A hybrid approach to IT project selection

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Abstract: -Numerous enterprises anticipate that Information Technology (IT) may enhance their competitive advantage and profitability, and provide them with a competitive edge in meeting the challenges from global competition. However, there is a critical issue of how to invest in IT judiciously and improve the performance of organizations successfully. Although several methods have been proposed for selecting appropriate IT projects, their models use few criteria and lack sufficient information for evaluation. Indeed, to ensure the alignment of IT investment and strategic needs in the real world, it is necessary to consider a variety of financial and non-financial factors within the evaluation structure. In order to devise a more useful way to solve IT project selection problems, this paper combines the decision making trial and evaluation laboratory (DEMATEL) with the analytic network process (ANP) and the zero-one goal programming (ZOGP) to propose an effective solution that considers both financial and non-financial factors. Additionally, an empirical study is presented to illustrate the application of the proposed solution.

Key-words: - Information Technology; Project Selection; DEMATEL; ANP; ZOGP

1 Introduction

Numerous enterprises anticipate that Information Technology (IT) will help them to meet the challenges from global competition [15]. The adoption of IT should be for the purpose of increasing profitability, productivity, and customer satisfaction, not for joining a race to IT investment. Consequently, there is a critical issue of how to invest in IT judiciously and improve the performance of organizations successfully. In this sense, the selection of IT projects is important to all kinds of enterprises [18]. In order to properly evaluate and select IT projects, both financial and non-financial factors are required to be considered, such as: total cost, implementation time, benefits, risks, strategic fitness, function and technology, vendor's ability, and vendor's reputation [45]. Thus, the IT project selection involving many complex evaluation factors is a kind of multiple criteria decision-making (MCDM) problem [1][6][43].

Although several previously proposed MCDM methods in terms of IT project selection are useful, they have generally considered only independent IT projects or in evaluation criteria [19]. For this shortcoming, [33] designed a nonlinear zero-one goal programming (ZOGP), which can handle interdependencies between IT projects. However, this model merely solved the problem of interdependencies among projects. Subsequently, [19] proposed a solution that combined the analytic network process (ANP) with the ZOGP model and attempted to deal with the interdependencies among both IT projects and evaluation criteria. Their proposed solutions, however, leave room for improvement, because their models apply too few criteria without containing sufficient information for evaluation. Moreover, [2] proposed a ZOGP model for project selection, including several practical criteria in one decision model. Their solution is useful and well thought out but still requires us to add several financial and non-financial factors for ensuring the alignment of IT investment and strategic needs.

The ANP can deal with all kinds of interactions among elements, while the ZOGP may cope with the problem of optimal project selection under limited resource restrictions. Hence, combining the ANP with the ZOGP is a favorable way to handle the problem of project selection. However, it is unsuitable to use the ANP in situations when there are many more than seven evaluation factors within a level. This is because too many evaluation factors may lead to a large number of pairwise comparisons required to perform and result in the increased difficulties of calculations and operations in the decision-making process. In this regard, it is better to divide these factors into two sub-groups by using the decision making trial and evaluation laboratory (DEMATEL). This is because the DEMATEL can divide multiple factors into a cause group and an effect group in order to better capture causal relationships visibly. This paper therefore combines the DEMATEL with the ANP and the ZOGP to propose an effective solution that considers both financial and non-financial factors, aiming for a more useful way to solve IT project selection problems.

The rest of this paper is organized as follows. In section 2, the prior literature related to IT project selection is reviewed. In section 3, the proposed solution is presented. In section 4, an empirical study is illustrated. Finally, according to the findings of this research, conclusions and suggestions are depicted.

2 Selecting IT projects with the MCDM method

The project selection is influenced by multiple factors, among which are decision-maker preferences and priorities, benefits, costs, project risk, required time for completion and training, and the availability of other scarce resources [1]. Thus, IT project selection is a kind of MCDM problem, and we need to employ MCDM methods to handle it well. The issue of IT project selection and the MCDM method for IT project selection are discussed below.

2.1 The issue of IT project selection

A successful project requires efforts of sensible project selection, performance evaluation [8], and control management [21]. The Project Management Institute (PMI) comments that projects are often implemented as a means of achieving an organization's strategic plan. A project can be defined as a temporary endeavor undertaken to create a unique product or service [26]. For project evaluation, there are two important aspects in terms of evaluation criteria, such as: the project contents and the project feasibility [4]. In particular, technology selection is highly influential on the profitability and growth of an enterprise, so that decision-makers must be aware of both the tangible and intangible factors in IT investment [6]. Moreover, [33] indicate that IT project selection is an arduous endeavor because of the multiple factors, the limitation of scarce resources, and the candidate projects entailing benefit and resource interdependencies. In addition, [18] performed research into critical issues in IT investment management, such as vendor selection, project manager, project planning, training, and infrastructure development. All these kinds of issues are worth careful consideration, when enterprises evaluate and select their IT projects.

Several methods and tools have been developed to calculate the cost-benefit of IT projects; one such tool is the constructive cost model (COCOMO), originally published by in 1981 [3]. Various other IT evaluation approaches and methods are also discussed, including: return on investment (ROI), economic value-add (EVA), internal rate of return (IRR), net present value (NPV), discounted cash flow (DCF) method, and the IT Balanced Scorecard approach. However, to ensure the alignment of IT investment and strategic needs, it is necessary to consider a variety of financial and non-financial factors within the evaluation structure. In practice, the National Institutes of Health (NIH) suggests the "Criteria for Ranking NIH IT Projects" [24] which consists of thirteen criteria for the IT project selection.

2.2 MCDM methods for IT project selection

Using appropriate MCDM methods may bring out new insights together with a documented defensible rationale for the decision. There are many MCDM methods that have been developed, such as the Elimination and Choice Translating Reality (ELECTRE), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and the Analytic Hierarchy Process (AHP). Unfortunately, none of these above methods deal with the interactions among elements. For handling this problem, [28] proposed the ANP as a new MCDM method.

As for the movement of the IT projects selection, it may be captured from three perspectives. First, the concept of IT projects selection has shifted from traditional financial measures toward incorporating non-financial measures, and away from using merely a single criterion. This is also the reason for the intense focus on the IT Balanced Scorecard. Secondly, regarding the evaluation technique, the use of goal programming (GP) is getting increasingly popular [1]. There are various methods proposed for solving IT project selection problems, such as the scoring approach [21], the ranking method [5], and the AHP method [23]. Moreover, in order to maximize the utilization of limited scarce resources, many researchers employ a solution with a mathematical programming model to pursue optimization, such as linear 0-1 mathematical programming [7], dynamic programming [42], quadratic programming [43], goal programming [31], and nonlinear ZOGP [33][34][1]. Thirdly, this is good combination with the ANP and the ZOGP for solving project selection problems. This is because the ANP is free to handle interdependencies within criteria or alternatives, and the ZOGP is good at handling the optimal problem under limited resource restrictions. Therefore, for example, [19] have proposed a solution for IT projects selection, combining the ANP with the ZOGP. In their proposed solution, interdependencies among project or evaluation criteria are allowed.

Although the above methods of IT project selection are useful, their models use few criteria and thus contain insufficient information for evaluation. In the real world, for ensuring the alignment of IT investment and strategic needs, it is necessary to consider several financial and non-financial factors within the evaluation structure. Furthermore, if evaluation factors become too many, employing the ANP is unsuitable because the pairwise comparisons would come to be extremely large together with the increased difficulties of calculations and operations in the decision-making process. Dealing with such difficulties, the DEMATEL is a desirable way to tackle problems that contain excess criteria. This is because the DEMATEL can divide multiple evaluation factors into a "cause group" and an "effect group" in order to better capture the causal relationship visually

3 The proposed solution

Referring to the analysis procedure suggested by [25], this paper proposes an effective solution which consists of two main analysis phases: the non-financial evaluation using the DEMATEL and the ANP, and the optimal solution using the ZOGP.

3.1 The non-financial evaluation using the DEMATEL and the ANP

Many works have mentioned that the evaluation of IT investments usually comprises several complicated aspects, including financial and non-financial aspects. To perform the non-financial evaluation, it is a favorable way to use the DEMATEL and the ANP. Some essentials of the ANP and the DEMATEL are briefly described as follows.

3.1.1 The DEMATEL

The Battelle Memorial Institute conducted the DEMATEL project through its Geneva Research Centre [12][13][10]. The original DEMATEL was aimed at the fragmented and antagonistic phenomena of world societies and searched for integrated solutions [10]. In recent years, the DEMATEL is becoming very popular in Japan [46][14][15] [47] because it is especially pragmatic for visualizing the structure of complicated causal relation through the directed graph named digraph. The digraph portrays a contextual relation among the elements of the system, in which the numeral represents the strength of influence.

The DEMATEL, which is based on graph theory, has two primary merits: it can divide a set of criteria into cause group and effect group for further applying to the ANP; and it can display causal relationships among criteria visually, thus enabling us to easily discover things inside the complex problem because the graph exhibits the mathematical results with visualization clearly and unambiguously. For using the DEMATEL smoothly, this paper refines the version used by [11] and suggests four steps as below.

Step 1: Producing the direct-relation matrix

Measuring the relationship between criteria requires that the comparison scale be designed as four levels: 0 (no influence), 1 (low influence), 2 (high influence), and 3 (very high influence). Next, experts make sets of the pairwise comparisons in terms of influence and direction between criteria. Then, as the result of these evaluations, the initial data can be obtained as the direct-relation matrix that is a $n \times n$ matrix A, in which a_{ij} is denoted as the degree to which the criterion i affects the criterion j.

Step 2: Normalizing the direct-relation matrix

On the base of the direct-relation matrix A, the normalized direct-relation matrix $\boldsymbol{X}$ can be obtained through formulas (1) and (2).

$$\boldsymbol{X} = k \cdot \boldsymbol{A} \quad (1)$$

$$k = \frac{1}{\max\limits_{1 \le i \le n} \sum_{j=1}^{n} a_{ij}}, \qquad i, j = 1, 2, ..., n \quad (2)$$

Step 3: Attaining the total-relation matrix

Once the normalized direct-relation matrix $\boldsymbol{X}$ is obtained, the total-relation matrix $\boldsymbol{T}$ can be acquired by using formula (3), in which the $\boldsymbol{I}$ is denoted as the identity matrix.

$$\boldsymbol{T} = \boldsymbol{X}(\boldsymbol{I} - \boldsymbol{X})^{-1}$$

Step 4: Analyzing the results

The sum of rows and the sum of columns are separately denoted as vector $\boldsymbol{D}$ and vector $\boldsymbol{R}$ through formulas (4), (5), and (6). Then, the horizontal axis vector ($\boldsymbol{D}+\boldsymbol{R}$) named "Prominence" is made by adding $\boldsymbol{D}$ to $\boldsymbol{R}$, which reveals how much importance the criterion has. Similarly, the vertical axis ($\boldsymbol{D}-\boldsymbol{R}$) named "Relation" is made by subtracting $\boldsymbol{D}$ from $\boldsymbol{R}$, which may divide criteria into a cause group and an effect group. Generally, when ($\boldsymbol{D}-\boldsymbol{R}$) is positive, the criterion belongs to the cause group. Otherwise, if the ($\boldsymbol{D}-\boldsymbol{R}$) is negative, the criterion belongs to the effect group. Therefore, the causal diagram can be acquired by mapping the dataset of the $(\boldsymbol{D}+\boldsymbol{R}, \boldsymbol{D}-\boldsymbol{R})$, providing valuable insight for making decisions.

$$\boldsymbol{T} = [t_{ij}]_{n \times n}, \qquad i, j = 1, 2, ..., n \quad (4)$$

$$\boldsymbol{D} = \left[\sum_{j=1}^{n} t_{ij} \right]_{n\times 1} = [t_{i\cdot}]_{n\times 1} \quad (5)$$

$$\boldsymbol{R} = \left[\sum_{i=1}^{n} t_{ij} \right]_{1\times n}^{t} = [t_{\cdot j}]_{n\times 1} \quad (6)$$

where vector $\boldsymbol{D}$ and vector $\boldsymbol{R}$ respectively denote the sum of rows and the sum of columns from total-relation matrix $\boldsymbol{T} = [t_{ij}]_{n\times n}$.

3.1.2 The ANP

Saaty [29] has demonstrated several types of ANP models, such as: the Hamburger Model, the Car Purchase BCR model, and the National Missile Defense model. However, from the viewpoint of [17], the ANP may simply be differentiated into two practical kinds of models: the Feedback System model and the Series System model (similar to the AHP model). In the Feedback System model, clusters link one by one in turn as a network system. This kind of model can capture effectively the complex effects of interplay in human society, especially when risk and uncertainty are involved [30]. In the Feedback System model (Fig. 1), there are three clusters (cause criteria, effect criteria, and alternatives) linked one by one in turn as a network system.

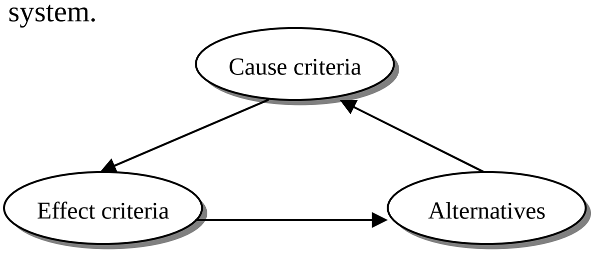

Fig. 1. The Feedback System model.

For determining the relative importance between elements, decision makers are asked to respond through a series of pairwise comparisons. These pairwise comparisons are based on Saaty's nine-point scale and represent how many times one element is more important than another, where a score of 1 indicates equal importance between the two elements and 9 represents the extreme importance of one element compared to the other. Moreover, for evaluating the weights of elements, the AHP uses the principal eigenvector of comparison matrix, whereas the ANP employs the limiting process method of the powers of the supermatrix [39]. For synthesizing overall priorities for the alternatives, it requires adjusting the unweighted supermatrix to keep it to be column stochastic [31]. The unweighted supermatrix contains the local priorities derived from the pairwise comparisons throughout the network as shown in Fig. 2, where W_S is a matrix that represents the weights of the cause criteria with respect to alternatives, and W_C is a matrix that denotes the weights of the effect criteria with respect to the cause criteria, W_A is a matrix that shows the weights of alternatives with respect to the effect criteria. Finally, the weighted supermatrix (the adjusted unweighted supermatrix) can be raised to limiting powers to calculate the overall priorities.

$$W = \begin{array}{l} \text{Cause criteria} \\ \text{Effect criteria} \\ \text{Alternatives} \end{array} \overset{\begin{array}{ccc} \text{Cause criteria} & \text{Effect criteria} & \text{Alternatives} \end{array}}{\begin{pmatrix} 0 & 0 & W_S \\ W_C & 0 & 0 \\ 0 & W_A & 0 \end{pmatrix}}$$

Fig. 2. The unweighted supermatrix.

According to the overall priorities of alternatives, alternatives can be compared and the best alternative can be selected. From a financial perspective, however, the best alternative selected by the ANP is not certainly the optimal choice due to limited resource restrictions. Hence, it is still necessary to employ the ZOGP for selecting the optimal alternative, and the overall priorities of alternatives can be used as a constraint in the ZOGP model.

3.2 The optimal solution using the ZOGP

Selecting an appropriate IT project requires the consideration of various sorts of factors, such as: the acceptable benefits, costs, and risks of the project; the required time for the completion of and training for the project; and especially the limitation of scarce resources [1]. As discussed previously, various methods have been proposed for solving IT project selection, each with its own merits and demerits. However, in a situation requiring the consideration of resource constraint or optimal solution, some methods are not suitable, such as the scoring approach, the ranking method, and the AHP or ANP method [20][1]. Hence, there are several works that attempt to solve the MCDM problem under conditions of resource constraint, combining the AHP or ANP with the GP, such as [36] [38][19][2].

The GP is a very suitable methodology to solve the allocation problem, especially when many decision variables and constraints are considered simultaneously [2]. Additionally, it can perform as a model to represent the abstraction of the real situation in a mathematical form. The GP handles multiple-goal situations within the framework of linear programming, and all goals are included in the model as constraints [35]. In the GP model, the objective function is to minimize each of the deviation variables for each constraint. Moreover, these goals are prioritized into three different types: the ordinal ranking type known as lexicographic goal programming (LGP), the cardinal ranking known as weighted goal programming (WGP), and the combination of the ordinal ranking and the cardinal ranking [41]. In addition, there are several other types, such as the MINMAX GP and the Fuzzy GP [40]. Among these types of the GP, the LGP is the most popular and is used widely [37]. The LGP attaches pre-emptive priorities to the different goals in order to minimize the unwanted deviation variables in a lexicographic order [27].

As a solution technique, the GP is suitable to handle decision making aimed at achieving a set of conflicting goals, and the objective function seeks to minimize deviations from the set of given goals, which is subject to restrictions such as limited budget, time, labor, and material. The ZOGP model proposed can be summarized as follows:

Minimize $$Z = \sum_{i \in m}^{m} P_i (d_i^+ + d_i^-) \tag{7}$$

subject to

$$\sum_{j=1}^{n} a_{ij} x_j - d_i^+ + d_i^- = b_i$$

$$(i = 1, 2, ..., m;\ j = 1, 2, ..., n) \tag{8}$$

$$\sum_{j=1}^{n} w_j x_j - d_i^+ + d_i^- = 1$$

$$(i = m+1, m+2, ..., m+n;\ j = 1, 2, ..., n) \tag{9}$$

$$x_j = 0 \text{ or } 1,\ \ d_i^-, d_i^+ \geq 0 .$$

in this ZOGP model, there are n projects available for selection under m goals. The objective function Z is given by Formula (7), seeking to minimize the deviation from desired targets for constraints, where P_i are preemptive priority factors for corresponding to goals, and d_i^+, d_i^- are denoted as the i th positive and negative deviational variables for goals. Also, d_i^+ signifies the over-achievement of the i th goal, and d_i^- implies the under-achievement of the i th goal. In Formula (8), the a_{ij} denotes the j th project usage of the i th resource, and the decision variable x_j are zero-one variables corresponding to the project selection, then, the b_i denotes the constraint of the i th resource. In Formula (9), the w_j denotes the overall priority of projects by the ANP. In addition, when $x_j = 1$ expresses that the j th project is selected, otherwise $x_j = 0$ expresses that the j th project is not selected.

4 An empirical study

In this section, an empirical study shows how a high-tech company applied the proposed solution for selecting IT projects. The case Company Y is a Taiwan firm with more than 1,700 employees in 15 countries and turnover in excess of US$ 265 million. The company is performing as a leading solution provider in the industrial automation market, offering more than 420 products and solutions covering the range from system-integration hardware and software to customer-driven service.

In order to cope with challenges from newcomers and to reach solutions that may lead to shorter lead-time, high quality, competitive prices, and improved customer service, Company Y decided to upgrade its IT systems for increasing customer convenience and maximizing operational efficiencies. To that end, Company Y set up an IT investment committee consisting of the general manager, and several managers representing the marketing, financial, production, human resource, and information-technology departments. The following shows how Company Y successfully utilized the proposed solution with the two-phase procedure to achieve its IT project selection.

4.1 Applications of proposed solution

In phase 1, it is required to determine a set of criteria and alternatives for selecting IT projects. After conducting the literature review and a profound discussion, the committee adopted the "Criteria for Ranking NIH IT Projects" [24] as the evaluation criteria. The "Criteria for Ranking NIH IT Projects" contains thirteen criteria, such as: Management Support (g_1), Risk of Not Doing It (g_2), Schedule Risk (g_3), Cost Sensitivity (g_4), Organizational Risk (g_5), Technical Risk (g_6), Scope of Beneficiaries (g_7), Business Process Redesign (g_8), Business Model (g_9), Quality of Work Life (g_{10}), Improvement of Internal Service (g_{11}), Improvement of Service to Public (g_{12}), and Benefit-Cost Impact (g_{13}).

These thirteen criteria were deemed to be significant and indispensable. However, too many evaluation criteria may result in the increased difficulties of calculations and operations in the decision-making process. Hence, the DEMATEL was employed to divide these criteria into two sub-groups. Once the relationships between these criteria were measured by the IT investment committee, the direct-relation matrix (see Table 1) was produced. Next, the normalized direct-relation matrix was obtained by formulas (1) and (2). Additionally, the total-relation matrix (Table 2) was acquired by using formula (3). Then, using formulas (4), (5), and (6), the causal diagram (see Fig. 3) could be acquired. Looking at the causal diagram, it is clear that evaluation criteria were visually divided into the cause group (g_4, g_5, g_6, g_8, g_9, and g_{13}), and the effect group ($g_1, g_2, g_3, g_7, g_{10}, g_{11}$, and g_{12}). These two groups are used to serve respectively as the "cause criteria" cluster and the "effect criteria" cluster in the ANP model.

Table 1 The direct-relation matrix of criteria

	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}	g_{11}	g_{12}	g_{13}
g_1	0	3	2	2	2	1	1	0	0	1	1	1	1
g_2	2	0	0	0	0	0	3	0	0	0	0	0	3
g_3	2	1	0	2	0	0	2	0	0	1	0	0	2
g_4	2	3	2	0	0	0	1	2	2	1	2	1	3
g_5	2	1	1	0	0	0	1	2	2	1	3	3	1
g_6	0	2	2	0	1	0	0	1	2	0	0	0	2
g_7	1	0	0	0	1	1	0	0	0	2	0	0	0
g_8	1	2	3	2	2	0	0	0	3	2	2	2	1
g_9	2	1	1	2	1	1	0	0	0	1	1	1	1
g_{10}	0	0	1	0	0	1	1	0	0	0	0	0	1
g_{11}	1	0	0	1	0	0	0	0	0	1	0	3	1
g_{12}	2	0	0	1	0	0	0	0	0	2	1	0	1
g_{13}	3	2	2	2	1	1	1	2	1	2	1	1	0

Table 2 The total-relation matrix of criteria

	g_1	g_2	g_3	g_4	g_5	g_6	g_7	g_8	g_9	g_{10}	g_{11}	g_{12}	g_{13}
g_1	0.134	0.246	0.182	0.172	0.142	0.083	0.143	0.053	0.057	0.140	0.118	0.121	0.177
g_2	0.171	0.066	0.057	0.052	0.043	0.033	0.192	0.031	0.027	0.065	0.036	0.037	0.197
g_3	0.189	0.135	0.072	0.157	0.044	0.035	0.162	0.040	0.039	0.120	0.049	0.046	0.181
g_4	0.271	0.283	0.219	0.127	0.076	0.054	0.162	0.153	0.163	0.178	0.183	0.147	0.297
g_5	0.235	0.153	0.144	0.106	0.061	0.042	0.124	0.136	0.150	0.163	0.223	0.239	0.168
g_6	0.110	0.178	0.169	0.075	0.091	0.029	0.070	0.087	0.142	0.072	0.055	0.056	0.188
g_7	0.077	0.032	0.032	0.020	0.066	0.064	0.024	0.015	0.019	0.121	0.021	0.022	0.035
g_8	0.228	0.231	0.259	0.217	0.158	0.049	0.112	0.061	0.212	0.222	0.194	0.202	0.212
g_9	0.206	0.148	0.132	0.170	0.093	0.081	0.073	0.046	0.049	0.127	0.112	0.114	0.156
g_{10}	0.034	0.029	0.075	0.023	0.016	0.061	0.071	0.015	0.016	0.027	0.013	0.013	0.078
g_{11}	0.110	0.048	0.042	0.090	0.022	0.018	0.033	0.022	0.021	0.099	0.035	0.177	0.101
g_{12}	0.151	0.056	0.050	0.091	0.027	0.023	0.039	0.023	0.023	0.141	0.081	0.037	0.104
g_{13}	0.304	0.242	0.224	0.211	0.123	0.098	0.160	0.154	0.124	0.218	0.142	0.145	0.161

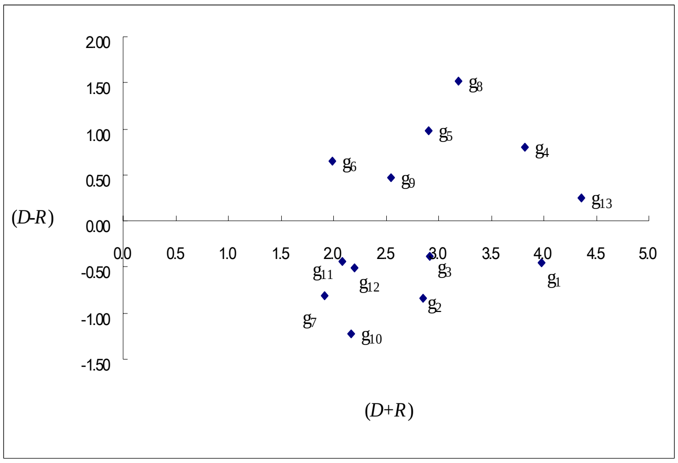

Fig. 3. The causal diagram of criteria.

After the criteria are divided into the cause group and effect group, it is necessary to generate alternatives for evaluation. Through the screening of several alternatives, the IT investment committee listed five potential projects. Then the evaluation structure was built, including three clusters with a chain of the cause criteria, effect criteria, and alternatives. Next, for deriving the relative importance between elements, members of the committee were asked to respond with a series of pairwise comparisons. From the results of pairwise comparisons, three matrices (W_S, W_C, and W_A) were obtained to shape the unweighted supermatrix (Table 3). Finally, the calculations of the supermatrix can be easily solved by using the professional software named "Super Decisions", and then the overall priorities of alternatives were obtained from the limit supermatrix: $W_A = (A_1, A_2, A_3, A_4, A_5)$ = (0.195, 0.228, 0.209, 0.170, 0.198). Therefore, the best alternative is project 2 due to the highest priority of 0.228, followed by project 3 of 0.209, and so on.

Table 3 The unweighted supermatrix of IT project selection

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	A_1	A_2	A_3	A_4	A_5	S_1	S_2	S_3	S_4	S_5	S_6
C_1	0	0	0	0	0	0	0	0	0	0	0	0	0.093	0.121	0.256	0.092	0.208	0.077
C_2	0	0	0	0	0	0	0	0	0	0	0	0	0.144	0.060	0.058	0.207	0.211	0.151
C_3	0	0	0	0	0	0	0	0	0	0	0	0	0.153	0.173	0.143	0.099	0.062	0.162
C_4	0	0	0	0	0	0	0	0	0	0	0	0	0.191	0.273	0.181	0.138	0.078	0.113
C_5	0	0	0	0	0	0	0	0	0	0	0	0	0.167	0.113	0.105	0.149	0.158	0.235
C_6	0	0	0	0	0	0	0	0	0	0	0	0	0.109	0.107	0.119	0.170	0.156	0.148
C_7	0	0	0	0	0	0	0	0	0	0	0	0	0.145	0.152	0.138	0.144	0.127	0.115
A_1	0.116	0.199	0.156	0.311	0.162	0.288	0.119	0	0	0	0	0	0	0	0	0	0	0
A_2	0.213	0.173	0.201	0.269	0.354	0.138	0.223	0	0	0	0	0	0	0	0	0	0	0
A_3	0.260	0.261	0.202	0.155	0.150	0.159	0.290	0	0	0	0	0	0	0	0	0	0	0
A_4	0.187	0.189	0.194	0.113	0.143	0.240	0.138	0	0	0	0	0	0	0	0	0	0	0
A_5	0.224	0.179	0.247	0.152	0.190	0.175	0.229	0	0	0	0	0	0	0	0	0	0	0
S_1	0	0	0	0	0	0	0	0.269	0.239	0.102	0.107	0.148	0	0	0	0	0	0
S_2	0	0	0	0	0	0	0	0.118	0.187	0.193	0.224	0.110	0	0	0	0	0	0
S_3	0	0	0	0	0	0	0	0.109	0.112	0.119	0.224	0.193	0	0	0	0	0	0
S_4	0	0	0	0	0	0	0	0.120	0.101	0.122	0.224	0.300	0	0	0	0	0	0
S_5	0	0	0	0	0	0	0	0.223	0.216	0.169	0.113	0.135	0	0	0	0	0	0
S_6	0	0	0	0	0	0	0	0.161	0.145	0.295	0.108	0.113	0	0	0	0	0	0

In phase 2, for evaluating five potential projects (see Table 4) with a financial perspective, the IT investment committee designed five indicators and applied the ZOGP in order to pursue the favorable combination of IT projects. Their five indicators were the completion time, training time, NPV-based cash outflow, NPV-based cash inflow, and NPV-based ROI. Specifically, the NPV-based cash outflow was calculated in term of the total cost of ownership (TCO), which including all the direct and indirect costs, such as the development cost, transition cost, maintenance cost, and expansion cost. The NPV-based cash inflow was converted from the benefits of the proposed project. Then, the ratio NPV-based ROI was calculated by taking the NPV-based cash inflow divided by the NPV-based cash outflow, represented as a percentage for judging IT investments.

Table 4 Relevant information about projects

	Project 1	Project 2	Project 3	Project 4	Project 5	Targets
completion time (days)	15	20	20	25	14	69
training time (days)	7	9	10	12	4	30
NPV-based cash outflow ($000)	170	220	140	290	210	740
NPV-based cash inflow ($000)	200	280	220	300	260	920
NPV-based ROI	117.6%	127.3%	157.1%	103.4%	123.8%	124.3%

The IT investment committee wanted to arrive at a favorable combination of IT projects with the purpose of reaching the expected NPV-based ROI with regard to several goals. With respect to strategic fitness perspective, the first goal mandates that project 2 must be included in the combination because its overall priority was the highest derived from the ANP analysis. The second goal is to ensure that the NPV-based cash inflow is able to reach a level of at least US$920,000 in one year. The third goal is to limit the NPV-based cash outflow so that it may not exceed US$740,000 yearly. The fourth goal is to ensure that the completion time not exceed a 69-day limit. The fifth goal is to allow that the training period may be in excess of 30 days. The final goal is to consider and utilize the overall priorities of projects derived from the ANP analysis. Hence, the ZOGP model can be expressed as follows:

Minimize $Z = P_1(d_1^- + d_1^+) + P_2(d_2^-) + P_3(d_3^+) + P_4(d_4^+) + P_5(d_5^-) + P_6(d_6^- + d_6^+)$

subject to

$$x_2 + d_1^- - d_1^+ = 1,$$

$$200\,x_1 + 280\,x_2 + 220\,x_3 + 300x_4 + 260x_5 + d_2^- - d_2^+ = 920\,,$$

$$170\,x_1 + 220\,x_2 + 140\,x_3 + 290\,x_4 + 210x_5 + d_3^- - d_3^+ = 740\,,$$

$$15\,x_1 + 20\,x_2 + 20\,x_3 + 25\,x_4 + 14x_5 + d_4^- - d_4^+ = 69\,,$$
$$7\,x_1 + 9\,x_2 + 10\,x_3 + 12x_4 + 4x_5 + d_5^- - d_5^+ = 30\,,$$
$$0.195\,x_1 + 0.228\,x_2 + 0.209\,x_3 + 0.170\,x_4 + 0.198x_5 + d_6^- - d_6^+ = 1,$$
$$x_j = 0 \text{ or } 1\,,$$
$$d_i^-, d_i^+ \geq 0\,.$$

Under this ZOGP model, the results show that $x_1 = x_2 = x_3 = x_5 = 1$, $x_4 = 0$, $d_1^- = d_1^+ = d_2^- = d_3^+ = d_3^- = d_4^- = d_4^+ = d_5^- = d_5^+ = d_6^+ = 0$, $d_2^+ = 40$, $d_6^- = 0.17$. Thus, the IT investment committee may accept the solution. This is because projects 1, 2, 3, and 5 are selected, and the favorable combination provides the NPV-based cash inflow US$960,000 more than the targeted US$920,000. Also, the NPV-based ROI may better achieve at 129.7%, higher than the targeted 124.3%.

4.2 Discussions

As IT project selection is complex MCDM problem, it requires MCDM methods to handle appropriately. For a proper IT project selection, it is necessary to enrich not only the evaluation criteria but also the selection methodology.

Regarding the evaluation criteria, the most popular criteria involved such items as benefits, costs, risk, completion time, and training time of project. But these criteria alone are not sufficient to provide adequate information for evaluation. This paper adds two kinds of evaluation criteria for use in IT project selection. One is the qualitative factors in terms of strategic fitness, such as the “Criteria for Ranking NIH IT Projects” [24]. The other kind is the quantitative factors which relate to economic justification that can be calculated by several useful methods, such as the NPV-based cash outflow, the NPV-based cash inflow, and the NPV-based ROI.

Concerning the selection methodology, there are various methods proposed for solving IT project selection problems, such as the scoring approach, the ranking method, the AHP or ANP method, and the ZOGP model. Among these methods, the combination of the ANP with the ZOGP is particularly powerful and pragmatic. The ANP is a multi-criteria approach for decision-making, able to deal with all kinds of interactions among elements, and has the capacity to transform qualitative judgments into quantitative values. The ZOGP has sufficient flexibility to solve the allocation problem with multiple goals, especially when many decision variables and constraints are considered simultaneously. In other words, the ANP method is helpful in handling qualitative factors, and the ZOGP model is good at dealing with quantitative factors. Thus, integrating the ANP with the ZOGP is an excellent way to solve project selections.

However, when we want to enrich the contents of evaluation criteria, the quantity of criteria may become quite large. Solution of this kind of problem may be achieved with the help of the DEMATEL. The DEMATEL, which is based on graph theory, is able to divide complex factors into cause and effect groups, displaying causal relationships among criteria visually. In particular, the DEMATEL is constructive in situations where it is not suitable to employ the ANP directly, due to evaluation criteria being in excess of seven.

Additionally, an empirical study of IT project selection was presented. The results show that the case company applied our solution and finally arrived at a favorable combination of IT projects. Furthermore, the proposed solution has several obvious performances. One is that this paper first linked the DEMATEL with the ANP and ZOGP to deal with the IT project selection, and took great considerations into either quantitative and qualitative factors or financial and non-financial factors. In addition, the proposed solution can divide a set of important factors into cause group and effect group, so as to better capture causal relationships apparently. In particular, a set of n evaluation criteria that requires operating $\frac{1}{2}n\,(n-1)$ pairwise comparisons [23]. Using the proposed solution in this study, the original 13 criteria were divided into 6 cause criteria and 7 effect criteria, so that the number of required pairwise comparisons were reduced from 78 to 36. This means that the decision-making task may become easier and faster with saving 42 pairwise comparisons.

5 Conclusions

In the accelerating Information Age, competitive pressures are accumulating and multiplying. As enterprises increasingly face struggles with intense global competition and suffer weak corporate performance, IT investments are more and more taking the form of an MCDM type of problem. To that end, both strategic needs and financial outcomes require more concern and attention than before, together with creating a need for more profound evaluation criteria and selection methodologies.

Several methods are proposed for selecting IT projects, however, previous models are simple and do not contain sufficient information for evaluation. In order to ensure the alignment of IT investment and strategic needs, we are required to consider a variety of financial and non-financial factors within the evaluation structure. This paper therefore proposes an effective solution using a hybrid approach that allows consideration of both strategic fitness and economic justification. As the DEMATEL, the ANP, and the ZOGP each have their own advantages, this hybrid approach combines these three powerful MCDM methods in order to devise a more useful way to solve IT project selection problems.

As a test case, this paper presents an empirical study of IT project selection in order to demonstrate the proposed solution with regard to its usefulness. Further, the proposed solution is applicable to all enterprises that face multifaceted criteria and need to solve multiple goals for seeking optimal solutions under limited resources. To promote continuing research in future, it would be worthwhile to investigate more cases in order to uncover invaluable new study issues using current optimization techniques like Genetic algorithms or Neural Networks.

References

[1] M.A. Badri, D. Davis, D. Davis, A comprehensive 0–1 goal programming model for project selection, *International Journal of Project Management*, Vol. 19, No.4, 2001, pp.243-252.

[2] M.A. Badri, A combined AHP-GP model for quality control systems, International *Journal of Production Economics*, Vol.72, No.1, 2001, pp.27-40.

[3] B.W. Boehm, E. Horowitz, R. Madachy, D. Reifer, B.K. Clark, B. Steece, A.W. Brown, S. Chulani, C. Abts, *Software Cost Estimation with Cocomo II*, Prentice Hall PTR, 2000.

[4] M. Bohanec, V. Rajkovic, B. Semolic, A. Pogacnik, Knowledge-based Portfolio Analysis for Project Evaluation, *Information & Management*, Vol.28, No.5, 1995, pp.293-302.

[5] M.D.J. Buss, How to rank computer projects, *Harvard Business Review*, Vol.61, No.1 1983, pp.118-125.

[6] S. Chakraborty, A Simulation Based Comparative Study of Normalization Procedures in Multiattribute Decision Making, Proceedings of the 6th WSEAS Int. Conf. on Artificial Intelligence, Knowledge Engineering and Data Bases, Corfu Island, Greece, February 16-19, 2007, pp.102-109.

[7] F.T.S. Chen, M.H. Chen, N.K.H. Tang, Evaluation methodologies for technology selection, *Journal of Materials Processing Technology*, Vol.107, No.1-3, 2000, pp.330-337.

[8] S.H. Cheng, H.M. Yang, C.C. Shen, K.L. Hsieh, Incorporating Fuzzy Aggregation Weight and Multiple Criterions Decision-Making into Project Performance Evaluation, *WSEAS TRANSACTIONS on BUSINESS and ECONOMICS*, Vol.3, No.6, 2006, pp.461-466.

[9] G. Dantzig, *On integer and partial linear programming problems*, The Rand Corporation, 1958, pp. 1410.

[10] E. Fontela, A. Gabus, *Current Perceptions of the World Problematique*. In: World Modelling: A Dialogue C.W. Churchman and R.O. Mason (ed.), Amsterdam, Oxford, North-Holland Publishing Company, 1976.

[11] E. Fontela, A. Gabus, *The DEMATEL Observer, DEMATEL 1976 Report. BATTELLE Institute*, Geneva Research Center, 1976.

[12] A. Gabus, E. Fontela, World Problems, *An Invitation to Further Thought Within the Framework of DEMATEL*, Battelle Geneva Research Centre, Geneva, Switzerland, 1972.

[13] A. Gabus, E. Fontela, *Perceptions of the World Problematique: Communication Procedure*, Communicating With Those Bearing Collective Responsibility (DEMATEL Report No. 1). Battelle Geneva Research Centre, Geneva, Switzerland, 1973.

[14] S. Hori, Y. Shimizu, Designing methods of human interface for supervisory control systems, *Control Engineering Practice*, Vol.7, No.11, 1999, pp.1413-1419.

[15] H. Jiang, J. Yang, Information Technology Support System of Supply Chain Management, Proceedings of the 11th WSEAS International Conference on APPLIED MATHEMATICS, Dallas, Texas, USA, March 22-24, 2007, pp.138-142.

[16] M. Kamaike, Design Elements in the Passenger Car Development: The Classification and the Influence Analysis in Case of Recreational Vehicle. *Bulletin of JSSD*, Vol.48, No.1, 2001, pp.29-38.

[17] E. Kinosita, From AHP to ANP, *Operations Research of Japan*, Vo.48, No.9, 2003, pp.677-683.

[18] V. Kumar, B. Maheshwari, U. Kumar, An investigation of critical management issues in ERP implementation: empirical evidence from Canadian organizations, *Technovation*, Vol.23, No.10, 2003, pp.793–807.

[19] J.W. Lee, S.H. Kim, Using Analytic Network Process and Goal Programming for Interdependent Information System Project Selection, *Computers & Operations Research*, Vol.27, No.4, 2000, pp.367-382.

[20] J.W. Lee, S.H. Kim, An integrated approach for interdependent in project selection, *International Journal of Project Management,* Vol.19, No.2, 2001, pp.111-118.

[21] S.C. Lee, J. Tang, Effect of The Project Control Management Through Networking Communication Perspective, *WSEAS TRANSACTIONS on BUSINESS and ECONOMICS*, Vol.4, No.6, 2007, pp. 95-103.

[22] H. Lucas, J. Moore, A multiple criterion scoring approach to information system project selection, *INFOR*, Vol.14, No.1, 1976, pp.1-12.

[23] I. Millet, P.T. Harker, Globally Effective Questioning in the Analytic Hierarchy Process, European Journal of Operational Research. *Amsterdam*, Vol.48, No.1, 1990, pp.88-98.

[24] NIH, Criteria for Ranking NIH IT Projects, *National Institutes of Health*, 2000, Downloadable from website (April 7, 2004): <http://wwwoirm.nih.gov/itmra/ >

[25] S. Opricovic, G.H. Tzeng, Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS, *European Journal of Operational Research*, Vol.156, No.2, 2004, pp.445-455.

[26] PMI. *A Guide to the Project Management Body of Knowledge (PMBOK Guide) 2000 Edition*, Project Management Institute, 2001.

[27] C. Romero, Extended lexicographic goal programming: a unifying approach, *Omega-The International Journal of Management Science*, Vol.29, No.1, 2001, pp.63-71.

[28] T.L. Saaty, *Decision Makings With Dependence and Feedback The Analytic Network Process*, Pittsburgh, PA, RWS Publications, 1996.

[29] T.L. Saaty, *Fundamentals of the Analytic Network Process*, Japan, Kobe, ISAHP, 1999.

[30] T.L. Saaty, *The Analytic Hierarchy Process (AHP) for Decision Making and The Analytic Network Process (ANP) for Decision Making with Dependence and Feedback*, Creative Decisions Foundation, 2003.

[31] J. Sarkis, A methodological framework for evaluating environmentally conscious manufacturing programs, *Computers & Industrial Engineering*, Vol.36, No.4, 1999, pp.793-810.

[32] R. Santhanam, M. Schniederjans, A model and formulation system for information system project selection, *Computers and Operations Research*, Vol.20, No.7, 1993, pp.755-767.

[33] R. Sanathanam, G.J. Kyparisis, A multiple criteria decision model for information system project selection, *Computers and Operations Research*, Vol.22, No.8, 1995, pp.807-818.

[34] R. Sanathanam, G.J. Kyparisis, A decision model for interdependent information system project selection, *European Journal of Operational Research*, Vol.89, No.2, 1996, pp.380-399.

[35] R.A. Sarker, M.A. Quaddus, Modelling a nationwide crop planning problem using a multiple criteria decision making tool, *Computers and Industrial Engineering*, Vol.42, No.2-4, 2002, pp.541-553.

[36] M.J. Schniederjans, R. Wilson, Using the analytic hierarchy process and goal programming for the information system project selection, *Information and Management* Vol.20, No.5, 1991, pp.333-342.

[37] M.J. Schniederjans, *Goal programming: methodology and applications*, *Boston*, Kluwer, 1995.

[38] M.J. Schniederjans, T. Garvin, Using the analytic hierarchy process and multi-objective programming for the selection of cost drivers in activity-based costing, *European Journal of Operational Research*, Vol.100, No.1, 1997, pp.72-80.

[39] K. Sekitani, I. Takahashi, A unified model and analysis for AHP and ANP, Journal of the *Operations Research Society of Japan*, Vol.44, No.1, 2001, pp.67-89.

[40] M. Tamiz, D. Jones, C. Romero, Goal programming for decision making: An overview of the current state-of-the-art, *European Journal of Operational Research,* Vol.111, No.3, 1998, pp.569-581.

[41] E. Turban, J. *Meredith*, *Fundamental of management science*. New York, Irwin, McGraw-Hill, 1994.

[42] Z. Ullmann, *Dynamic programming and the capital allocation problem*, Doctoral Dissertation. Baltimore, MD, The John Hopkins University, 1967.

[43] T.C. Wang, S.C. Hsu, Multi-criteria Decision Making with Incomplete Linguistic Preference Relations, Proceedings of the 6th WSEAS International Conference on Applied Computer Science, Hangzhou, China, April 15-17, 2007, pp.19-24.

[44] R. Weber, B. Werners, H. Zimmerman, Planning models for research and development, *European Journal of Operational Research,* Vol.48, No.2, 1990, pp.175-188.

[45] C.C. Wei, M.J.J. Wang, A comprehensive

framework for selecting an ERP system, *International Journal of Project Management*, Vol.22, 2, 2004, pp.161-169.
[46] M. Yamazaki, K. Ishibe, S.Yamashita, I. Miyamoto, M. Kurihara, H. Shindo, An Analysis of Obstructive Factors to Welfare Service Using DEMATEL Method, *Reports of the Faculty of Engineering. Yamanashi University*, Vol.48, 1997, pp.25-30.
[47] A. Yuzawa, A State and Subjects of TMO Conception for City Core Vitalization Countermeasure: A Case Study of Maebashi TMO Conception. *Bulletin of Maebashi Institute of Technology*, Vol.5, 2002, pp.61-67.