained from the FANP is then used to formulate a ZOGP model as a weight. The solution of the ZOGP provides a pattern for allocating resources for the different projects. ZOGP has been used in a variety of ranked resource selection schemes, including selecting a corporate acquisition candidate [27], library journal acquisition candidates [28], and faculty course assignments [24]. ZOGP permits considering resource limitations and other selection limitations that must be rigidly observed.

ZOGP also permits the ranked inclusions of revitalization so that their selection is based, in part, on the FANP ranking system previously discussed. The ZOGP model for the present study can be stated as follows:

$$\text{Minimize} \qquad Z = P_K(w_j d_i^+, w_j d_i^-) \qquad (1)$$

Subject to $a_{ij}x_j + d_i^- - d_i^+ \le b_i$

$$\text{for } i = 1, 2, \ldots, m, j = 1, 2, \ldots, n \quad (2)$$

$$x_j + d_i^- = 1$$

$$\text{for } i = m+1, m+2, \ldots m+n, j = 1, 2, \ldots, n \quad (3)$$

$$x_j = 0 \text{ or } 1$$

$$\text{for } \forall j \quad (4)$$

where m = the number of revitalization of cultural heritages project goals to be considered in the model, n = the pool of revitalization of cultural heritages projects from which the optimal set will be selected, w_j = the FANP mathematical weight on j = 1, 2,…, n revitalization of cultural heritages projects, P_k = some k priority preemptive priority ($P_1 > P_2 > \ldots > P_k$), for i = 1, 2,…, m revitalization of cultural heritages project goals, d_i^+, d_i^- = the ith positive and negative deviation variables for i = 1, 2,…, m revitalization of cultural heritages project goals, x_j = a zero-one variable, where j = 1, 2,…, n possible projects to choose from and where $x_j = 1$, then select the jth revitalization of cultural heritages project or when $x_j = 0$, then do not select the jth revitalization of cultural heritages project, a_{ij} = the jth revitalization of cultural heritages project usage parameter of the ith resources, and b_i = the ith available resource or limitation factors that must be considered in the selection decision.

The ZOGP model bases the selection of the revitalization of the cultural heritages projects x_j on the FANP determined weights of w_j for corresponding d_i^-. The larger w_j, the more likely that the corresponding revitalization of cultural heritages project will be selected.

This property of ZOGP enables us to incorporate multiple goals, such as the planning and design fees, available cost budget, field construction period, and clerical fees, into the revitalization of the cultural heritages projects selection process. The weighted goal programming model considers all the goals simultaneously by forming an achievement function that minimizes the total weighted deviation from all the goals stated in the model. The weights are not preemptive but reflect the decision makers' preferences about the relative importance of each goal. The incommensurability issue faced in weighted goal programming when using goals that are measured with different units, such as available the cost budget goal and the field construction period goal, can be resolved using a normalization scheme [29]. Numerous studies in diverse areas concerning integrated AHP and ZOGP models conclude that combined models provide more realistic solutions by avoiding infeasibility [30], [31]. FANP enables modeling more complex relationships that include dependence between decision levels, and, therefore were used in the integrated decision approach proposed in this paper.

IV. An Empirical Study of the Revitalization of the Cultural Heritages Project Selection

To illustrate the use and advantages of the combined FANP and ZOGP model in the revitalization project selection of the cultural heritages, we used a case study obtained from Taipei City, Taiwan. This paper presents a real-world empirical example on an ongoing decision-making project called "Revitalization of the Cultural Heritages Projects Planning and Evaluation of Taipei City."

Most of the cultural heritages in Taipei were built for 200-300 years ago. In the history of the development of architecture engineering, this creative technique could be considered as a great work. Taipei City has an ongoing project to decide on the alternatives proposed for improving urban redevelopment. A council of 10 experts has been appointed to decide on the best solutions. The Council proposed that Taipei City review 7 of the alternative revitalization of the cultural heritages project by July, 2010.

Under the Council, a committee for choosing the methodology for evaluating these alternatives and their priorities was organized. As Committee members, the authors proposed a consensus-making method for reaching a group decision, based on a combination of FANP and ZOGP, as described in this paper.

The problem consisted of prioritizing these seven revitalization based on four criteria deemed important for the cultural heritages' future development. As a typical planning problem, there are multiple criteria, with both quantitative and qualitative elements, for comparing candidate alternatives. The proposed FANP model consists of a control hierarchy and a network of connections between the clusters of alternatives, actors, and criteria. The strategic criteria were included in the model to rate benefits (B), opportunities (O), costs (C), and risks (R). A final synthesis of alternatives was obtained using rated BOCR. Each alternative was evaluated with respect to these 4 criteria by evaluators and specialist teams consisting of authorities in their corresponding fields. These teams reported their evaluation of each alternative by assigning a pairwise comparison cardinal number score: the higher the score, the better the evaluation.

The BOCR criteria are compared by asking what gives the greatest benefit or opportunity. For costs and risks the question is "What incurs the greatest cost or risk?" After all the criteria comparisons, the weights of the criteria (criteria matrix and unweighted supermatrix of the BOCR criteria) are calculated. A weighted supermatrix is obtained by multiplying the elements of the unweighted supermatrix by the appropriate criteria weight. In other words, the values in the criteria matrix are used to weight the unweighted supermatrix values by multiplying the value in the cell of the criteria matrix times the value in each cell in the component of the unweighted supermatrix to produce a weighted supermatrix. Every component is weighted with its corresponding criteria matrix weight in this way. BOCR weights of the alternatives and criteria weights are obtained by the limits of the weighted supermatrix. For the benefit subnet, the weighted supermatrix and the limit matrix were calculated individually in the FANP. Being different from classic AHP applications, alternatives are influenced by the criteria and vice-versa. To measure the effects of the alternatives on criteria, it is necessary to know how much more important any given criterion is than any other one for C1, C2, C3, and C4. The space is filled by Saaty's 1-9 scale.

To determine the weights of the degree of influence between the criteria and candidate alternatives, we show the procedure using the matrix manipulation based on Saaty's supermatrix and his nine scales. More important, all these data were collected in a group discussion to avoid a unilateral decision based upon one individual's subjective judgment. The algorithm presented in Section III is applied to determine the importance ratings within each level by pairwise comparisons. The application is stated in stepwise form below:

Step 1. To compare the criteria, one responds to this question: Which criteria should be emphasized more when evaluating the revitalization of the cultural heritages project, and how much more? Using a pairwise comparison of all pairs with respect to the four criteria, we will obtain the following data using the AHP method, assuming no interdependence between them. These data provide only relative weight without considering independence between the criteria. We defined the weight matrix of criteria as w_1 = (B, O, C, R) = (0.50, 0.27, 0.17, 0.06).

Step 2. Again, by assuming that there is no interdependence between the seven projects (P_1-P_7), they are compared with respect to each criterion and yield a normalized weight (W_2) with respect to each criterion.

Step 3. Then, by assuming that there is no interdependence between the four criteria (C_1-C_4), they are compared with respect to each project and yielding a normalized weight with respect to each project.

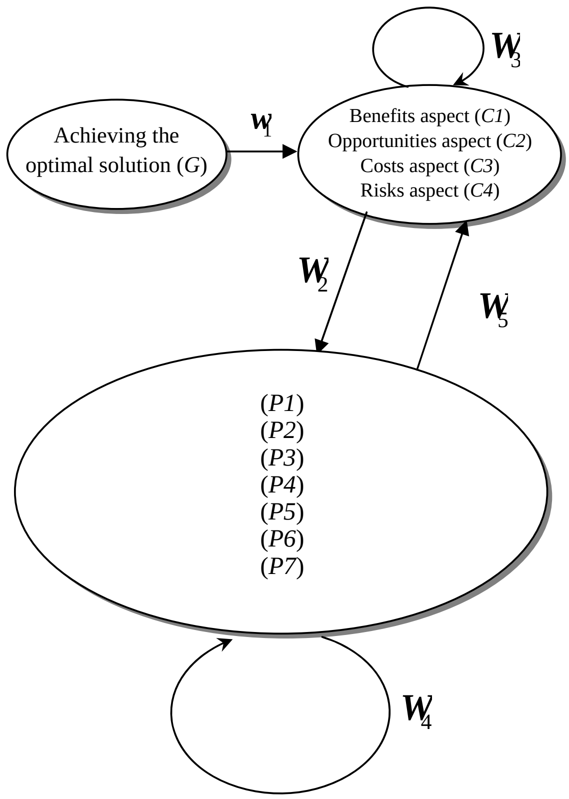
Step 4. Next, we consider the interdependence between the criteria. When we select the revitalization, we cannot concentrate on only one criterion but must consider the other criteria with it. Therefore, we need to examine the impact of all the criteria on each by using pairwise comparisons. We obtain the four sets of weights through expert-group interviews. These data tell us the relative impact of each criterion. For example, the degree of relative impact of B (*C1*) for O (*C2*) is 0.35, of C (*C3*) for R (*C4*) is 0.25, and of R (*C4*) for O (*C2*) is 0.30.

We defined the interdependence weight matrix of the criteria as W_3.

Step 5. Next, we dealt with interdependence between the alternatives with respect to each criterion and defined the weight matrices as W_4. An illustration of the question to which one must respond is "With respect to satisfying criterion 1 (Benefits), which project contributes more to the effect of project 1 on criterion 1, and how much more?"

Step 6. We now obtain the interdependence priorities of the criteria (w_c) by synthesizing the results from Steps 1 to 4, which is equal to W_3*w_1, namely $w_c= W_3*w_1$.

Step 7. The priorities of the Projects W_P with respect to each of the four criteria are given by synthesizing the results from Steps 2 and 5 as follows: $W_P = W_4*W_2$. Finally, the overall priorities for the candidate projects w_{FANP} are calculated by multiplying W_P by w_c.



$$W = \begin{array}{r} \\ Goal(G) \\ Criteria(C) \\ Alternatives(A) \end{array} \begin{array}{c} \begin{array}{ccc} G & C & A \end{array} \\ \begin{bmatrix} 0 & 0 & 0 \\ w_1 & W_3 & W_5 \\ 0 & W_2 & W_4 \end{bmatrix} \end{array}$$

Fig. 2 Decision network structure and corresponding supermatrix representations

The Proposed Method Applied

The committee followed our proposed method. First, they defined the decision goal for selecting a favorable revitalization strategy. Second, they used three evaluation clusters were used: the goal they had just defined, the criteria cluster, and the alternatives cluster. The criteria cluster contained the BOCR evaluation factors C_1-C_4, and the alternatives cluster contained the seven project strategies P_1-P_7. Fourth, they used our proposed interdependence and feedback system model, and, fifth, they shaped the decision network structure and corresponding supermatrix representations (Fig. 2) was for evaluating the project strategies; the looped arcs in the figure indicate inner dependencies. Sixth, to determine the relative importance of each element, the committee members were asked to respond, using Saaty's nine-point scale, to a series of pairwise comparisons. The results of their aggregated assessments are expressed as an unweighted supermatrix. Finally, to evaluate the weights of the elements, we used the limiting process method of the powers of the supermatrix. We used both the computation steps of Lee and Kim[20]and *Super Decisions* software (Creative Decisions Foundation, Pittsburgh, PA, USA) developed to implement Saaty's ANP (available at: http://www.superdecisions.com/)

The calculations of the supermatrix can be easily solved by either following the computation steps of Lee and Kim [20], or by using the professional software named "Super Decisions", and then the overall normalized priorities were obtained.

Our final results in the FANP Phase were (P_1,…P_7) = (0.21, 0.28, 0.06, 0.07, 0.23, 0.08, 0.07). The project with the highest weight was P_7, and the project with the second highest weight was P_5. These weights were used as priorities in goal programming formulation: (P_1,…P_7) = (w_1,…w_7) = (0.21, 0.28, 0.06, 0.07, 0.23, 0.08, 0.07).

To formulate the ZOGP model, we used an empirical example obtained from Taipei City based on the results of the prior FANP phase. The weights for each of the integer variables were determined via the FANP calculations. The weights were divided by one and allocated to each of the alternatives. Thus, the allocation/distribution process is the normalization of the stated variables of the objective function. On the other hand, normalized control variables are not needed for the constraints part of the method. The following is a summary of the empirical example. Suppose that there exist several obligatory and flexible goals that must be considered when selecting from the available pool of seven revitalization of cultural heritages projects. There are three major obligatory goals: (1) a maximum of $6,000,000 for planning and design fees is available, (2) a maximum budget of $3,100,000,000 is available, and (3) a maximum of 26 months of field construction time is available. Each strategy's contribution to planning and design fees, budgeted costs, and field construction time is proportional to the rate of project production that is currently established.

Note that these three resource factors are not constraints. It is not even expected that all of them can be satisfied simultaneously. The goal column values are not fixed constants but are flexible managerial goals to be approached as closely as possible.

In addition to the goal of selecting the revitalization of the cultural heritages projects, there are two other flexible goals, stated in order of their importance: (1) an initial limited allocation of budgeted available dollars was set but could be adjusted to a maximum amount, and (2) an initial allocation goal of clerical fees was set, but deviation from this allocation was possible.

Based on these data and the previously computed FANP values, we can formulate the goal constraints for this empirical problem. This ZOGP model was solved using optimization software (LINDO API 5.0; Lindo Systems, Inc., Chicago, IL, USA) on an Intel® 4.25 GHz Core™ 2 microcomputer in a few seconds of computer time. The results are summarized as follows:

For the empirical test, Projects 1, 2, 5, and 6 were chosen; their total budgeted cost was then determined. The planning and design fees were also calculated and less than the initial allocation fee. Also, the calculated field construction time was 20 months, 6 months less than the maximum of 26 months.

V. Conclusion

The set of all cultural heritages projects determined using the combined FANP and ZOGP approach is different from the solutions obtained by applying either AHP or ANP by itself. Considering interdependencies of the criteria and the analysis of the revitalization projects selection problem from a multi-objective perspective result in a need to focus on different evaluation and selection attributes. The combined FANP and ZOGP approach, which aims to quantify the interdependencies and multiple objectives inherent in the revitalization of the cultural heritages problem in a systematic way, appears to be an effective solution aid. The application of the FANP-ZOGP model to this empirical example demonstrates the procedure of finding weight by considering the interdependencies of criteria or alternatives.

This empirical example uses the FANP/ZOGP methodology for analysis. When all of the non-dominated solutions are found by our proposed algorithm, a decision-maker can evaluate the objective values of these solutions and identify a satisfactory alternative. In this paper, we have shown an alternative method of quantifying the combined effects of factors on organizational performance measures using the supermatrix approach. The selection of an appropriate set of revitalization of the cultural heritages projects is helpful to all land use and engineering organizations.

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