



Using analytic network process and goal programming for interdependent information system project selection

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Abstract

Information system (IS) project selection problems are multi-criteria decision-making (MCDM) problem. Existing methods for IS project selection does not reflect interdependencies among criteria and candidate projects. Considering these interdependencies among criteria provides valuable cost savings and greater benefits to organizations. When we evaluate project problems, we need to collect a group opinion because to know the interdependence relationship among criteria and criteria in considered project problems is very important. In order to collect group opinion for interdependent project problem, we use expert interview.

In this paper, we suggest an improved IS project selection methodology which reflect interdependencies among evaluation criteria and candidate projects using analytic network process (ANP) within a zero–one goal programming (ZOGP) model.

Scope and purpose

When information system (IS) projects are selected from a suggested competing projects they are evaluated according to different criteria. Prior research neglected an important aspect of information technology, namely the interdependencies that exist among IS projects. When we select IS project in organization, to select IS project through recognizing and modeling these project interdependencies provides valuable cost savings to organizations. Among the proposed methodologies of multi-criteria decision making (MCDM), goal programming (GP) is widely used for IS project selection. Although GP incorporates multiple objectives and arrives at an optimal solution, its major drawback is dependent on the judgment of decision maker(s). In order to provide a systematic approach to set priorities among multi-criteria and trade-off among objectives, analytic network process (ANP) is suggested to be applied prior to GP formulation. In this paper, we present a methodology using analytic network process and zero–one goal programming (ZOGP) for IS projects

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selection problems that have multiple criteria and interdependence property. © 2000 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Information system (IS) project evaluation and selection is concerned with the allocation of scarce organizational resources. These IS project evaluation and selection problems are multi-criteria decision-making problems. Numerous methodologies for selection IS project or research and development projects have been developed and reported on, in the last two decades [4].

Prior IS project selection techniques proposed are useful but have restricted application because they consider only independent IS Projects or evaluation criteria. However, IS project problems have interdependence property. There exist a great amount of sharing of hardware and software resources at the result of various IS project execution. For example, portions of programming code written for one application such as edit routines, sort routines, and other generic codes are being reused as code for several other application projects providing substantial savings in developmental cost [12]. The interdependencies among IS projects can be classified into three main types [24]. These are (1) resource interdependencies, (2) benefit interdependencies, and (3) technical interdependencies. Resource interdependencies arise because of sharing of hardware and software resources among various IS projects such that the implementation of two or more related projects will require less resources than if they were implemented separately. For example, if software code developed for one project is used in the second project, then the total programming resources required by the second project are accordingly reduced.

Benefit interdependencies occur when the total benefits to the organization derived from implementing two related projects increase due to their synergistic effect [13].

Finally, when the development of an IS necessitates the development of a related project it creates a technical interdependence. By selecting interdependent projects, valuable IS resources can be shared among IS projects, thus reducing the total resource expenditures. Many researchers have highlighted the practical importance of this issue [3,25]. Recently Santhanam and Kyparisis [24,25] proposed a nonlinear programming model that considered interdependencies. In their model, they suggested the model for solving problems which have project interdependence. But the model does not solve problems that have multiple criteria among project or evaluation criteria. In addition, when we consider project evaluation problem, we need to collect an expert group discussion because it is very dangerous to determine the criteria or the degree of interdependence for considering project problem by one or two decision maker(s).

The objective of this paper is to suggest a solving methodology for IS project selection problems that have interdependence property among project or evaluation criteria. In order to reflect the interdependencies property in IS project selection in which exist multiple criteria, we used an analytic network process (ANP)[35] model and zero–one goal programming (ZOGP) [8] by group

expert interview. Specifically, we demonstrated how a combined ANP and ZOGP model can be used as aid in IS project selection problem.

2. Review of the IS project selection problem

Several methods have been proposed to help organizations make good IS project selection decisions [1,2,7,33]. The existing methodologies for IS project selection range from single-criteria cost/benefit analysis to multiple criteria scoring models and ranking methods, or subjective committee evaluation methods [3,5,9,11,22–25,37].

Buss [6] attempts to provide an alternative approach to project selection with the ranking technique. The ranking method does not solve problems that require resource feasibility and an existing project interdependent property.

Lootsma et al. [14] and Lucas and Moore [15] suggested a multiple-criterion scoring methods for IS project selection. This method also does not carry out a limitation ranking method. Muralidhar and Wilson [16] proposed a methodology for IS project selection using an analytic hierarchy process (AHP), however, they did not consider interdependence property but consider independence property among alternatives or criteria. Ranking, scoring and AHP methods do not apply to problems having resource feasibility, optimization requirements or project interdependence property constraints. In spite of this limitation, the scoring and ranking method and AHP method have been much used with real problems because they are very simple and easy to understand, so decision-makers feel comfortable with them. In order to solve optimization problems, many researchers use a mathematical model, such as goal programming, dynamic programming, Linear 0–1 programming, etc. [8,18–22,25,30]. Many prior methodologies are assumed independent among criteria or candidate projects.

Many real-world problems have an interdependent property among the criteria or candidate projects [35]. Consideration for these interdependencies among criteria provides valuable cost savings and greater benefits to organizations. Santhanam and Kyparisis [24,25] proposed a mathematical methodology using nonlinear 0–1 programming for interdependent information system selection. Their model considered project interdependence and resource optimization. They considered project selection problems that have only one criteria not multiple criteria. In reality, it will be more appropriate to consider multiple criteria than to consider only one or two criteria in IS project selection problems which have interdependence property. No prior study reported in the literature has ever demonstrated the solving methodology of an IS project selection that have both multiple criteria and interdependence property. We will consider an interdependent IS selection problem having multiple criteria. Table 1 shows a list of prior research and their suitability in problem situation.

3. A goal programming using ANP approach for IS project selection

The initial study identified the multi-criteria decision technique known as the Analytic Hierarchy Process (AHP) to be the most appropriate for solving complicated problems. AHP was proposed by Saaty in 1980 [34] as a method of solving socio-economic decision making problems and has been used to solve a wide range of problems.

Table 1
Suitability of project selection methods for various problem characteristics

Project selection method	Project parameters unknown	Resource feasibility required	Multiple criteria exist	Project interdependence exists	Optimization required
Ranking [6]	Yes	No	Yes	No	No
Scoring [15]	Yes	No	Yes	No	No
AHP [16]	Yes	No	Yes	No	No
GP [26]	No	Yes	Yes	No	Yes
AHP&GP [17]	No	Yes	Yes	No	Yes
Dynamic Programming [19]	No	Yes	No	Yes	Yes
Linear 0–1 [8]	No	Yes	No	No	Yes
Quadratic linear 0–1 [21,35]	No	Yes	No	Yes	Yes
Quadratic 0–1 [34]	No	Yes	No	Yes	Yes
Nonlinear 0–1 [24,25]	No	Yes	No	Yes	Yes
ANP&ZOGP (This paper)	No	Yes	Yes	Yes	Yes

The AHP is a comprehensive framework that is designed to cope with the intuitive, the rational, and the irrational when we make multi-objective, multi-criterion, and multi-actor decisions with and without certainty for any number of alternatives. The basic assumptions of AHP are that it can be used in functional independence of an upper part or cluster of the hierarchy from all its lower parts and the criteria or items in each level.

Many decision problems cannot be structured hierarchically because they involve the interaction and dependence of higher-level elements on a lower-level element [35]. Structuring a problem involving functional dependence allows for feedback among clusters. This is a network system. T.L. Saaty accomplished a comprehensive study of this problem. He suggested the use of AHP to solve the problem of independence on alternatives or criteria and the use of ANP to solve the problem of dependence among alternatives or criteria. The ANP addresses how to determine the relative importance of a set of activities in a multi-criteria decision problem. The process utilizes pairwise comparisons of the project alternatives as well as pairwise comparisons of the multiple criteria.

Generally, we solve complex problems by discussing them with group members. However, when we do not know the exact relationship in the network structure or the degree of interdependence among considering criteria, it is dangerous to determine by one or two decision maker(s). To determine the relationship of a network structure or the degree of interdependence is the most important function of ANP. When we meet these problems, we collect data by group expert discussion in general.

The process of solving interdependence IS project selection problem is summarized as follows: In order to consider interdependence, the first step is to identify the multiple criteria that merit consideration and then draw a relationship between criteria that shows the degree of interdependence among the criteria. To show a method of drawing interdependence relationship, we will use

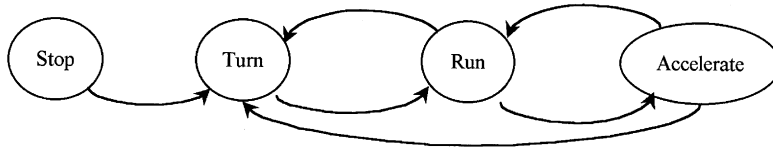


Fig. 1. Relationship between the four functions.

a simple example [31]. For example, cars have four basic functions: Stop, Turn, Run, and Accelerate. Generally, to stop a moving car requires only the function of stopping by removing the foot from the pedal followed by braking. To make a turn, one may first slow down and turn by using steering but keeping the motor running; then one accelerates to the previous speed. To run a car smoothly requires the function, ‘Turn’, to avoid obstacles, as well as ‘Run’ and ‘Accelerate’. To accelerate the car, it must first be running and acceleration is obtained by pushing the pedal. These four functions have interdependent relationship among the functions. Fig. 1 represents interdependence relationship.

Next, determining 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 projects 1 and 2, on the basis of cost reduction, which project is preferred?” When there is interdependence, one answers the following kind of question in making the pairwise comparisons: “Given an alternative and an attribute, which of two alternatives influences the given alternatives more with respect to the attribute and how much more than another alternative?” The responses are presented numerically, scaled on the basis of Saaty’s proposed 1–9 scale [34,35] with reciprocals, in a project comparison matrix. The final step is to determine the overall prioritization of the IS projects.

The information obtained from the ANP is then used to formulate a zero–one goal programming (ZOGP) model as a weight. The solution to ZOGP will provide a pattern by which resources will be allocated among different projects. Fig. 2 shows the general overview of the proposed model. Zero–one goal programming has been applied in a variety of ranked resource selection schemes, including the selection of corporate acquisition candidate [29], library journal acquisition candidates [27,28], and faculty course assignment [30]. ZOGP permits the consideration of resource limitations and other selection limitations that must be rigidly observed in the IS project selection problems.

ZOGP also permits the ranked inclusions of IS projects so their selection is based, in part, on the ANP ranking system previously discussed. The ZOGP model for IS project selection can be stated as follows:

$$\begin{aligned}
 &\text{Minimize} && Z = P_k(w_j d_i^+, w_j d_i^-) \\
 &\text{subject to} && \\
 & && a_{ij} x_j + d_i^- - d_i^+ \leq b_i && \text{for } i = 1, 2, \dots, m, j = 1, 2, \dots, n && (1) \\
 & && x_j + d_i^- = 1 && \text{for } i = m + 1, m + 2, \dots, m + n, j = 1, 2, \dots, n \\
 & && x_j = 0 \text{ or } 1 && \text{for } \forall j,
 \end{aligned}$$

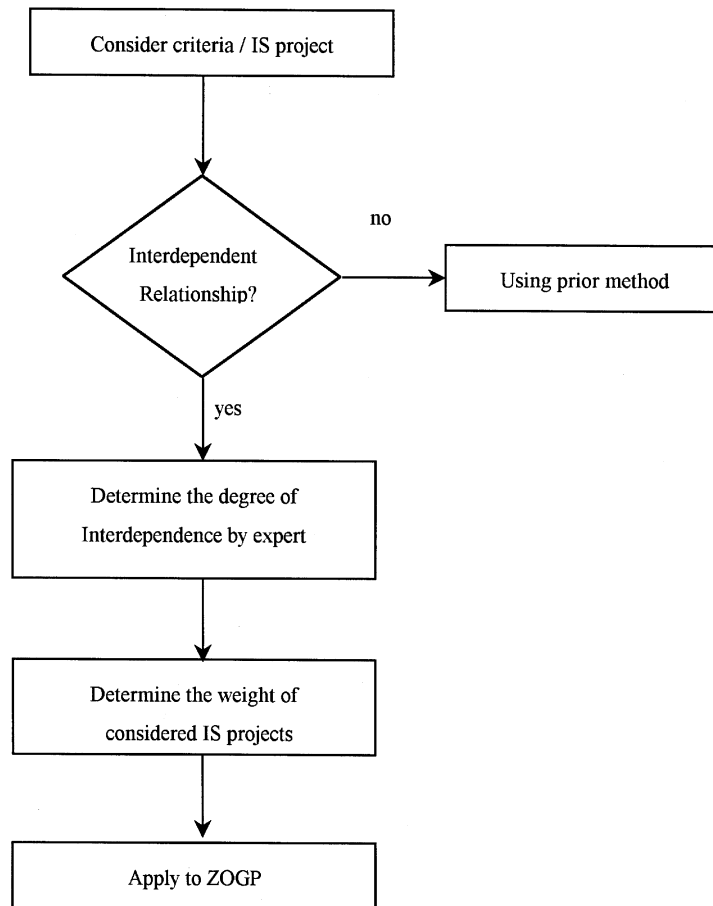


Fig. 2. An overview of the proposed model.

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

The ZOGP model bases the selection of the IS projects x_j on the ANP determined weights of w_j for corresponding d_i^- . The larger the w_j , the more likely the corresponding IS project will be selected.

4. An illustrative application of IS project selection

To illustrate the use and advantages of the combined ANP and ZOGP model in IS project selection, we will use Schniederjans and Wilson’s hypothetical example [17].

Their problem consisted of prioritizing six IS projects on the basis of four criteria deemed to be important for a hypothetical organization. The criteria used were (1) Increased accuracy in clerical operations (AC), (2) Information processing efficiency (*E*), (3) Promotion of organizational learning (OL), and (4) Cost of implementation (IC). Schniederjans and Wildson’s example were assumed to be independent among these four criteria. That is, they applied this problem to Saaty’s AHP without considering interdependence property among the criteria. However, we are of the opinion that there is an existence of interdependence relationship among these four criteria in IS projects problems. Generally, if we promote an organization learning, accuracy will be increased in clerical operations. Similarly, in order to increase information processing efficiency, we will have to increase cost and accuracy in clerical operations. Likewise, In order to increase accuracy in clerical operations, we will increase implementation cost. So, there is an interdependence relationship among criteria; the attribute of criteria AC influence criteria *E*, the attribute of criteria IC influence criteria AC and *E*, and criteria OL influence criteria AC. In order to check network structure or relationship in considered criteria or candidate project, we need to have group discussion because the type of network or relationship depends on the decision makers’ judgment. We show the relationship having interdependence among the criteria in Fig. 3.

In order to find the weight of the degree of influence among the criteria, we will show the procedure using the matrix manipulation based on Saaty and Takizawa’s concept [31] in place of Saaty’s supermatrix [34,35]. This procedure will be helpful to researchers who want to know ANP and study solving method of interdependence relationship. The procedure is shown as follows, the data of example used in this paper are based on Saaty’s nine scales [34,35]:

Step 1: To compare the criteria, one responds to this question: Which criteria should be emphasized more in an IS project, and how much more? By comparing all pairs with respect to the six projects, we will obtain the following data like $(OL, AC, IC, E) = (7, 5, 9, 1) \cong (7/22, 5/22, 9/22, 1/22) = (0.32, 0.23, 0.41, 0.04)$, assuming that there is no interdependence among them. This data means only relative weight without considering independence among criteria. We defined the weight matrix of criteria as $W_1 = (OL, AC, IC, E) = (0.32, 0.23, 0.41, 0.04)$.

Step 2: Again, by assuming that there is no interdependence among the six projects, $(p_1, p_2, p_3, p_4, p_5, p_6)$, they are compared with respect to each criterion yielding the column normalized weight with respect to each criterion, as shown in Table 2.

The second row of data in Table 2 mean the degree of relative importance for each criteria, and the data of third row are normalized to sum to one for each criteria. We defined the weight matrix

$$\text{of six projects for criteria OL as } w_{21} = \begin{bmatrix} 0.219 \\ 0.156 \\ 0.281 \\ 0.156 \\ 0.094 \\ 0.094 \end{bmatrix}.$$

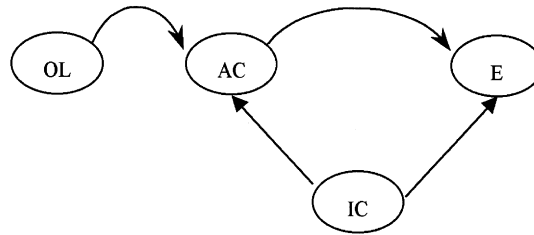


Fig. 3. Interdependent relationship among the criteria.

Table 2
Data five project to four criteria

	OL	AC	IC	E
p_1	7	5	3	5
p_2	5	7	5	7
p_3	9	7	3	9
p_4	5	3	7	7
p_5	3	7	7	7
p_6	3	5	5	7
p_1	0.219	0.147	0.100	0.119
p_2	0.156	0.206	0.167	0.167
p_3	0.281	0.206	0.100	0.213
p_4	0.156	0.088	0.233	0.167
p_5	0.094	0.206	0.233	0.167
p_6	0.094	0.147	0.167	0.167
	w_{21}	w_{22}	w_{23}	w_{24}

Step 3: Next, we considered the interdependence among the criteria. When we select the IS project, we cannot concentrate only on one criteria, 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. In Table 3, We obtain the four sets of weight through expert group interviews. The data of Table 3 mean four criteria's degree of relative impact for each four criteria. For example, the OL's degree of relative impact for AC is 0.2, the AC's degree of relative impact for E is 0.1, and the IC's degree of relative impact for E is 0.4.

We defined the interdependence weight matrix of criteria as

$$W_3 = \begin{bmatrix} 1.0 & 0.2 & 0.0 & 0.0 \\ 0.0 & 0.5 & 0.0 & 0.1 \\ 0.0 & 0.3 & 1.0 & 0.4 \\ 0.0 & 0.0 & 0.0 & 0.5 \end{bmatrix}$$

Table 3
Data among four criteria

w_3	OL	AC	IC	E
OL	1	0.2	0	0
AC	0	0.5	0	0.1
IC	0	0.3	1	0.4
E	0	0	0	0.5

Table 4
Data among five project for criteria 1 (OL)

w_{41}	p_1	p_2	p_3	p_4	p_5	p_6
p_1	5	1/3	1/5	1/7	1/9	1/7
p_2	3	5	1/3	1/5	1/7	1/5
p_3	5	3	5	1/7	1/7	1/7
p_4	7	5	3	5	1/5	1/5
p_5	9	7	7	5	5	1/7
p_6	7	5	7	5	7	5
p_1	0.139	0.012	0.008	0.009	0.009	0.025
p_2	0.083	0.199	0.013	0.013	0.011	0.035
p_3	0.139	0.119	0.222	0.009	0.011	0.025
p_4	0.194	0.198	0.133	0.323	0.016	0.035
p_5	0.251	0.274	0.312	0.323	0.401	0.025
p_6	0.194	0.198	0.312	0.323	0.552	0.855

Step 4: Next, we dealt with interdependence among the alternatives with respect to each criterion. An illustration of the question to which one must respond is: with respect to the satisfaction of the criteria, criteria 1 (OL), with project, which project contributes more to the action of project 1 to criteria 1 and how much more? In this way, the data are shown in Tables 4–7.

In Table 4, the data of second row were obtained from decision maker by Saaty’s nine scales, which means the degree of interdependence among the alternatives with respect to each project, and the data of third row are normalized to sum to one. We defined the project interdependence weight matrix for criteria OL as

$$w_{41} = \begin{bmatrix} 0.139 & 0.012 & 0.008 & 0.009 & 0.009 & 0.025 \\ 0.083 & 0.199 & 0.013 & 0.013 & 0.011 & 0.035 \\ 0.139 & 0.119 & 0.222 & 0.009 & 0.011 & 0.025 \\ 0.194 & 0.198 & 0.133 & 0.323 & 0.016 & 0.035 \\ 0.251 & 0.274 & 0.312 & 0.323 & 0.401 & 0.025 \\ 0.194 & 0.198 & 0.312 & 0.323 & 0.552 & 0.855 \end{bmatrix}.$$

Table 5
Data among five project for criteria 2 (AC)

w_{42}	p_1	p_2	p_3	p_4	p_5	p_6
p_1	7	1/5	1/5	1/3	1/7	1/7
p_2	5	7	1/5	1/5	1/7	1/5
p_3	5	5	5	1/3	1/5	1/5
p_4	3	5	3	7	1/3	1/5
p_5	7	7	5	3	5	1/7
p_6	7	5	5	5	7	5
p_1	0.206	0.009	0.011	0.021	0.011	0.025
p_2	0.147	0.239	0.011	0.013	0.011	0.034
p_3	0.147	0.171	0.272	0.021	0.016	0.034
p_4	0.088	0.171	0.172	0.441	0.026	0.034
p_5	0.206	0.239	0.272	0.199	0.390	0.024
p_6	0.206	0.171	0.272	0.315	0.546	0.850

Table 6
Data among five project for criteria 3 (IC)

w_{43}	p_1	p_2	p_3	p_4	p_5	p_6
p_1	7	1/3	1/5	1/7	1/3	1/5
p_2	3	5	1/3	1/5	1/5	1/7
p_3	5	3	3	1/5	1/5	1/3
p_4	7	5	5	3	1/7	1/5
p_5	3	5	5	7	3	1/5
p_6	5	7	3	5	5	5
p_1	0.230	0.010	0.010	0.010	0.034	0.033
p_2	0.100	0.200	0.020	0.013	0.023	0.024
p_3	0.170	0.110	0.180	0.013	0.050	0.050
p_4	0.230	0.200	0.305	0.190	0.033	0.033
p_5	0.100	0.200	0.305	0.450	0.033	0.033
p_6	0.170	0.280	0.180	0.324	0.827	0.827

Step 5: We now obtain the interdependence priorities of the criteria by synthesizing the results from Steps 1 to 3 as follows:

$$W_c = W_3 \times W_1 = \begin{bmatrix} 1.0 & 0.2 & 0.0 & 0.0 \\ 0.0 & 0.5 & 0.0 & 0.1 \\ 0.0 & 0.3 & 1.0 & 0.4 \\ 0.0 & 0.0 & 0.0 & 0.5 \end{bmatrix} \times \begin{bmatrix} 0.32 \\ 0.23 \\ 0.41 \\ 0.04 \end{bmatrix} = \begin{bmatrix} 0.366 \\ 0.119 \\ 0.495 \\ 0.020 \end{bmatrix}.$$

Thus we have $W_c = (OL, AC, IC, E) = (0.366, 0.119, 0.495, 0.020)$.

Table 7
Data among five project for criteria 4 (E)

w_{44}	p_1	p_2	p_3	p_4	p_5	p_6
p_1	5	1/7	1/5	1/7	1/7	1/7
p_2	7	7	1/3	1/5	1/5	1/7
p_3	5	3	5	1/7	1/7	1/5
p_4	7	5	7	5	1/5	1/7
p_5	7	5	7	5	5	1/7
p_6	7	7	5	7	7	5
p_1	0.132	0.004	0.008	0.008	0.011	0.025
p_2	0.184	0.258	0.012	0.012	0.016	0.025
p_3	0.132	0.110	0.204	0.008	0.011	0.035
p_4	0.184	0.185	0.286	0.286	0.016	0.025
p_5	0.184	0.185	0.286	0.286	0.397	0.025
p_6	0.184	0.258	0.204	0.400	0.549	0.865

Step 6: 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 4 as follows:

$$W_{p1} = W_{41} \times W_{21} = \begin{bmatrix} 0.039 \\ 0.060 \\ 0.116 \\ 0.166 \\ 0.275 \\ 0.344 \end{bmatrix}, \quad W_{p2} = W_{42} \times W_{22} = \begin{bmatrix} 0.031 \\ 0.065 \\ 0.097 \\ 0.133 \\ 0.271 \\ 0.403 \end{bmatrix},$$

$$W_{p3} = W_{43} \times W_{23} = \begin{bmatrix} 0.025 \\ 0.054 \\ 0.065 \\ 0.150 \\ 0.273 \\ 0.432 \end{bmatrix}, \quad W_{p4} = W_{44} \times W_{24} = \begin{bmatrix} 0.027 \\ 0.056 \\ 0.091 \\ 0.147 \\ 0.266 \\ 0.412 \end{bmatrix}.$$

We define the matrix W_p by grouping together the above four columns:

$$W_p = (W_{p1}, W_{p2}, W_{p3}, W_{p4}).$$

Step 7: Finally, the overall priorities for the candidate projects are calculated by multiplying W_p by W_c .

$$\text{We have } W_p \times W_c = \begin{bmatrix} 0.031 \\ 0.058 \\ 0.088 \\ 0.154 \\ 0.264 \\ 0.395 \end{bmatrix}.$$

Our final results in the ANP Phase are $(p_1, p_2, p_3, p_4, p_5) = (0.031, 0.058, 0.088, 0.154, 0.264, 0.395)$. These ANP results are interpreted as follows. The most high weight of criteria in this IS Project selection example is p_6 . Next is project 5, p_5 . These weights are used as priorities in goal programming formulation. That is $(p_1, p_2, p_3, p_4, p_5, p_6) = (w_1, w_2, w_3, w_4, w_5, w_6) = (0.031, 0.058, 0.088, 0.154, 0.264, 0.395)$, w_j values of the six IS projects. In order to formulate the ZOGP model, we also used Schniederjans and Wilson's hypothetical example [17] based on the results of the prior ANP phase. The hypothetical examples are summarized as follows; suppose that there exist several obligatory and flexible goals that must be considered in the selection from the available pool of six IS projects. There are four obligatory goals: (1) a total yearly maximum of 15,000 h of programmer time is available to complete all of the IS projects selected, (2) a total yearly maximum of 6500 h of analyst time is available to complete all of the IS projects selected, (3) a total yearly maximum budget of \$200,000 is available to complete all of the IS projects selected, and (4) project 2 is a necessary maintenance activity and therefore is a mandated project that must be one of the set of IS projects selected. In addition to the goal of selecting the IS projects, there are two other flexible goals, stated in order of their importance: (1) an initial yearly allocation of budgeted dollars is set at \$180,000 but can vary up to but not beyond the total maximum value of \$200,000 and (2) an initial allocation goal of clerical hours of labor is set at 3700 h but deviation from this allocation is possible. In Table 8, the yearly cost and human resource usage information for each of the six projects is presented.

Based on these data and the previously computed ANP values, we can formulate the goal constraints for this hypothetical problem in Table 9. This ZOGP model was solved using LINDO on a 586-based microcomputer in a few seconds of computer time. The results are summarized as follows: $x_2 = x_4 = x_5 = x_6 = 1$, $x_1 = x_3 = 0$,

$$d_1^- = 0, d_1^+ = 0, d_2^- = 0, d_2^+ = 0, d_3^- = 20, d_3^+ = 0, d_4^- = 0, d_5^- = 1, d_6^- = 0, d_7^- = 1,$$

$$d_8^- = 0, d_9^- = 0, d_{10}^- = 0, d_{11}^+ = 0, d_{11}^- = 0, d_{12}^- = 0, d_{12}^+ = 300.$$

Projects 2, 4, 5, and 6 were chosen consuming the total budgeted cost of \$180,000. We will use exactly 6500 h of analyst time. Also, we will use 300 more hours of clerical help than the initial 3700 h, so $d_{12}^+ = 300$ is shown.

Although the resultant example ANP and AHP shows no great disparity, there are some different point in deviation variables and the weight of IS priorities differ. In Table 10 we present a comparison of using the AHP ranking order and the resulting combined ANP–ZOGP approach.

Table 8
Yearly cost and human resources usage information on IS projects

	IS project yearly resource usage (a_{ij})						b_i
	x_1	x_2	x_3	x_4	x_5	x_6	
Programmer hours	6000	10,000	1000	750	2250	2000	15,000 h
Analyst hours	1300	1250	1800	2000	1500	1750	6,500 h
Budgeted costs (000)	\$80	\$25	\$55	\$40	\$65	\$50	\$200
Clerical labor hours	1000	800	500	1200	900	1100	3,700 h

Table 9
ZOGP model formulation

ZOGP model formulation	Goals
Minimize $Z =$ $pl_1(d_1^+ + d_2^+ + d_3^+ + d_4^-)$ $pl_2(0.031d_5^- + 0.058d_6^- + 0.188d_7^- + 0.154d_8^- + 0.264d_9^- + 0.395d_{10}^-)$ $pl_3(d_{11}^- + d_{11}^+)$ $pl_4(d_{12}^- + d_{12}^+)$	Satisfy all obligatory goals Select highest ANP weighted IS projects Use \$180,000 for all IS projects selected Use 3700 h clerical help for all IS projects
Subject to $6000x_1 + 10000x_2 + 1000x_3 + 750x_4 + 2250x_5 + 2000x_6 + d_1^- - d_1^+ = 15000$ $1300x_1 + 1250x_2 + 1800x_3 + 2000x_4 + 1500x_5 + 1750x_6 + d_2^- - d_2^+ = 6500$ $80x_1 + 25x_2 + 55x_3 + 40x_4 + 65x_5 + 50x_6 + d_3^- - d_3^+ = 200$ $x_2 + d_4^- = 1$ $x_1 + d_5^- = 1$ $x_2 + d_6^- = 1$ $x_3 + d_7^- = 1$ $x_4 + d_8^- = 1$ $x_5 + d_9^- = 1$ $x_6 + d_{10}^- = 1$ $80x_1 + 25x_2 + 55x_3 + 40x_4 + 65x_5 + 50x_6 + d_{11}^- - d_{11}^+ = 180$ $1000x_1 + 800x_2 + 500x_3 + 1200x_4 + 900x_5 + 1100x_6 + d_{12}^- - d_{12}^+ = 3,700$ $x_j = 0$ or $\forall j = 1, 2, \dots, n$	Avoid over utilizing max. programmer hours Avoid over utilizing max. analyst hours Avoid over utilizing max. budgeted dollars Select obligatory project 2 Select project 1 Select project 2 Select project 3 Select project 4 Select project 5 Select project 6 Avoid over or under utilizing expected budget Avoid over or under utilizing clerical hours

5. Discussion

The application of the ANP–ZOGP model to the hypothetical example demonstrates the procedure of finding weight that considers interdependence among criteria or alternatives. The proposed model provides a way for researcher finding methodology in a project selection problem having an interdependent relationship.

Table 10
Original AHP solution and ANP solution comparison

	Selected Projects	Resulting unused resources			
		Programmer hours	Analyst hours	Budget cost	Clerical labor hours
Original AHP Solution (Assuming the AHP ranking order is used)	Project 1, 5, 6	4750	1950	9000	700
ANP-ZOGP solution	Project 2, 4, 5, 6	0	0	20 0000	0 ^a

^aWe will use 300 more hours of clerical help than the initial 3700 hours.

Scoring and ranking techniques are intuitively simple but they do not ensure resource feasibility and are insufficient for dealing with project interdependence. Prior research mainly focused on problems assuming independence. Although there are many prior researches in independent problem using AHP or other DA methodology, there are no studies or research on interdependent problem. It is seen that AHP is most appropriate in situations where project costs and benefits are not known, resource constraints do not exist, project interdependencies do not exist and an optimal solution is not needed. Although there are lots of difficulties for solving problems considering interdependent property, most of real-world problems especially, IS project evaluation problems, have interdependent property. However, it is very difficult to judge whether they are having interdependent property or not. Therefore, group decision making is more helpful to determine such an interdependent property than to decide by only one or two decision maker(s). Group discussion is more needed to determine the degree of impact among the considered criteria or alternatives because the degree of impact is varied according to decision maker. Group discussion is very effective to determine important problems or is likely to be biased if the problem is addressed by single decision maker. Group expert interview can minify DM's partiality. The man who considers this methodology applicable to real problems may not be bothered by the cost through group expert interview.

In project selection, it is very important to consider the interdependent relationship among projects or criteria because of the characteristics of interdependence that exists in real problems. In addition, the cost of difficulty in data gathering for modeling is not so critical than the risk in selecting the wrong project without considering the interdependencies.

In this paper, we show an illustrative example through prior published example. In further research, it is needed to show an application of real-world problems. It might be argued that managers might not be inclined to use sophisticated method. Recent survey indicate that the use of mathematical models are becoming more prevalent with the availability of Decision Support Systems or commercial software packages such as Expert Choice, Lindo, MathPro, and Microsoft Excel now integrate nonlinear programming techniques with spreadsheets and also provide some model formulation tools [32].

This paper shows an example solving project interdependence based on ANP and ZOGP by group expert interview. Using this method we conclude that we can solve problems having multiple criteria, interdependence and resource feasibility.

6. Concluding remarks

The selection of an appropriate set of IS projects is very helpful to all business organizations. In addition, to consider interdependency among projects is one of the most important issues because it results in saving costs. This paper has addressed IS management concerns by demonstrating that exploiting project interdependencies is one way of saving IS costs and frugality resources.

Although there is much research on IS project selection, prior research has ignored the presence of project interdependencies. Therefore, we develop upon the work conducted on IS project selection considering the impact relationship among criteria. This paper moves us one step closer to the developing of a new methodology for interdependent IS project selection. In this paper, we did not consider sensitivity analysis applicable to real-world project problem. Our subsequent research will be addressing these points.

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