

Development of a Project Selection Method on Information System Using ANP and Fuzzy Logic

Ingu Kim, Shangmun Shin, Yongsun Choi, Nguyen Manh Thang, Edwin R. Ramos, and Won-Joo Hwang

Abstract—Project selection problems on management information system (MIS) are often considered a multi-criteria decision-making (MCDM) for a solving method. These problems contain two aspects, such as interdependencies among criteria and candidate projects and qualitative and quantitative factors of projects. However, most existing methods reported in literature consider these aspects separately even though these two aspects are simultaneously incorporated. For this reason, we proposed a hybrid method using analytic network process (ANP) and fuzzy logic in order to represent both aspects. We then propose a goal programming model to conduct an optimization for the project selection problems interpreted by a hybrid concept. Finally, a numerical example is conducted as verification purposes.

Keywords—Analytic Network Process (ANP), Multi-Criteria Decision-Making (MCDM), Fuzzy Logic, Information System Project Selection, Goal Programming.

I. INTRODUCTION

PROJECT selection problems on management information system (MIS) are often considered a multi-criteria decision-making (MCDM) for a solving method. In many real world industrial situations, a MIS manager performs a number of important activities associated with project selections. A number of methodologies for the selection of information system (IS) projects have reported in literature [1, 2, 3, 4, 5, 7]. These problems contain two aspects, such as interdependencies among criteria and candidate projects and

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qualitative and quantitative factors of projects. However, most existing methods reported in literature consider these aspects separately even though these two aspects are simultaneously incorporated. Furthermore, most existing methodologies reported in literature consider only independent IS projects [7], or evaluation criteria [4, 8], or qualitative factors [2, 13]. In addition, they may not consider the success probability of projects.

For this reason, the primary objective of this paper is to propose a hybrid method using an analytic network process (ANP) and a fuzzy logic in order to represent both aspects simultaneously. To reflect the interdependence in an IS project selection in which exist multiple criteria, an ANP method is used. In order to consider quantitative and qualitative factors, fuzzy logic is applied to find weights among projects. After obtaining the weights, a goal programming (GP) model is proposed to conduct an optimization for the project selection problems interpreted by a hybrid concept. Next, this paper also demonstrates how the proposed hybrid method combining ANP, a fuzzy logic, and a GP method can effectively solve a project selection problem on IS. Finally, a numerical example is conducted as verification purposes. Fig. 1 illustrates an overview of the proposed method.

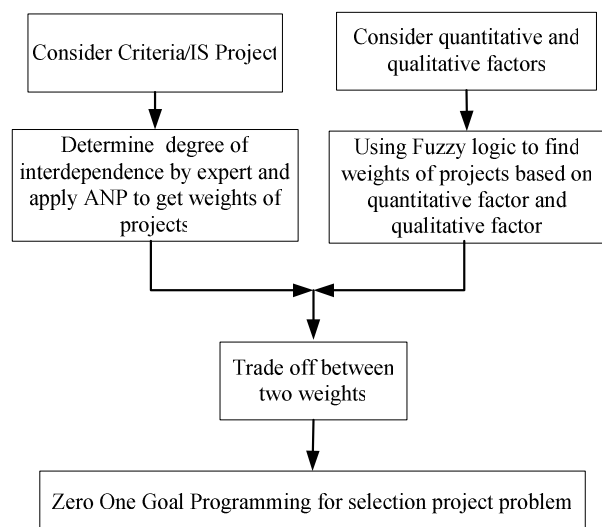


Fig. 1 An overview of the proposed method

II. LITERATURE REVIEW

In the real world industrial situations, a manager has to choose projects to do base on constraints among candidate projects. This is an optimization problem. To solve an optimization problem, many researches use a mathematical model like for instance Linear Programming, Goal Programming, Dynamic Programming, Integer Linear Programming, Linear 0-1 programming and a lot more. Zero-One Goal Programming is one of the methods that can be used for optimal selection problem.

There are many researchers with their methods have proposed to help organizations, companies or IT managers make good IS project selection problem. Ranking technique (Buss[3]), scoring methods introduced by Lucas[5] are proposed to solve IS project selection problem. AHP(Saaty[11]) is a well known method which is applied in IS project selection by Muralidhar[6]. Marc[7] proposed goal programming using AHP to solve this problem. However, they did not consider interdependence property itself 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.

Various real-world problems have an interdependent property among the criteria or candidate projects. Consideration for these interdependencies among criteria provides valuable cost savings and greater benefits to organizations. While AHP employs a unidirectional hierarchical relationship among decision levels, ANP (Saaty[12]) enables interrelationships among the decision levels and attributes will be taken into consideration in a more general form. ANP uses ratio scale measurements based on pair wise comparisons. Lee[4] proposed ANP and Goal Programming for solving IS project selection. Nonetheless, the above methods don't reflect many influence quantitative and qualitative factors such as investment cost, return of investment, probability of success, time for project and so on. Chen [2] and Kuanchin[1] introduced fuzzy logic to consider about influence of quantitative and qualitative factors. Previous researches extracted a list of influence quantitative and qualitative factors are shown in Fig.2(Chen[2]).

For the next part we introduced a simple hybrid method using ANP, Fuzzy logic, ZOGP in dealing with interdependence among criterion of candidate projects, quantitative, qualitative factors and optimal problem.

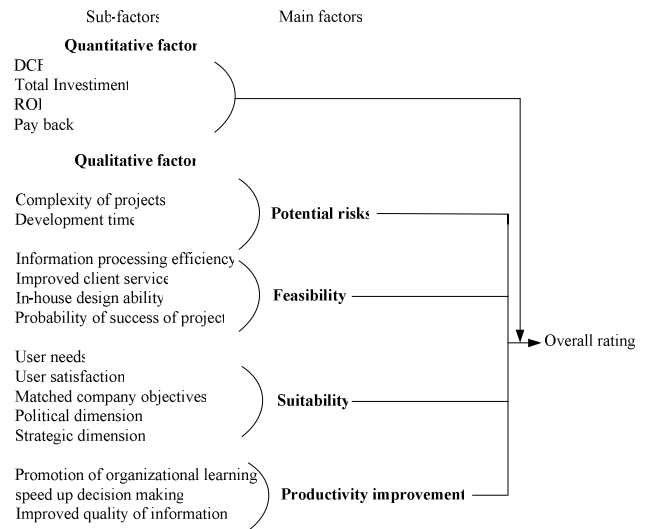


Fig. 2 Sub and main quantitative and qualitative factors [2]

III. PROPOSED METHOD

The proposed method includes the following five steps.

Step 1: Identify the multiple criteria that merit consideration and then draw a graph of relationship between criteria that show the degree of interdependence among the criteria.

Marc [7] showed a simple example of IS project selection with four criteria:

- (1) Increased accuracy in clerical operations (AC),
- (2) Information processing efficiency (E)
- (3) Promotion of organizational learning (OL)
- (4) Cost of implementation (IC).

Marc's [7] example was assumed that these four criteria are independent. However, there is an existence of interdependence relationship among these four criteria in IS projects problems and the relationship having interdependence among the criteria is shown Fig. 3 (Lee [4]).

Step 2: Determine the degree of impact or influence between the criterions by pair wise comparisons with ANP model based on the basic 1-9 scale of Saaty's with reciprocals, in a project comparison matrix. The degree of impact or influence between the criterions is simulated in Fig. 3.

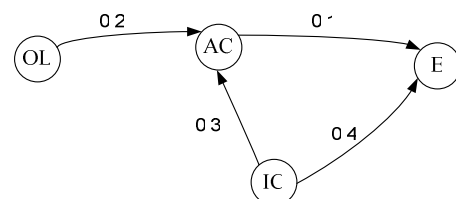


Fig. 3 Interdependent relationship among the criterion

AHP is suitable to solve the problem of independence on alternatives or criteria and ANP is useful to solve the problem of dependence among alternatives or criteria.

Step 3: Use fuzzy logic to consider about qualitative and quantitative factors. Chen[1] used fuzzy logic (Zadeh[15]) to evaluate quantitative factor and qualitative factors but the

difference between projects is not much and just suitable when choosing one of two projects did not mention about interdependence among criterion and projects.

Step 4: Determine the overall prioritization of the is projects.

In real world the weight trade-off function should be: $w=f(w_{ANP}, w_{fuzzy})$. In this paper we proposed a simple hybrid method that can combine weight between ANP and fuzzy logic as follow:

$$w = w_{ANP} * w_{fuzzy}$$

Step 5: Zero One Goal Programming (final step).

The ZOGP model for IS project selection can be stated as follows (Lee [4]):

$$\begin{aligned} & \text{Minimize } Z = P_k(w_j d_i^+, w_j d_i^-) \\ & \text{Subject to:} \\ & \sum a_{ij} x_j + d_i^- - d_i^+ \leq b_i, \text{ for } i=1, 2, \dots, m \\ & x_j + d_i^- = 1, \text{ for } i=m+1, m+2, \dots, m+n. \quad j=1, 2, \dots, n \\ & x_j = 0 \text{ or } 1, \text{ for } \forall j, \\ & m: \text{ number of constraints,} \\ & n: \text{ number of projects.} \end{aligned}$$

Fig. 4 Zero One Goal Programming model for IS Project selection

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 and Fuzzy logic which determined weights of w_j for corresponding d_i^- . The larger the w_j , the more likely the corresponding IS project will be selected.

After having weights of projects we used goal programming for optimization problem wherein you have to choose some IS projects that have to satisfy some constraints. Many constraints of problems in the real world are linear constraints based on add operator example sum of money pay for project must not be over the budget. When you choose project you have to satisfy some goals.

IV. CASE STUDY

In case study we used the old data in Lee [4] with result of ANP step. Their problem consisted of prioritizing six IS projects on the basis of four criteria (AC, E, OL, IC) with interdependence relationship or network structure among the criteria which is show in Fig. 5 based on discussion of experts. Assumption that after ANP step (Lee[4]) we get weights of project base on criteria as follow: $w_{ANP}(p_1, p_2, p_3, p_4, p_5, p_6) =$

(0.031, 0.058, 0.088, 0.154, 0.264, 0.395)

But ANP does not consider about many important quantitative and qualitative factors as probability of success, potential risk, suitability and cost of project. We used Fuzzy step to get weights of projects (that considers about many important quantitative and qualitative factors) and used these weights to adjust parameters after ANP step.

We made a theoretical data about these factors of six projects to apply fuzzy logic to find overall weight for projects based on qualitative and quantitative factors of projects.

TABLE I

THEORETICAL DATA ABOUT MAIN QUALITY FACTORS OF SIX PROJECTS

Factors	Probability of success	Time for complete	Cost of project(000)	Suitability
Project1	80%(0.8)	7300(0.65)	80(1)	60%(0.6)
Project2	90%(0.9)	11250(1)	25(0.31)	80%(0.8)
Project3	85%(0.85)	2800(0.25)	55(0.69)	90%(0.9)
Project4	95%(0.95)	2750(0.25)	40(0.5)	90%(0.9)
Project5	95%(0.95)	3750(0.33)	65(0.81)	80%(0.8)
Project6	100%(1)	3750(0.33)	50(0.63)	70%(0.7)

We can think that probability of success can be low, medium or high. But we can also think that probability of success is equal 0.4 then it is quite medium a little low, and if probability of success is equal 0.9 then it is quite high, a little medium. Although the membership function for each linguistic term does not have to be in symmetric triangular form, but theoretically we can use the symmetric triangular form for all terms to demonstrate method to get weighted of project that base on quantitative and qualitative factors:

Short	$-2x+1$	$0 \leq x \leq 0.5$
Medium	$2x$	$0 \leq x \leq 0.5$
	$-2x+2$	$0.5 \leq x \leq 1.0$
Large	$2x-1$	$0.5 \leq x \leq 1.0$

We used the same method of Chen to find Potential Risk, Feasibility and Suitability of project and then get overall ratings for six projects.

A. Inference Process from Development Time to Potential Risk

The normalized development time (0.65) for project 1 triggers two terms: "medium" and "high". Note again that the terms for each linguistic variable may not be the same. For simplicity, we assumed that the terms can share the same membership function. So the membership functions for "long" and "large" are the same and membership functions for "short" and "small" are the same.

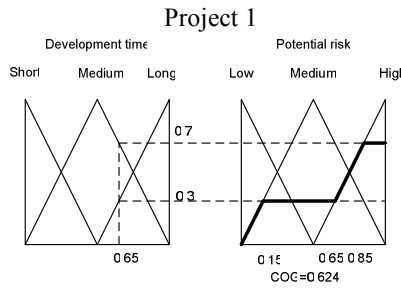


Fig. 5 Inference Process from Development Time to Potential Risk

The inference rules are as follows:

- 1) if DT = Medium then R = Medium
- 2) if DT = Short then R = Low
- 3) if DT = Long then R = Large

where DT is development time and R is risk. The rules mainly serve as guidance for fuzzy inference. Crisp inputs were translated into applicable terms for a linguistic variable (the applicable terms for project 1 are “medium” and “high”). The associated membership values are calculated (i.e., 0.7 and 0.3 for “high” and “medium” respectively). These membership functions are used to cut the membership functions on the consequent part of a rule. As a result, an outlined region is formed indicating the intersection of different terms (Fig. 5). Finally, the center of gravity (COG) of that outlined region is calculated and serves as the crisp output from the fuzzy inference engine.

The value of COG be calculated with this formula:

$$COG = \frac{\int f(x)xdx}{\int f(x)dx}$$

Potential risk of project 1 is 0.624 based on Fig. 5:

$$COG = \frac{\int_0^{0.15} (2x^2)dx + \int_{0.15}^{0.65} (0.3x)dx + \int_{0.65}^{0.85} (2x^2 - x)dx + \int_{0.85}^1 (0.7x)dx}{\int_0^{0.15} (2x)dx + \int_{0.15}^{0.65} (0.3)dx + \int_{0.65}^{0.85} (2x - 1)dx + \int_{0.85}^1 (0.7)dx} = 0.624$$

Results for Potential Risk of projects are in Table II.

B. Inference Process from Probability of Success to Feasibility

Two terms, “medium” and “high,” are applicable when the input values for probability of success are plugged into the system. Hence, two rules were fired:

- 1) If PS = Medium then F = Medium
- 2) If PS = High then F = High

where PS is probability of success and F is feasibility.

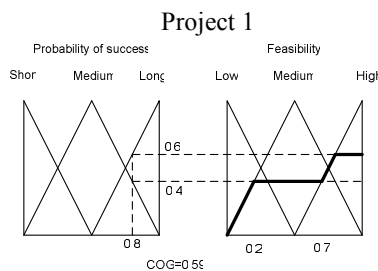


Fig. 6 Inference Process from Probability of Success to Feasibility

We have Feasibility of project 1 based on Fig. 6:

$$COG = \frac{\int_0^{0.2} (2x^2)dx + \int_{0.2}^{0.7} (0.4x)dx + \int_{0.7}^{0.8} (2x^2 - x)dx + \int_{0.8}^1 (0.6x)dx}{\int_0^{0.2} (2x)dx + \int_{0.2}^{0.7} (0.4)dx + \int_{0.7}^{0.8} (2x - 1)dx + \int_{0.8}^1 (0.6)dx} = 0.59$$

Results feasibility for projects are shown in Table II.

TABLE II
 VALUES OF MAIN FACTORS OF PROJECTS AFTER USING FUZZY LOGIC TO INFER (M: MEDIUM, H: HIGH, S: SMALL)

Factors	Cost of Project	Potential Risk	Feasibility	Suitability
Project1	1	0.624	0.59	0.6
	M:0	M:0.752	M:0.82	M:0.8
	H:1	H:0.248	H:0.18	H:0.2
Project2	0.31	1	0.87	0.8
	M:0.62	M:0	M:0.26	M:0.4
	S:0.38	H:1	H:0.74	H:0.6
Project3	0.69	0.44	0.59	0.9
	M:0.62	M:0.88	M:0.82	M:0.2
	H:0.38	S:0.12	H:0.18	H:0.8
Project4	0.5	0.44	0.87	0.85
	M:1	M:0.88	M:0.26	M:0.3
	H:0	S:0.12	H:0.74	H:0.7
Project5	0.81	0.51	0.87	0.75
	M:0.38	M:0.98	M:0.26	M:0.5
	H:0.62	H:0.02	H:0.74	H:0.5
Project6	0.63	0.51	1	0.7
	M:0.74	M:0.98	M:0	M:0.6
	H:0.26	H:0.02	H:1	H:0.4

For simplicity sake this paper having theoretical data, we assumed that we already have all suitability of projects.

C. Inference to get Overall Result for Projects

We assumed that we have information about project as in Table II, we used rules of fuzzy logic to find final weights of projects. Example for Project 1:

- 1) 1) If CP = H, R = M, F = M, S = M then OR = M → Med1 = min(1, 0.752, 0.82, 0.8) = 0.752
- 2) 2) If CP = H, R = M, F = M, S = H then OR = H → High1 = min(1, 0.752, 0.82, 0.2) = 0.2
- 3) 3) If CP = H, R = M, F = H, S = M then OR = M → Med2 = min(1, 0.752, 0.18, 0.8) = 0.18
- 4) 4) If CP = H, R = M, F = H, S = H then OR = H → High2 = min(1, 0.752, 0.18, 0.2) = 0.18
- 5) 5) If CP = H, R = H, F = M, S = M then OR = M → Med3 = min(1, 0.248, 0.82, 0.8) = 0.248
- 6) 6) If CP = H, R = H, F = M, S = H then OR = M → Med4 = min(1, 0.248, 0.82, 0.2) = 0.2
- 7) 7) If CP = H, R = H, F = H, S = M then OR = H → High3 = min(1, 0.248, 0.18, 0.8) = 0.18
- 8) 8) If CP = H, R = H, F = H, S = H then OR = H → High4 = min(1, 0.248, 0.18, 0.2) = 0.18

And then we have:

$$\text{Medium} = \max(\text{Med1}, \text{Med2}, \text{Med3}, \text{Med4}) = 0.752$$

$$\text{High} = \max(\text{High1}, \text{High2}, \text{High3}, \text{High4}) = 0.2$$

Fig. 7 shows overall inferences for six projects:

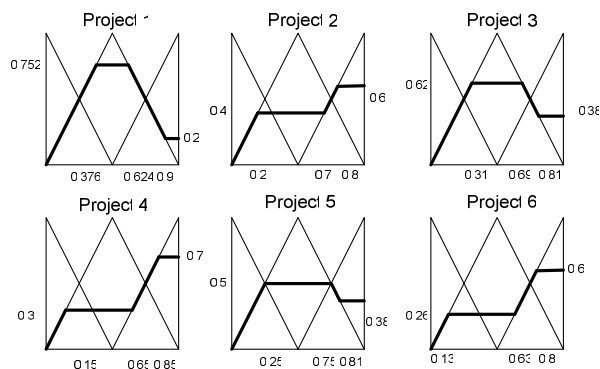


Fig. 7 Inference for six projects to get overall weights

Fuzzy weight for Project 1:

$$COG_1 = \frac{\int_0^{0.376} (2x^2)dx + \int_{0.376}^{0.624} (0.752x)dx + \int_{0.624}^{0.9} (2x - 2x^2)dx + \int_{0.9}^1 (0.2x)dx}{\int_0^{0.376} (2x)dx + \int_{0.376}^{0.624} (0.752)dx + \int_{0.624}^{0.9} (2 - 2x)dx + \int_{0.9}^1 (0.2x)dx} = 0.509737$$

The final results are:

$$W_{fuzzy}(p_1, p_2, p_3, p_4, p_5, p_6) = (0.509737, 0.587805, 0.533981, 0.624393, 0.538345, 0.623382).$$

Calculate $w = W_{ANP} * W_{fuzzy}$ you can get weights of projects that consider both interdependence among criterion and qualitative, qualitative factors:

$$w_{hybrid} = (0.016, 0.034, 0.047, 0.096, 0.142, 0.246)$$

Also assumed that we have 6 projects with their parameters as follow (see Table III):

TABLE III
PARAMETERS OF SIX PROJECTS

Parameters	Programmer hours(h)	Analyst hours(h)	Budgeted costs(000)	Clerical labor hours(h)
Budget	15000	6500	\$200	3700
Project1	6000	1300	\$80	1000
Project2	10000	1250	\$25	800
Project3	1000	1800	\$55	500
Project4	750	2000	\$40	1200
Project5	2250	1500	\$65	900
Project6	2000	1750	\$50	1100

We have to choose some projects that satisfy 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.
- 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.

And two flexible goals in order:

- 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.
- 2) An initial allocation goal of clerical hours of labor is set at 3700 h but deviation from this allocation is possible.

The model of Zero One Goal Programming now is:

TABLE IV
ZERO ONE GOAL PROGRAMMING FOR IS PROJECTS SELECTION PROBLEM

Minimize
$b_1 + b_2 + b_3 + a_4$
$C 016a_1 + C 034a_2 + C 047a_3 + C 096a_4 + C 142a_5 + C 246a_6$
$a_{11} + b_{11}$
$a_{12} + b_{12}$
SUBJECT TO
$6000x_1 + 10000x_2 + 1000x_3 + 1000x_4 + 750x_5 + 2250x_6 + 2000x_7 + a_{11} - b_{11} = 15000$
$1300x_1 + 1250x_2 + 1800x_3 + 2000x_4 + 1500x_5 + 1750x_6 + a_{12} - b_{12} = 6500$
$80x_1 + 25x_2 + 55x_3 + 40x_4 + 65x_5 + 50x_6 + a_4 - b_4 = 200$
$x_2 + a_4 = 1$
$x_1 + a_4 = 1$
$x_2 + a_4 = 1$
$x_3 + a_4 = 1$
$x_4 + a_4 = 1$
$x_5 + a_4 = 1$
$x_6 + a_1 = 1$
$80x_1 + 25x_2 + 55x_3 + 40x_4 + 65x_5 + 50x_6 + a_{11} - b_{11} = 180$
$1000x_1 + 800x_2 + 500x_3 + 1200x_4 + 900x_5 + 1100x_6 + a_{12} - b_{12} = 3700$
$a_i \geq C$
$b_i \geq C$
$x_i \geq C$
END
$x = C$ or 1

Projects 2, 4, 5, and 6 were chosen (as result of ZOGP with Lindo 6.1) consuming the total budgeted cost of \$180,000. We will use exactly 6500 hours of analyst time and use 300 more hours of clerical help than the initial 3700 hours.

V. CONCLUSION

Multi-Criteria Decision Making is an interesting problem because it has many applications in the real world especially when dealing with MCDM problem manager of organization wherein you have to consider all property.

Interdependence property among criterion is very important for decision makers. Group decision making is more helpful to determine such an interdependent property than to decide by only one or two decision makers.

Beside that, quantitative and qualitative factors are also very important for decision maker. The decision maker should consider very carefully about some quantitative and qualitative factors such as cost for project, time for project, probability of success, suitability and so on of the projects. These quantitative and qualitative factors can be obtained by collecting information from experts.

Our proposed method introduced a simple hybrid method (ANP and Fuzzy logic and ZOGP) to solve IS Project Selection Problem. ANP and Fuzzy logic are used for dealing with interdependence property among criterion, important quantitative and qualitative factors. ZOGP is used to solve optimization problem because almost constraints in IS project selection problem are linear constraints.

The ZOGP that we used in our method is Preemptive/Lexicographic Goal Programming with priority among goals. A weakness of Preemptive/Lexicographic Goal

Programming is that it is not flexible when dealing with integer problem with many goals. Actually for optimization problem we can use other types of Goal Programming such as Weighted Sum Goal Programming (that mean we have to find weights of goals to trade off goals) or Weighed Tchebycheff Goal Programming so on and so forth. If you can collect experience of experts to get weights to trade off goals then using Weighted Goal Programming to get credible results.

For further research, it is needed to show an application of real-world problems. Recently, decision makers often use mathematical models to help them on making decision like for instance Matlab, MathPro, Lindo, Lingo, Microsoft Excel, Expert Choice and etc. After constructing model formulation decision makers can use software packets or Decision Support Systems to find optimal solution.

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