A GA-BASED BORROWING STRATEGY FOR CONSTRUCTION SMES IN HONG KONG

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Small and Medium Enterprise (SME) contributes 98% of the economy in Hong Kong. However, the semi-structured nature of finance optimization problems is still unsolved in financial decisions, especially in the construction industry. The research presented in this paper illustrates an adaptive genetic algorithm (AGA) approach to the selection of funding schemes by a modified construction loan acquisition model that was developed by Lam *et al*. (1998). Multiple projects being undertaken by a medium-size construction firm in Hong Kong were used as a real case study to demonstrate the application of AGA to the borrowing decision problems. A monthly borrowing strategy was finally achieved. SME Loan Guarantee Scheme (SGS) that was launched by the HKSAR was first identified as the source of external financing. Selection of sources of funding can be made such that a more accurate, objective and reliable borrowing decision can be provided for the decision- maker to analyze the financial options.

Keywords: construction firm, genetic algorithm, loan and finance, optimization.

INTRODUCTION

Comparing to the other industries in Hong Kong, the construction industry generally experience a unreasonably greater number of bankruptcies since the financial crisis of 1997. One of the major reasons of this phenomenon is that the financial resources are insufficient, or even worse, fail to persuade creditors. Financial decisions are some of the most important decisions in the investment management process. They involve the capital structure, leasing or borrow-and-buy decision as well as dividend decisions. The primary objective of financial management in a firm is to set and manage the capital budgeting practices employed (Padberg and Wilczak 1999). Firms with low gearing should borrow to finance their investment schedules because interest payable on borrowing is tax deductible (Pike and Dobbins 1986). Myers (1977) showed that firms with excessive debts might gain efficient investments opportunities as creditors are the main recipients of the cash flow in the future. However, to ensure the survival of the firm, borrowing needs to be carefully monitored and evaluated and over-borrowing should not be adopted. Construction managers should also have an optimal borrowing schedule and strategies for emergencies to eliminate the financial distress suffered by the shareholders. Thus the possibility of bankruptcy can be minimized or avoided. In financial decision-making, a number of mathematical models have been developed for construction financial management problems (Hanssmann 1968; Jennergren 1990). However, less than 30% of respondents (building contractors) claim that their firms used financial modelling

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tools for managing their projects (Lam *et al.* 2002). As many businesses have grown significantly and the environment has become more unpredictable, a borrowing decision model is required to provide the decision-maker a tool kit for analyzing his financial decisions.

The study in this paper aims at optimizing multiple-project loans acquisition in medium-size construction firms in Hong Kong that represent 45% of the industry (Group B contractors for contracts of value up to $50 million in the list of approved contractors for public works) at maximum efficiency. A borrowing decision model developed by Lam *et al.* (1998) is improved by classifying the qualitative factors into external, interactive and internal types and taking additional qualitative factors including sovereignty, credit ability and networking into consideration. An adaptive genetic algorithm (AGA) approach is then applied to the search for sources of funding schemes arriving at a compromise solution of the monthly borrowing schedule of medium-size projects. This will enable on time arrangements for acquiring funds from outsiders to be made to avoid the possibility of financial problems incurred. It has the following three objectives: (a) To improve a multi-objective decision model for multi-project borrowing decisions, undertaken in the fuzzy environment of a medium-size building contractor; and (b) To establish a GA-based borrowing strategy by the improved borrowing optimization model with an AGA approach.

GENETIC ALGORITHMS (GAS)

The GAs, developed by Holland in 1960s and 1970s, simulate Darwin-type natural evolution (Holland 1975). GAs are powerful and largely applicable stochastic search techniques, that can search large and complex spaces based on the ideas from natural genetics of a population and natural selection (Davis 1991) in a number of applications (Colin 1994). These algorithms have been successfully applied to a number of areas of construction project management, such as construction resource scheduling problems (Alcaraz and Maroto 2001); the time-cost trade-off problem (Feng and Liu 1997); especially in the financial application in budget allocation, portfolio selection, bankruptcy prediction and credit evaluation (Shin and Lee 2002) and cash flow forecasting (Lam *et al.* 2001). However, financial decision modelling is still ill-defined and the optimization of multi-project loan acquisition problems involving fuzziness and imprecision have not been modelled and solved using a mathematical approach.

MODELLING OF THE BORROWING DECISION

A multiple-objective borrowing model was developed to assist the decision-maker in deciding upon suitable sources of funding. The model was based on a mathematical model developed by Lam *et al.* (1998). However, it was based on the assumptions that contractors have no problems in acquiring funds from financial institutions and only depend on self-assessments of financial capability in acquisition of funds. There was deficiency in the input of qualitative variables. A further study involving a novel and realistic mathematical model for the borrowing decision problem in fuzzy environments is proposed. Figure 1 shows the procedures for modelling the construction borrowing decision. The procedure consists of two phases: modelling and application. In the modelling phase, objective functions are set. The basic objectives of the model are to optimise the discounted loan and to minimize the discounted interest payments for all projects. To determine whether a loan is maximized or minimized, the tax-shield and profit conditions of a firm are considered. If the existing tax-shield is greater than the allowable one and the amount of payable interest incurred through borrowing plus the capital allowable is smaller than the gross profit in a year, the loan is maximized.

Selection of funding schemes is based on the qualitative contributors rather than the quantitative contributors. The remaining objectives are to maximize or minimize qualitative factors. The type of qualitative factor determines whether it is maximized or minimized. In this study, the qualitative factor for the borrowing decision model is considered in terms of the chance of having an unfavourable source of finance for SMEs. Thus the third objective is to minimize this risk. There are numerous factors such as the track record of the borrower, the style of the lender, the type of loan and agreement terms, etc. With the professional knowledge and experience of the experts in the top level management team, the factors under considerations are divided into three categories: external, interactive, and internal. Different weights are assigned by the experts to each category respectively. The linguistic variables that deemed to be essential in the decision-making process are classified as: a) external: type of banker IQV_{1t}, sovereign IQV_{2u}; b) interactive: relationship with the banker, IQV_{2v}, long term prospects, IQV_{4w}, past cooperation, IQV_{5x} and c) internal: credit ability, IQV_{6y}, networking, IQV_{7z}. These variables are deemed to be the characteristics of the qualitative factors, and are considered as the input variables in the borrowing model. The details of the input variables are given in Table 1. The newly added variables, sovereign, credit ability and networking are discussed in details. Since the estimation of parameters in the constraints (e.g. periodic cash requirements, tax-shields and the capital gearing ratio) are fuzzy in nature in the forecasting stage, a fuzzy reasoning technique is applied in the model. The variables are then solved by the AGA in the application phase.

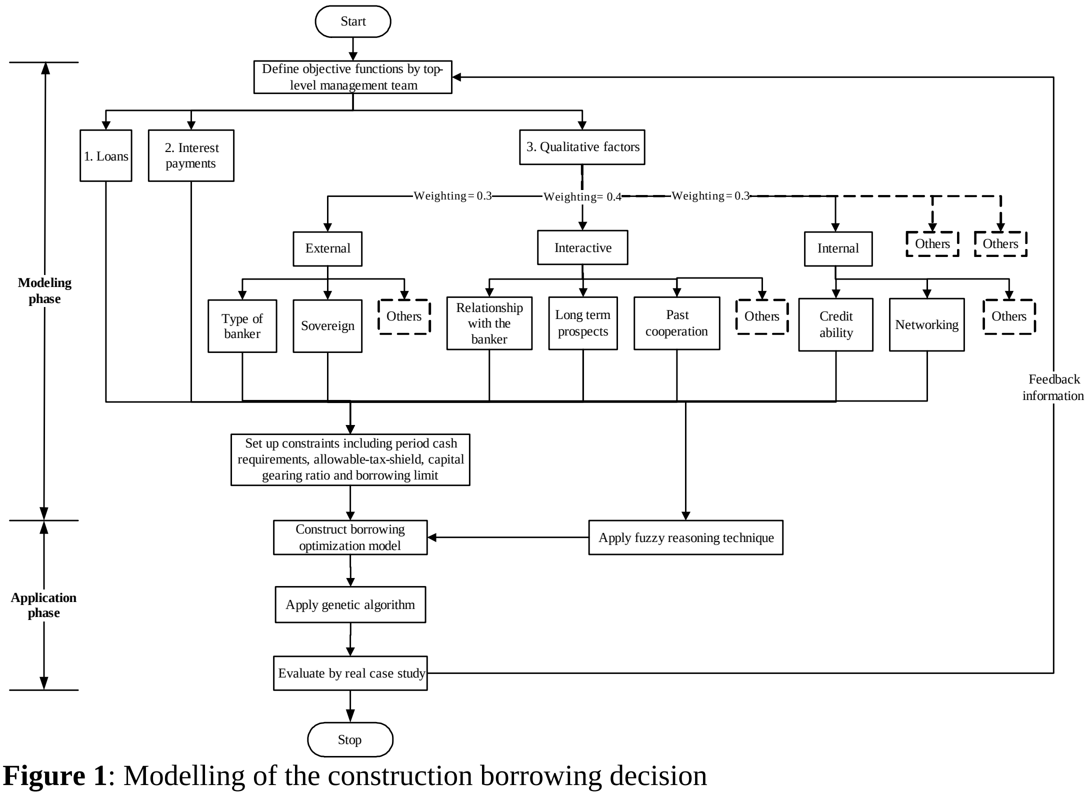

Figure 1: Modelling of the construction borrowing decision

Table 1: New input variables in the borrowing decision model

Input variables	Items for qualitative factors
External	Weighting = 0.3
Sovereign, IQV_{2u}	where u = 1…3
IQV_{21}	Soft: flexible government's action(s) to prevent the repayment and/or the raising of funds from financial institutions
IQV_{22}	Mild: moderate government's action(s) to prevent the repayment and/or the raising of funds from financial institutions
IQV_{23}	Strict: harsh government's action(s) to prevent the repayment and/or the raising of funds from financial institutions
Internal	Weighting=0.3
Credit ability, IQV_{6y}	where y = 1…5
IQV_{61}	Very low debt capacity: over 30% of financial transaction delayed in the past 5 years
IQV_{62}	Low debt capacity: 20-40% of financial transaction delayed in the past 5 years with
IQV_{63}	Medium debt capacity: 10-30% of financial transaction delayed in the past 5 years
IQV_{64}	High debt capacity: below 20% of financial transaction delayed in the past 5 years
IQV_{65}	Very high debt capacity: below 10% of financial transaction delayed in the past 5
Networking, IQV_{7z}	where z = 1…5
IQV_{71}	Highly inactive: very poor business performance
IQV_{72}	Inactive: poor business performance
IQV_{73}	Slight: moderate business performance
IQV_{74}	Active: good business performance
IQV_{75}	Highly active: excellent business performance

Input variables

Sovereign (External factor): A country's political atmosphere has a differential and significant impact on local and foreign firms. There are many kinds of government policies such as expansionary policies including increased government expenditure and lower or redefinition of taxes, development of bonds (Nazmi 2002) and issuance of government credit program (Espinosa-Vega *et al.* 2002). Expansionary policies stimulate economic growth (Barro 1989). The combination of expansionary policy with creditor lending to provide loan is to launch a credit program or a finance scheme to increase long-run production. The policy reaction will add to bank reserves through open market purchases. Creditors are willing to convert these excess reserves into loans with lower borrowing rates for the lenders. Sovereign as a variable is defined as the type of government's actions that prevent the repayment and /or the raising of funds from financial institutions such that if a soft financial scheme is launched by the government for firms to assist them in acquiring capital to enhance their productivity and competitiveness, the level of sovereign is classified as soft. The stricter the government action is, the higher the level of sovereign available to a company.

Credit ability (Internal factor): Financial credibility indicates that creditors allocate a relatively high chance to a firm that it will carry out the promise to repay the loan within the predetermined period. Credit ratings become more crucial in financial markets and have a direct relationship with the debt capacity granted to a firm. Debt capacity provides valuable information in the stage of capital planning by establishing margin on the quantity of the investment projects (Hogan 1985). It is a function of its ability defined as the availability of cash flow as well as its willingness to repay the loan (Jain 1990). The rate at which a firm can borrow is decided by its ability to repay the loan. Therefore, the percentage of financial transactions delayed in the past 5 years with the counter party was adopted to quantify the credit ability such that, if a firm has over 30% of financial transactions delayed in the past 5 years with the counter party, it is classified as having a very low debt capacity and thus a low credit rating. The larger the percentage of financial transactions delayed, the smaller the debt of a company.

Networking (Internal factor): Networking is a subjective factor defined as the process of sharing contracts among parties outside and inside a firm (Dubini and Aldrich 1991). A network supports the decision-makers by providing useful information and resources and sometimes opportunities to a firm. Successful entrepreneurs have large social networks (Hansen 1995). Lending institutions usually make decisions by considering whether the firm has a good network to maintain its business, so that loan can be repaid easily. The levels of networking of a firm have positive relationship with their business performance which could be measured by the employment growth (Barkham *et al*. 1996). The networking is associated with the level of business performance. A marketing system is introduced such that, if the marks of business performance are less than 20, the networking of the firm is classified as "highly inactive". The higher the business performance, the greater the networking activity awarded to a company.

CASE STUDY

Problem background

A medium-size building contracting firm had three on-going projects and a fourth project which was newly granted. The four projects required similar resources in terms of labour, plant, materials and management expertise. They differ in sizes, profit margins and resource-mix proportions. In order to simplify the calculation, a 2-month delay in the payment was applied in this case study. According to the conditions stated in the contracts, some 1.5 % of the retention money was deducted from the interim payment each month. Table 2 shows the details of the case study projects

Table 2: Details of the projects

Project type	Public housing	Public housing	Public housing	Civil works
Contract sum, HK$ in millions	6.85	18.40	10.19	14.69
Contract period, month(s)	9	21	15	13
Start, month	10th	3rd	5th	14th
Profit margin, %	17.5	20.0	18.0	25.0
Certificate and payment period	21 days and another 21 days			
Retention, HK$ in millions	1.5% or max. 0.1	1.5% or max. 2.2	1.5% or max. 1.58	1.5% or max. 0.2
Release retention	Release after 3-month defects liability periods			

External financing can be classified into short- and long-term loans in satisfying the specific needs of borrowers. Ten sources of finance, coming from six different financial institutions, were allowed in satisfying a contractor's borrowing requirements as shown in Table 3. This is because different borrowing and lending rates for the financing decisions are realistic (Padberg and Wilczak 1999). The interest rate that banks charge to their preferred customers is the prime rate (P). P equals 5% at the time of study. The first source provided an upper limit of 1 million with interest being the P plus 1.0 %. Sources 2 and 3 were granted from the same financial institution, and involved a 2 year, medium-term loan of 15 and 20 millions respectively and interest calculated as the P plus 1.5 %. The schedule was jointly agreed upon by the bank and the contractor to follow the schedule of corporate cash flow, such that 50 % of the loan was withdrawn at the beginning, and 30 % and 20 % of the loan would be withdrawn at stages 2 and 3, respectively. Sources 3, 4 and 5 of finance were negotiated between the bankers and the contractor with terms and interest rates as shown in Table 3.

SMEs are the backbone of Hong Kong's economy (HKSAR 2002). In 1998, the HKSAR Government launched the SME Loan Guarantee Scheme (SGS) for SMEs to help them in acquiring the installations and equipment they need to enhance their productivity and competitiveness. SGS was used as sources 6 to 10 in this study. Sources 6 to 8 were selected from the same bank with the same interest rate (P-1.00%). Sources 9 and 10 came from the other bank. Source 6 (Type 1 of SGS) was business installation and equipment loans assisting the company to buy business installations and equipment to enhance business efficiency. The loan is up to 6 millions and tenor up to 5 years. Source 7 was an associated working capital loan (Type 2 of SGS) to meet additional operational expenses arising from or in relation to the business installations and equipment acquired/to be acquired under the SGS. The loan upper limit of source 7 is as high as 3 millions. This kind of loan allows the choices of instalment loan and overdraft. Source 8 (Type 3 of SGS) was accounts receivable loan to meet the working capital needs arising from provision of credit terms to the applicant's customers. For source 8, the contractor can obtain the loan amount of 3 millions and its guarantee period is up to 2 years. About source 9 (Type 1 of SGS) and 10 (Type 2 of SGS), the interest rates are as low as P+2.5 % and P+3 % respectively. Also, the types of the loan terms are different. The former one is the instalment loan while the latter one is the unsecured overdraft.

Table 3: Financial data for a contracting firm and the terms of loans from different sources

Types	Term loans					SGS				
Items	1	2	3	4	5	6	7	8	9	10
Loan terms	OD	2 yrs	2 yrs	1 yr	2 yrs	5 yrs	2 yrs	2 yrs	OD	2 yrs
Upper limit	1m	15m	20m	7m	20m	6m	3m	3m	3m	2m
Lower limit	–	10m	15m	5m	16m	–	–	–	–	–
Interest rate (Prime rate +)	1%	1.5%	1.5%	1.75%	2%	-1%	-1%	-1%	3%	2.5%
Stage 1	–	50%	60%	50%	25%	50%	25%	50%	–	–
Stage 2	–	30%	20%	50%	25%	50%	25%	50%	–	–
Stage 3	–	20%	20%	–	25%	–	25%	–	–	–
Stage 4	–	–	–	–	25%	–	25%	–	–	–

Capital structure: Approximately 50 to 60%
Allowable tax-shield forecast: Around 6m to 6.5m
Total assets of the firm: Approximately 550m

Note: OD means Over-draft; m in HK$ million(s); – means no restrictions

Procedure to solve the problem

The procedure of converting real data into membership values is known as fuzzification. The qualitative factors predetermined are fuzzificated first. The popular technique for fuzzification is either the *S* function or the π function that is a combination of two *S* functions (Zadeh 1975). An adaptive genetic algorithm (AGA) is applied in searching the optimization results. Basically, a GA undergoes the search process in four stages: initialization, selection, crossover, and mutation (Davis 1991). The GA initializes with a random population of chromosomes, probability of crossover and mutation. The formulation of a GA needs the designation of a fitness function that assigns an overall performance value to each set of decision variable values, which is based on the realization of an objective function and an abuse of the constraints of diverse solutions. In the operation phase, Roulette Wheel Selection (RWS) is used to select the number of population from parents in which individuals are mapped to contiguous segments of a line, such that each individual's segment is identical in size to its fitness. Crossover and mutation operations are then applied to produce consecutively fitter chromosomes. The process is repeated until the desired number of individuals is obtained in the decision phase. Constant parameters are adopted in most applications of GAs. The parameters are decided on a set-and-test basis. Since GA has an inherently dynamic and adaptive nature, the change of the strategy parameter values during the optimization process is necessary by using: a) a rule; b) feedback mechanism; and c) self-adaptive mechanism (Gen and Cheng 2000) to reach the evolutionary principle. In this study, the second method is used to determine the direction of the change in the strategy parameter. The GA optimization software, Evolver™ (Palisade 1998), is used as it provides a steady state (Cheung *et al.* 2002). An adaptive phase is included in the algorithm and is effective in the presence of a new loan source.

ANALYSIS OF THE RESULTS

The monthly borrowing schedule from different sources of finance was found by applying the borrowing optimization model. Table 4 shows that financing started with sources 7 through 10 and later moved to sources 6 and 3 as work progresses. This means the favourable loan sources were mainly SGS (Sources 6-10) and after they have been used up, the term loan (Source 3) became the choice of the favourable loan. The lending scheme (SGS) is a government policy. With smaller input variables, "sovereign (0.17)", SGS source of finance was first identified as the start of external financing.

Table 4: Monthly borrowing strategy (HK$)

Working month	Source									
	Term loans					SGS				
	1	2	3	4	5	6	7	8	9	10
4	–	–	–	–	–	–	360988	480751	302271	162725
5	–	–	–	–	–	–	741672	650315	371748	466152
6	–	–	–	–	–	–	675094	137740	142307	294325
7	–	–	–	–	–	–	698941	762039	311864	27627
8	–	–	–	–	–	–	341617	547585	316030	691997
9	–	–	–	–	–	–	180354	420327	706093	342440
10	–	–	–	–	–	–	–	–	783816	14734
11	–	–	–	–	–	29163	–	–	65871	–
12	–	–	–	–	–	1800472	–	–	–	–
13	–	–	–	–	–	2177092	–	–	–	–
14	–	–	648922	–	–	1000232	–	–	–	–
15	–	–	1767399	–	–	33072	–	–	–	–
16	–	–	1729649	–	–	70822	–	–	–	–
17	–	–	8281307	–	–	889087	–	–	–	–

Note: – means the absence of external financing

Sources 7 and 8 came from the same financial institution, with identical lending policy and characteristics. Source 7 was associated working capital loan (Type 2 of SGS) to meet additional operational expenses arising from or in relation to the business installations and equipment acquired/to be acquired under the SGS while source 8 (Type 3 of SGS) was accounts receivable loan to meet the working capital needs arising from provision of credit terms to the applicant's customers. Sources 7 and 8 had the lowest interest rate (P-1%) and qualitative factor parameter (0.252) among both the SGS and term loans. The chance of obtaining an unfavourable source of finance was extremely small compared with the other sources. For sources 9 (Type 1 of SGS) and 10 (Type 2 of SGS) which were from the same financial institution, with the highest interest rate (P+3% and P+2.5% respectively) but the second lowest qualitative factor (0.263), the chance of obtaining an unfavourable source of finance was still small comparatively, such that the model was balanced between the two objective functions, and a compromise solution was achieved for the analysis.

The implementation of both type 2 SGSs at the start of financing revealed a large additional operational expenses arising from business installations and required equipment under SGS. For source 6 (Type 1 of SGS), even though the lending term was the same as that of source 8, it was not chosen in the first instance due to its lengthy period of loan terms (5 years). For acquiring new or second-hand business installations and equipment, source 9 (Type 1 of SGS) was enough to meet the requirement at the starting stage. In the working month 10, the previous sources were nearly used up together with the introduction of a new project (project 1). The periodic cash requirement was about 0.8 millions. In order to meet the short-term financing, the remaining SGS loan, source 6, was enough and thus found to be the choice of external financing. In the working month 14, the last project (project 4) started. Due to its highest profit margin (25%), large amount of external financing was needed to propel the schedule upwards. For source 3, even though the qualitative factor was highest (0.846), the largest proportion of loans offered at the early stage and at comparatively low interest rate (P+1.5%) made it the optimized choice. Although overdraft source 1 had the lowest interest rate, its sum of loans was not enough to meet the requirement.

Results of AGA

Since the tax-shield and profit conditions of the firm were different in the study, the overall goal of the three objectives was different so that some were minimization and some were maximization. The GA optimization parameters such as the population size, the crossover rate and mutation rate varied throughout the optimization process. The values used ranged from 250 to 300, 0.5 to 0.8 and 0.1 to 0.25 respectively. The initial operation parameters were set such that population size was 300, crossover rate was 0.5 and mutation rate was 0.15. Table 5 shows the optimization results by the Evolver™ by the AGA. The time to find the near optimal solution ranged from one second to 17 minutes, 29 seconds with three seconds and 28 minutes, 55 seconds total optimization time respectively. In the first working month, no trials of input at the starting point led to large searching time. The searching times in the following working month (5 to 9) were very short (maximum about 1min) after the initial sources of finance have been identified. The algorithm then provided feedback information to the borrowing model. In the working month 10, sources 7 and 8 were used up while sources 9 and 10 were still being used. Operation parameters were changed by the decision-makers with a decrease in the population (250) and increase in both the crossover rate (0.6) and mutation rate (0.25). The time to search the optimal value was nine seconds and occurred in trial number 814.

In the working month 11, identification of a new loan source, source 6, appeared and thus the operation parameters should be modified in the adaptive phase with an increase in both the population (300) and crossover rate (0.8) and a decrease in the mutation rate (0.1). The searching time was 21 seconds. In the working month 12, only one source 6 was still being used. Only one gene was presented. No offspring was produced. The mutation and crossover were set to zero. The searching time was just one second. In the working month 14, a new loan source, source 3, was identified and operation parameters were changed with a decrease in the population (250) and an increase in both the crossover (0.7) and mutation rate (0.2). The searching time was large (9min 34s) as the other category of source of finance (term loans) was also identified. Although Evolve™ divided the number of individual trials, the solutions obtained could be easily trapped in local optimum before reaching the global optimum. In this study, the adaptive phase in the algorithm improved the converging time of the GA. The searching ability of AGA in the borrowing optimization model was thus viable and thus prevented the possibility of trapping in local optimum

Table 5: Optimization results by the AGA (selected working month)

	Run results							
Working month	Goal	No. of trials	Original value	Best value found	Occurred on trial no.	Time to find this value	Termination condition (No change until)	Total time
4	Min	222932	2635292	2605968	136762	0:17:29	252932 trials	0:28:55
10	Max	1000	N/A	1014255	814	0:00:09	6000 trials	0:00:10
11	Min	20615	5380853	5350919	7	0:00:21	22867 trials	0:02:11
12	Min	30	N/A	2726452	19	0:00:01	50 trials	0:00:02
13	Min	60	N/A	5858910	23	0:00:01	80 trials	0:00:03
14	Max	109850	1293402	1669808	78639	0:09:34	112827 trials	0:18:21

CONCLUSIONS

As shown in this paper, the application of GA in modelling financial decision is demonstrated (i.e. optimizing both quantitative and qualitative factors simultaneously) without making the usual simplifying assumptions as required by many conventional techniques. The optimization results showed that the introduction of an adaptive phase in GA increased the converging chance to avoid being easily trapped in local minima before exploiting the global minimum. With the optimal monthly borrowing schedule, the amount of borrowing from external sources could be more realistic, thus reflecting the contractor's financial position. The contractor could manage his cash efficiently and effectively and over or under-borrowings at the corporate level can be avoided. This analysis also provides useful complementary information during loan negotiations. The decision-maker can develop their own strategies for emergencies to eliminate the financial distress suffered by the shareholders. And the possibility of getting an unfavourable source of finance and bankruptcy can be minimized or avoided.

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