THE GA AND FUZZY MODM APPLIED IN FINANCIAL PLANNING FOR A CONSTRUCTION PROJECT

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ABSTRACT

The financial planning for a construction project always plays an important role in making profit. Due to the uncertainty of future situations and planning data, the risk of finance is also an important objective for financial planning. Moreover, the constraints of capitals and time are the key point for intact planning. Consequently, the financial planning can be defined as combinatorial planning problem, which can be referred to the field of multi-criteria decision issue. In this paper, the situation and requirement for construction project financial planning in practice will be discussed. Based on cash flow analysis, a mathematical planning model is proposed. It contains the maximizing objective of economic value and minimizing objective of financial risk which is subjected to the condition of capital and time. In this paper, the fuzzy theory is utilized to deal with the uncertainties included in the multi-objective characteristics. As a result, the genetic algorithm is applied to search a better solution for the planning model.

KEY WORDS

financial planning, cash flow, fuzzy MODM, genetic algorithms

INTRODUCTION

The basic theme of surviving in the business for a construction company depends on the management and control of the project to pursuit the maximum profit. High demand of cash is usually required for a construction project. Thus, a well-planned financial planning is necessary for a construction company to reduce the redundant cost and ensure the profit. The construction business typically involves various kinds of works such as production, manufacture, and service, which is different from other businesses. Its financial feature includes the following items, namely, (1)highly influence by outside factors, (2)low rate of self-own cash, (3)long construction time, (4)high cash flow, (5)contract-based type of product, (6)difficulty of management and control, (7)high risk, (8)variety of costumers, and

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etc. The major goal of a construction project is to complete the work on schedule and gain the maximum profit. The maximum profit of a construction project can be obtained from the following conditions (Tseng, 2001; Liu, 2000):

(1) maximizing the net present value of cash flow to obtain the highest investment return,

(2) balancing the cash flow from income and cost to ensure a better capital function,

(3) minimizing the interest cost and reducing the construction expend payment.

Therefore, the financial planning of construction project has multi-criteria characteristics. Most multi-criteria decision making problems exist uncertainties caused by the lack of enough information and variant future. The uncertainty can be expressed by using the fuzzy theory, which was given by Zadeh (1965). Many applications were evaluated by using the fuzzy multi-objective method. The concept of fuzzy multi-objective optimization can also be used to find the maximal satisfying degree among constraints of conflicting objectives (Chen, 1999). To solve a complicated planning problem, it is likely to be treated as a NP-hard problem. Previous researches indicated that several heuristic methods to determine the solution by using Greedy Algorithm, Effective Branch-and Bound and Cutting Plane, etc.(Reeves, 1993). In most cases, the heuristic method can effectively deal with the problem and yield a reasonable solution. However, it often results in a local optimum solution. In 1989, the Mate-Heuristic method concept was introduced by Glover, which was approved by many mathematicians. This method is based on the traditional solution combined with higher level of Meta-strategies, which enable a better solution without the confinement of local optimization (Osman and kelly, 1996). The use of genetic evolution technique was introduced by Holland in 1975. In this method, many possible solution sets are produced for determining the better solution directly. Recently, genetic algorithm (GA) has been applied to different fields due to the fact that it is suitable to solve complicated and non-linear problems (Goldberg, 1997).

In order to establish the prototype financial planning model for construction business, one single construction project with multi activities is considered in this study. The analysis of cash flow is based on the following considerations and objectives: the most economical benefit, the least financial risk, and the shortest construction period. In addition, different capital sources and times for cash flow-in and flow-out are pre-defined. This paper presents a financial planning model which is established by mathematical programming form. To avoid the drawbacks of explicitly adopting heuristics to solve this finance planning, the concept of fuzzy MODM and GA are considered to obtain the better solution. It is suggested that this research result can be applied for contractor to manage the financial planning, which can reduce its financial risk and increase profit.

METHODOLOGY

The methodology proposed in this study is discussed in detail. First, a mathematical model is constructed to represent the construction project finance planning problem. Next, the concept of GA is employed to transform the model parameters into a set of genetic codes to search for solutions. Some distinctive parameter coding and algorithm settings developed in this paper are also noted.

MODEL FORMULATION

1. Objective functions

(1) Maximizing net present value

$$Max\,Z_1 = NPV = \sum_{t=0}^{T'+E_N} \frac{AR_t - AC_t}{(1+R)^t} \tag{1}$$

where *NPV* is the net present value, *T'* is the deadline of the project, E_N is the time between the last payment and the completion of the project, AC_t is the cost of project at time *t*, and AR_t is the income of project at time *t*. AC_t and AR_t are expressed as follows:

$$AC_t = \sum_{i=1}^{N} \sum_{t=t}^{t+D_i-1} AC_{it} * \delta_{it}; \qquad t = 1,2,3,\ldots,T' \tag{1-1}$$

$$AR_t = AC_{t-E_i} * (1-r) \;\; ; \;\; t = 1,2,3,\ldots,T' \tag{1-2}$$

$$AR_t = 0 \qquad ;\ t = T'+1,\ T'+2, \ldots, (T'+E_n)-1 \tag{1-3}$$

$$AR_t = \sum_{t=1}^{t=T'} (AC_t * r) \;\; ;\ t = T'+E_n \tag{1-4}$$

In the above equations, δ_{it} is equal to 1 if activity item *i* is completed in period *t* and equal to 0 otherwise, AC_{it} is the unit cost of activity item *i*, D_i is the duration of activity *i*, *r* is the ratio of reserved fund, and E_i is the time between the payment and the completion of the activity *i*. The unit cost is assumed as an average cost during the time period for the execution of activity. The payment of each activity is received in the interval of E_i after completed. Both parameters of *r* and E_i are given in the project.

(2) Minimizing Capital Cost

$$Min\,Z_2 = R = \frac{\sum_{k=1}^{K} BP_k * R_k}{\sum_{k=1}^{K} BP_k} + R_R \tag{2}$$

where BP_k is the capital accumulated from the k^{th} source, *R* is the average interest rate, R_k is the interest rate of the k^{th} source, and R_R is the extra interest rate against risk.

(3) Minimizing the variation of Accumulative net cash flow

$$Min\,Z_3 = \sum_{t=1}^{T'} \left(DP_t - \frac{\sum_{t=1}^{T'} DP_t}{T'} \right)^2 \tag{3}$$

DP_t = *accumulative net cash flow at period t*

$$= \sum_{i=1}^{t} (AR_t - AC_t) \tag{3-1}$$

(4) Minimizing the time for project completion

$$Min \;\; Z_4 = \sum_{t=0}^{T'} \delta_t * t \tag{4}$$

where δ_t is equal to 1 if project is completed in time t and equal to 0 otherwise.

2. Constrain functions

(1) Time constraints

Time constraints are required for each project and activity to be completed within a pre-determined time frame as given in Eq. (5) and Eq. (6), respectively.

$$\sum_{t=1}^{T'} \delta_t = 1 \tag{5}$$

$$\sum_{t=T_i}^{T_i'} \delta_{it} = 1 \;\; ; \quad i = 1 \sim N \tag{6}$$

where T_i is the earliest possible period in which activity *i* can be completed, T_i' is the latest possible period in which activity *i* can be completed, *N* is the total number of activity in the project. T_i and T_i'can be analyzed by using the Critical Path Method.

(2) Time-logic constraints

A project is considered to be completed only when every activities in it are completed, which can be expressed in Eq.(7).

$$\delta_T \le \left[1/N \right] * \sum_{i=1}^{N} \sum_{t=1}^{T} \delta_{it} \quad ; \quad T = 1, 2, 3, \cdots \cdots, T' \tag{7}$$

An activity is considered to be started only after all of the activities preceding it are completed, which can be expressed in Eq.(8).

$$\sum_{t=T_{ip}}^{T_{ip}'} t * \delta_{ip} \le \sum_{t=T_{ij}}^{T_{ij}'} t * \delta_{it} * - d_i \quad ; \qquad \forall i, ip \tag{8}$$

where *ip* represents all the activities preceding the activity *i* and T_{ip}' is the earliest possible completed time of activity *ip*.

(3) Capital constrains

The demand of cash should not be exceeded to the supply of cash as given in Eq. (9).

$$\sum_{k=1}^{K} BP_k - DP_t \ge 0 , \quad t = 1,2,...T' \tag{9}$$

The constraint of capital can be expressed in the following equation.

$$BP_k = BP_k^{'} * X_k \quad k = 1,2,...K \tag{10}$$

where K is the k^{th} capital source, $BP_k^{'}$ is the upper limit of k^{th} capital source, and X_k is the spent ratio of the k^{th} capital.

(4) System variable constrains

The system variables X_k, δ_{it} and δ_t are defined in the following equations.

$$0 \leq X_k \leq 1 \;\; ; \;\; \forall \text{ k} \tag{11}$$

$$\delta_{it}, \delta_t = \{0,1\} \qquad ; \;\; \forall\, i, t \tag{12}$$

To simplify the scope of problem, it is assumed that certain related information of project is known, which includes symbolic terms in the proposed mathematical model, i.e., N, K, T_i, $T_i^{'}$, $T^{'}$, D_i, E_i, r, R_k, R_R, and $BP_k^{'}$. The variables of δ_{it} and X_k together form the solution of the problem, and δ_t, AC_{it}, AC_t, AR_t are all dependent variables of δ_{it} and X_k.

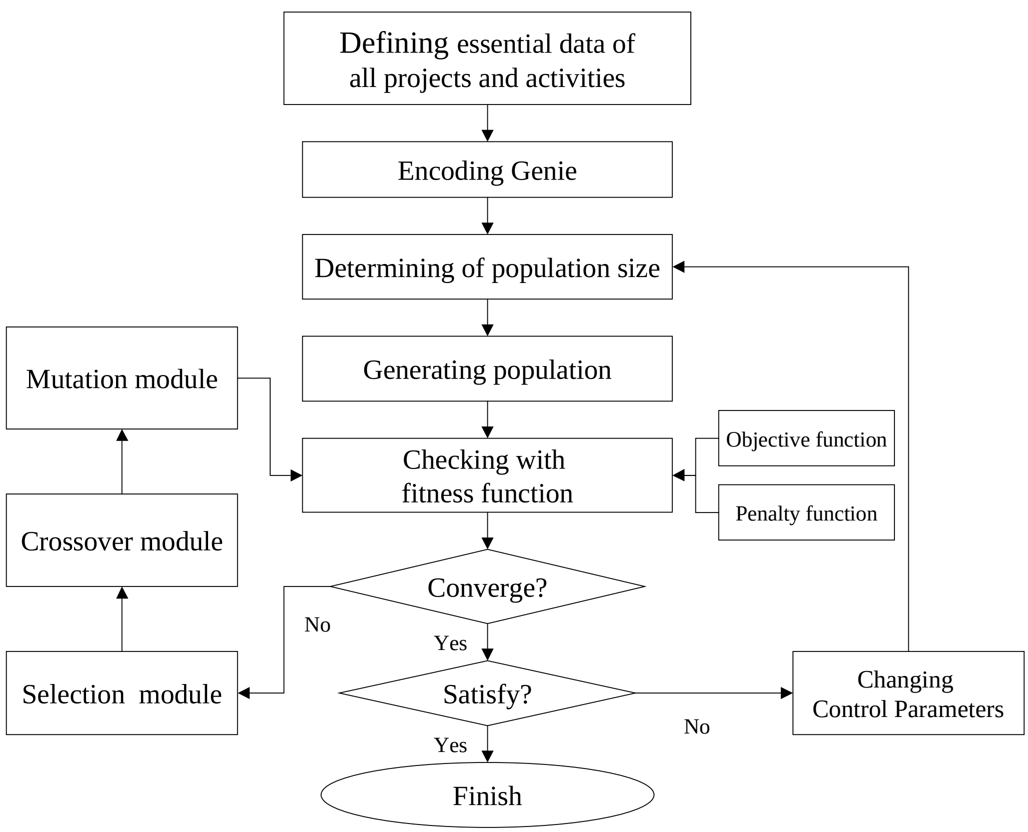

Figure 1: Procedure of Implementing the GA Concept

SOLUTION PROCEDURES

Due to the NP hard nature in the construction project finance planning problem, this work adopts the GA concept to avoid the associated computational complexity and potential local optimality. The challenge of adopting GA resides in the need to transform the model parameters from the mathematical form into a genetic form. The procedure for implementing the GA concept is depicted in Figure 1.

1. Encoding mechanism

The first step is to transform the model parameters into a chromosome string. Each chromosome will represent a particular solution for the problem. To streamline the GA model, δ_{it} is replaced by an auxiliary variable S_i. S_i represents the period during which activity *i* is completed and, therefore, its value is between T_i and T_i'. With the addition of S_i, the following procedural requirements must be specified:

(1) S_i is generated randomly between T_i (the earliest completion period) and T_i'. If S_i is equal to t', δ_{it} is equal to one in period t' and zero in all other periods. As a result, Eq. (6) and Eq.(11) are therefore satisfied.

(2) Another auxiliary variable *S* is defined which represents the period during which project is completed. Therefore, *S* is the maximum value of S_i for all *i*, in which *i* is from 1 to *N*. If *S* is equal to t', then δ_i is equal to one in period t' and zero in all other periods. Since S_i will always be larger than S_{ij}, Eq. (7) is satisfied.

Furthermore, since the available value of X_k is between 0 and 1, Eq.(12) is satisfied. By modifying the system parameters and using the chromosome pattern, constraint functions of Eq.(5), Eq. (6), Eq. (7), Eq. (11)and Eq. (12) can be relaxed. This reduces the total model constraints into two formulations, namely Eq. (8) and Eq. (9). The chromosome used for this problem is defined in Table 1.

Table 1: The available value for the chromosome

Gene	S_i ($i=1\sim N$)	X_k ($k=1\sim K$)
Available value	$T_i \sim T_i'$	0~1

2. Determining population size

After defining the chromosome, the population size in each generation can be decided. This population size represents the number of possible solution sets in each iteration. Normally, a suitable population size is determined through empirical knowledge or test. A size between 30 and 200 is commonly chosen (Goldberg, 1997). After determining the population size, the initial chromosome population can be randomly generated.

3. Evaluating the population fitness

The fitness function validates the degree of achieving model objectives and ensures the effective solution search in each iteration. In this work, the fitness function *Fit(x*) consists of two sub-functions, namely a goal function *G(x)* and a penalty function *P(x)*. The fitness function is formulated as follows:

$$Fit(x)=W_G*G(x)+W_p*P(x) \quad (13)$$

where W_G and W_p are the weight of $G(x)$ and $P(x)$, which sole function is to ensure an efficient GA iteration. $G(x)$ quantifies the degree to which the objectives are achieved, and $P(x)$ quantifies the degree to which the constraints are satisfied. The deciding on W_G and W_p could depend on the decision maker's demand or examination.

A great variety of ways exist in the literature for designing $G(x)$. A fuzzy multi-objective approach is applied in this study because the optimal solution for Eqs.(1)~(4) is hard to find. In this study, a basic concept of fuzzy multi-objective optimization is used to find the maximal satisfying degree among constraints of conflicting objectives(Chen, 1999). Z_i^+ is the most likely optimistic value of Z_i, and Z_i^- is the most likely pessimistic value for Z_i. Z_i^+ and Z_i^- can be chosen by evaluating fitness value of chromosome, which have been generated in evolution. Z_i* is the satisfying degree or fuzzy membership function of Z_i. The process may be carried out according to either of the following conditions:

(1) For objectives to be maximized

$$Z_i*= (Z_i-Z_i^-) /(Z_i^+- Z_i^-) \quad (14)$$

(2) For objectives to be minimized

$$Z_i*= (Z_i^+-Z_i) /(Z_i^+- Z_i^-) \quad (15)$$

Then, the $G(x)$ could be defined as λ which is expressed as follows:

$$\begin{aligned} & Max\ \lambda \\ & \text{st} \\ & \quad \lambda \le Z_i^* \quad \text{i} = 1,2,3,4,5 \end{aligned} \quad (16)$$

The penalty function reveals the level to which the constraints are satisfied. To incorporate time-logic and resource constraints, the penalty function is formulated as follows:

$$P(x)= (C_1+C_2)/ C* \quad (17)$$

where C_1 is the number of satisfied time-logic constraints and can be derived by judging the inequality below.

$$S_i -d_i >= S_{ip} \quad \forall\, i, ip \quad (18\ )$$

S_{jp} represents the period in which activity *ip* is completed and is a precedent activity to activity *i*. Once Eq. (18) is included in the model, the constraint given in Eq. (7) becomes redundant. C_2 can be conveniently obtained by counting the times in which Eq. (8) is satisfied each iteration. $C*$ is defined as the total number of constraint checks in each iteration. The total number of time-logic constraint checks (N_{TL}) is obtained by examining the precedence relationship among all sub-projects. The total number of capital constraint (N_c) is T^*. Therefore, $C*$ is obtained from Eq. (19) as given below.

$$C*= N_{TL}+ N_c= N_{TL}+ T' \quad (19)$$

4. Selection

Selection is a process, which involves collecting useful chromosomes for the next generation. The useful chromosomes are those who receive a high fitness value. The selection process is carried out in two stages as described below.

Stage (1)：First, the best chromosome bank (BCB) is initiated, which includes B_1 members. Each member of BCB should at least satisfy all constraints, i.e., *P(x)* equals to one, and has a high *G(x)* value. All members in the BCB will replace those poorly performing chromosomes in the previous population.

Stage (2)：The number of promising chromosomes B_2 is further duplicated, i.e., those with a high *Fit(x)* value, in the previous generation, are appended to the population, and the same number of poorly performing chromosomes are removed from the population.

The values of B_1 and B_2 may be dependent upon the size of the population.

5. Crossover and mutation

Crossover refers to the exchange of genes between two chromosomes. The number of chromosomes opted for exchange is determined by the crossover rate. Through the exchange of genes, improved chromosomes may be generated. Several exchange types are commonly considered, including uniform crossover, two-point crossover and multi-point crossover, etc. A crossover rate from 0.5 to 1 is recommended by Goldberg (1997). The uniform crossover process is applied in this study.

In the mutation process, the value of a gene may be changed within its allowable range. The main purpose of mutation is to maintain the diversity of candidate salutations. The new value is given to a gene is random so that the likelihood of generating better solutions can be increased. N_m is the number of genes, which are given a new value. The mutation rate is defined as the ratio between N_m and the product of the total number of genes in a chromosome and the population size. In general, the acceptable mutation rate range is between 0.001 and 0.01(Goldberg, 1997).

6. Convergence Determination

The iteration of the preceding algorithms will continue until a solution convergence is observed. Since the optimal solution is hardly defined, the following strategies are adopted for the solution search and as a guideline for judging a convergence, i.e., (1) when the variation in the fitness level among generations is within a satisfied limit, (2) when the variation in the goal function value among generations is within a satisfied limit, and (3) when the number of generations generated has accumulated to a predetermined level. If a better solution must be generated, the iteration will resume and the control parameters adjusted before the rerun.

7. Tuning control parameters

The control parameters are embedded in the selection method, the crossover method, the objective weights, the goal and penalty function weights, the population size, the selection rate, the crossover rate, the mutation rate and the convergence coefficient. Adjusting the control parameters may expedite the convergence of the search or produce a better solution.

CONCLUSIONS

In this paper, a single construction project is considered and solved by using well-developed methods. A financial planning model for a construction project established by Fuzzy MCDM model is discussed. The mathematical formulations by using the newly developed GA concept can effectively provide a better solution. It is suggested that this research result can be used for contractor to manage the financial planning, which can reduce its financial risk and increase profit of a construction project. For future research based on the methodology proposed in this paper, it should include: (1) the use of fuzzy theory to deal with the uncertainty factors of capital demand, cash demand, and activity's duration; (2) consideration of multi-project in practice.

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