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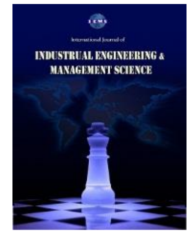

Optimization of project cash flow under uncertainty by Genetic algorithm

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A B S T R A C T

Optimization of project cash flow is an important problem in project management. On the other, the majority of projects will occur under uncertainty which makes it harder to manage projects. Accordingly, this paper are going to solve optimization of project cash flow problem under uncertainty. The main hypothesis in this paper is that inputs and outputs of the project can be evaluated in terms of project cash flow. Therefore, the performance goals of project that are an investment project construction are defined in three levels: time, cost and profit. Furthermore, a mathematical model is defined. In this model, the objective function maximizes the present value of project cash flow. Then, after adding the constraints, the model is solved by Genetic algorithm. Finally, to consider the risks of the project, the scenario-based approach is used by considering several executive positions for each of activities. It is believed that the proposed approach may also be useful for both managing of project cash flow and for project control.

1. Introduction

Planning is n necessary component of project management. Considerable effort and time goes into planning so that acceptable results are delivered in the constraints of time, budget, and other resources [23].

Project scheduling is the temporal coordination of the various tasks of a project too [29]. There are some precedence constraints between activities such as resource constraints for scheduling in all of projects. Resources create based on activities requirements and runtime and the related cash flow in construction. This means the resources represent contractors cost in construction and related cash flow of the project. Indeed, most of the failed contractors are related to finance issues.

Various financial factors such as interest rates, payment terms and credit limits not only affect the cash flow of the project, but affect the time and usage of resources. Therefore, due to the scheduling problem and the profit of cash flow, the aim of the project is to maximize profit by allocating resources and activities and make the forecasting program reliable cash flow to avoid the financial failure. There are different objective functions in all of the project scheduling problems (PSP) that the most common of them is the minimizing of project completion time. The project start time is usually considered at time t=0 and the objective function is the minimizing of the most ending time of project same as Equation (1).

$$\min Cmax = \min(\max(s_j + p_j)) \qquad (1)$$

The variables s_j and p_j are the start time and operating time of j activity.

2. Literature review

In the following, the literature on this paper will be reviewed.

2.1. Project Scheduling Problems

The classic planning of project determines optimality criteria such as minimal length or at least delay. Such criteria tend to maximize the use of equipment during the scheduled horizon implicitly. Whereas management typically tend to minimize costs and maximize the use of equipment and resources.

Other goals of the Project Scheduling Problems are the maximizing of Net Present Value (NPV) and the cash flow of budget constraints and resource leveling. In fact, the project encounters to a negative cash flow. So, cash flow management and objective functions optimization become more important.

The objective of resource leveling problem is the project completes before the deadline expires and use of flatted resources. Indeed, fluctuations in the level of required resources do not occur in each period. Therefore, without level limitation, considered deadline of project not to be more than the amount prescribed.

2.1.1 Variable Neighborhood and Tabu Search

In recent paper, a project scheduling issue proposed where the activities can be performed with several discrete modes and with four different payment patterns. Cash outflows depended on the activities' execution modes, while cash inflows were determined by the payment pattern. Under project deadline constraints, the objective was to minimize the maximal cash flow gap, which was defined as the greatest gap between the accumulative cash inflows and outflows over the course of the project. Optimization models were constructed using the activity-based method [12].

2.1.2 Project scheduling under uncertainty

In a paper, the authors considered a project scheduling problem under uncertainty and proposed a multiagent genetic optimization method based on evolutionary and multiagent modelling by implementing different decision searching strategies, including a simulation module and numerical methods application. The results of this paper has shown all features are effective in the stochastic scheduling problems [29].

2.1.2.1 Ant Colony (AC)

In a paper, the durations and costs of the activities are shown by random variables, the objective function find an optimal schedule so that the expected NPV of cash flows is maximized [5]. Then, an AC algorithm is designed for solving the problem [5]. The algorithm dispatches a group of ants to build baseline schedules iteratively using pheromones and an expected discounted cost (EDC) heuristic. In the end, the computational cost was reduced significantly [5].

2.1.2.2 Project scheduling by considering environmental criteria

In recent paper, authors propose a multi objective mathematical model to address a situation in which several projects are candidate to be invested completely or partially. Three objective functions are considered in this paper. In this objective, they consider the factor of time and its impact on value of money. In addition, they considered the objective, which are related to environmental issues as the final criterion too. [18].

2.2. Robust Optimization

In a paper, authors assumed that the parameters, cash inflows and cash outflows in their case, belong to a symmetric and bounded interval set, and defined a series of decision rules of NPV and IRR by considering robustness [12].

In literature of robust optimization issues, key recent points include [7]:

(i) An extensive body of work on robust decision-making under uncertainty with uncertain distributions, i.e., ‘‘robustifying’’ stochastic optimization.

(ii) A greater connection with decision sciences by linking uncertainty sets to risk theory.

(iii) Further results on nonlinear optimization and sequential decision-making.

(iv) Besides more work on established families of examples such as robust inventory and revenue management, the addition to the robust optimization literature of new application areas, especially energy systems and the public good.

2.3 trade-off problem

In another study, the trade-off problem was considered between the budgets of project and critical risks. The results suggested an integrated risk management plan [25]. Really, risks are natural and inherent characteristics of major projects [24].

Besides, another authors proposed two new metrics for project controlling and monitoring that combine Earned Value Management and Project Risk Management [22].

Another paper, considered a set of project activities for crashing in such a way that the expected project time, cost and risk are minimized and the expected quality is maximized. In this problem, each project activity was considered with a specific executive mode. Each executive mode is characterized with four measures, namely the expected time, cost, quality and risk. In this paper, linear relationships is considered in the state of probabilistic and discrete. Then, the combination of four measures are considered as uncertain for each executive mode [22].

2.4 fuzzy problems

Project cash flow analysis in the presence of uncertainty in activity duration and cost based on fuzzy theory issued too. According to the proposed approach, the project cash flow is represented by an S-surface (as opposed to the traditional S-curve) ensuing by connecting S-curves at different risk possibility levels [20].

2.5. Regular and irregular functions

The objective functions can also be divided into two categories: regular and irregular. The objective function is regular which its amount is not worse with reducing the time of doing an activity without the time of doing other things to increase. And the irregular objective function violates this issue.
These issues can be divided into the following sub-models:

1. Capital Constrained Project Scheduling Problem (CCPSP) [20]
2. Cost -Time Trade-off problem with limited resources [17]
3. Maximum NPV problem with limited resources [29]
4. Scheduling project problem with limited resources and discounted cash flows [17]
5. Project Payment Scheduling Problem (PPSP) [24]

2.6. Heuristic

Heuristic rules and exact solution methods dominate earlier operational research to support construction and engineering decision making.

2.7. Meta Heuristics

Meta Heuristics are general goal high level search that can be considered for each of optimization problem [29].

A recent paper represent interest trending related to Meta Heuristic computing and project control over the last 21 years is represented in Figure 1. [8].

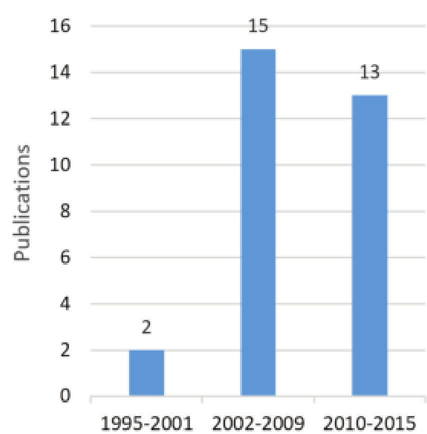

Figure 1: Interest trending related to Meta Heuristic computing and project control over the last 21 years [17].

Generally, there are some types of scheduling problem depending on the application sphere: operations calendar planning [20], [16], [26], [1], [14] assignment of limited resources to a set of tasks [4], [6], [30] and the travelling salesman problem [30]. Classical scheduling problem-solving methods have some disadvantages. Thus, the use of combinatorial methods and mathematical programming is associated with internal difficulties because the model of system processes is nonlinear, non-convex, and non-differentiable [29]. In addition, these methods are used poorly to problems with dynamically changing constraints. The use of genetic optimization allows the shortcomings of the previous methods to be overcome [30].

The application of genetic optimization with defined constraints is widely considered in the literature [20]–[30]. Hence, this paper focuses on the project cash flow problem under conditions of structural uncertainty by using Genetic algorithm. In our paper, we issue a new mathematical model and solve it by genetic algorithm that has been coded in Excel using macros. To consider the risks of the project, the scenario-based approach is used by considering several executive positions for each of activities too.

3. Model

The main hypothesis of this study is that inputs and outputs of the project can be evaluated in terms of project cash flow. Therefore, the performance goals of project that is an investment project construction are defined in three levels: time, cost and profit.

3.1 Project network

In the following, the project is represented on an Activity-on-Node network (Figure 2) where each node shows an activity and each edge between two nodes represents a precedence relationship between the activities associated to such nodes [27].

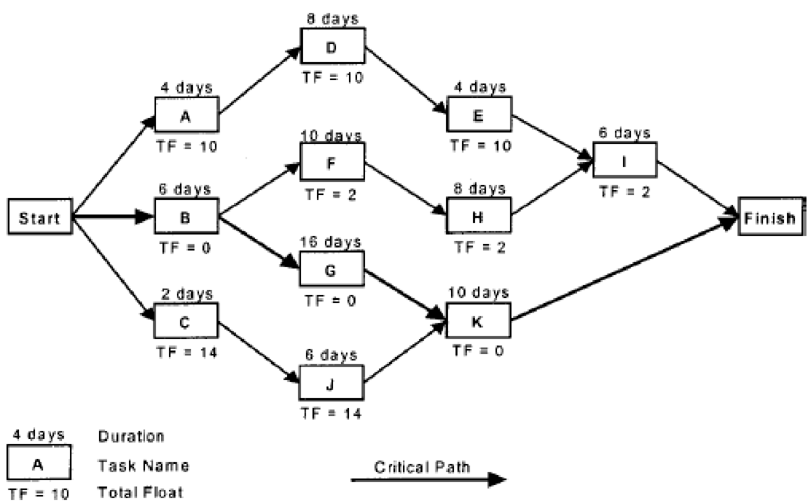

Figure 2: Project activities network

3.2 Mathematical model

Continuing to maximize the profit of the project, mathematical model is as follows:

Maximum f(r, x) = $\sum_{i \in v}(I_i - C_i^s)\exp(-\propto * x_i^s)$ (2)

s.t $x_j^s = x_i^s + d_{ij}^s + r_j \quad , \forall j \in v,\ s \in S$ (2a)

$x_n^s \leq \Delta \quad , \forall s \in S$ (2b)

$r_j \leq 5 \qquad , \forall j \in v \qquad (2c)$

$r_j\ as$ integer, $x_i \geq 0 \qquad (2d)$

3.3 Decision variables

Decision variables are considered as follows:

$$\gamma = (G, S, I, C, d, \Delta, \alpha)$$

And represent from left to right respectively:

- The project is represented on an AON project network as a graph $G = (V, E)$ where the nodes V represent the activities and the edges E represent the logical relationships between them.
- A set of scenarios S= {1, 2, … , m} that represent the different operating states for activities with different time and cost.
- $I_i - C_i^s$ represents the cash flow of i activity that is difference between its revenue and cost in s scenario and occurs in the beginning.
- d_{ij}^s is equal to the size of precedence relations E ∈ (i,j) in s∈S.
- Δ shows project completion time.
- ∝ shows interest rates in each period.

3.4 Objective function and constraints

The objective function maximizes the present value of project cash flow which is obtained by subtracting the revenues of activities and their costs and occurs in the beginning. The variables r and x are called start time of activities and delay in start time of them respectively.

- The first constraint indicates precedence relations between activities.
- The second constraint ensures the ending time of the project does not exceed the expected time.
- Third constraint indicates the maximum allowable for r_j that is delay in the activities start time.
- In addition, final constraint defines decision variables.

3.5 Model Solving

This mathematical model is implemented for a sample project that has come in T.Hegazy (2003) [25].
Activities properties and CPM calculation are shown in Table 1.

Table 1: CPM calculation

Activities properties	Predecessors	Successors	CPM calculation

ID	Name	Activity Duration	Cost x$1,000	P1	P2	P3	S1	S2	S3	ES	EF	LS	LF	TF
1	A	2.5	$2.2				4				2.5	3.5	6.0	3.5
2	B	6.0	$10.0				6	7			6.0		6.0	
3	C	2.0	$4.0				10				2.0	6.0	8.0	6.0
4	D	8.0	$18.0	1			5			4.5	12.5	8.0	16.0	3.5
5	E	4.0	$20.0	4			9			12.5	16.5	16.0	20.0	3.5
6	F	10.0	$15.0	2			8			6.0	16.0	6.0	16.0	
7	G	10.0	$11.6	2			11			6.0	16.0	7.0	17.0	1.0
8	H	2.0	$17.0	6			9			18.0	20.0	18.0	20.0	
9	I	6.0	$10.0	5	8					20.0	26.0	20.0	26.0	
10	J	6.0	$10.0							5.0	11.0	11.0	17.0	6.0
11	K	9.0	$9.0							16.0	25.0	17.0	26.0	1.0

In addition, three different scenarios including the time and cost of each activity are presented in Table 2.

Table 2: 3 scenarios of construction - Normal to Crash (No. 1 is cheapest and No. 3 is most expensive)

ID	Name	Activity Duration	Scenario Variable	Selected Scenario	Cost1 x1000	Time1	Cost2 x1000	Time2	Cost3 x1000	Time3
1	A	2.50	3	3	$2.00	4.00	$2.20	2.50	$2.20	2.50
2	B	6.00	1	1	$10.00	6.00	$12.00	4.00	$16.60	3.00
3	C	2.00	1	1	$4.00	2.00	$4.00	2.00	$5.20	1.00
4	D	8.00	2	2	$18.00	8.00	$18.00	8.00	$22.60	5.00
5	E	4.00	2	2	$20.00	4.00	$20.00	4.00	$26.11	3.00
6	F	10.00	3	3	$15.00	10.00	$15.00	10.00	$15.00	10.00
7	G	10.00	3	3	$12.00	16.00	$12.40	14.00	$11.60	10.00
8	H	2.00	3	3	$16.00	8.00	$16.20	6.00	$17.00	2.00
9	I	6.00	1	1	$10.00	6.00	$14.20	4.00	$14.20	4.00
10	J	6.00	3	3	$10.00	6.00	$10.00	6.00	$10.00	6.00
11	K	9.00	3	3	$8.00	10.00	$8.00	10.00	$9.00	9.00

Each metaheuristic has its own set of tunable parameters. An important issue in using a metaheuristic is selecting a good set of values [12]. For solving this model, Genetic algorithm is used. The answers representation of Genetic algorithm are considered according to Table 3 as follows:

Table 3: Representation of Genetic algorithm answers

Selection procedure Activity					Determination Activity delay				
1	2	3	…	N	N+1	N+2	N+3	…	2N

1	5	3	…	2	2	3	1	…	2

By coding algorithm in Visual Basic macro in Excel, the initial population size and maximum days of project completion time are considered 100 and 28 respectively. In the next step, algorithm is run.

4. Results

Project control is a complex task that involves vagueness in concepts and uncertainty in information, a situation where the use of CI techniques yields good results. The content under discussion provides support to improve decision-making in project-oriented organizations by using Genetic algorithm. Table 4 shows the project information during the run of the algorithm.

Table 4: Project information during the run of Genetic algorithm

ID	Name	Activity Duration	Delay	Scenario Variable	Selected Scenario	Cost1 x1000	Time1	Cost2 x1000	Time2	Cost3 x1000	Time3
1	A	2.50	2	3	3	$2.0	4.0	$2.2	2.5	$2.2	2.5
2	B	6.00	5	1	1	$10.0	6.0	$12.0	4.0	$16.6	3.0
3	C	2.00	5	1	1	$4.0	2.0	$4.0	2.0	$5.2	1.0
4	D	8.00	4	2	2	$18.0	8.0	$18.0	8.0	$22.6	5.0
5	E	4.00	5	2	2	$20.0	4.0	$20.0	4.0	$26.1	3.0
6	F	10.00	4	3	3	$15.0	10.0	$15.0	10.0	$15.0	10.0
7	G	10.00	5	3	3	$12.0	16.0	$12.4	14.0	$11.6	10.0
8	H	2.00	3	3	3	$16.0	8.0	$16.2	6.0	$17.0	2.0
9	I	6.00	3	1	1	$10.0	6.0	$14.2	4.0	$14.2	4.0
10	J	6.00	4	3	3	$10.0	6.0	$10.0	6.0	$10.0	6.0
11	K	9.00	3	3	3	$8.0	10.0	$8.0	10.0	$9.0	9.0
Total Profit						76707.1 &					
Total Cost						146399.9 $					
Project Duration						36.0 day					

As is clear in Table 4, total profit and total cost are equal to $76,707.1 and $146,399.9 respectively and project duration is equal to 36 days.

After the completion of the algorithm, the final result is shown in Table 5.

Table 5: Final results of the run of Genetic algorithm

ID	Name	Activity Duration	Delay	Scenario Variable	Selected Scenario	Cost1 x1000	Time1	Cost2 x1000	Time2	Cost3 x1000	Time3
1	A	2.50		3	3	$2.0	4.0	$2.2	2.5	$2.2	2.5
2	B	6.00		1	1	$10.0	6.0	$12.0	4.0	$16.6	3.0

3	C	2.00		1	1	$4.0	2.0	$4.0	2.0	$5.2	1.0
4	D	8.00	2	2	2	$18.0	8.0	$18.0	8.0	$22.6	5.0
5	E	4.00		2	2	$20.0	4.0	$20.0	4.0	$26.1	3.0
6	F	10.00		3	3	$15.0	10.0	$15.0	10.0	$15.0	10.0
7	G	10.00		3	3	$12.0	16.0	$12.4	14.0	$11.6	10.0
8	H	2.00	2	3	3	$16.0	8.0	$16.2	6.0	$17.0	2.0
9	I	6.00		1	1	$10.0	6.0	$14.2	4.0	$14.2	4.0
10	J	6.00	3	3	3	$10.0	6.0	$10.0	6.0	$10.0	6.0
11	K	9.00		3	3	$8.0	10.0	$8.0	10.0	$9.0	9.0
Total Profit						68384.7 &					
Total Cost						139799.5 $					
Project Duration						26.0 day					

As shown in Table 5, total profit and total cost are equal to $68,384.7 and $139,799.5 respectively and project duration is equal to 26 days. Fortunately, as it clear, all of results are better than primary results. The project cash flow will show in Figure 3 too.

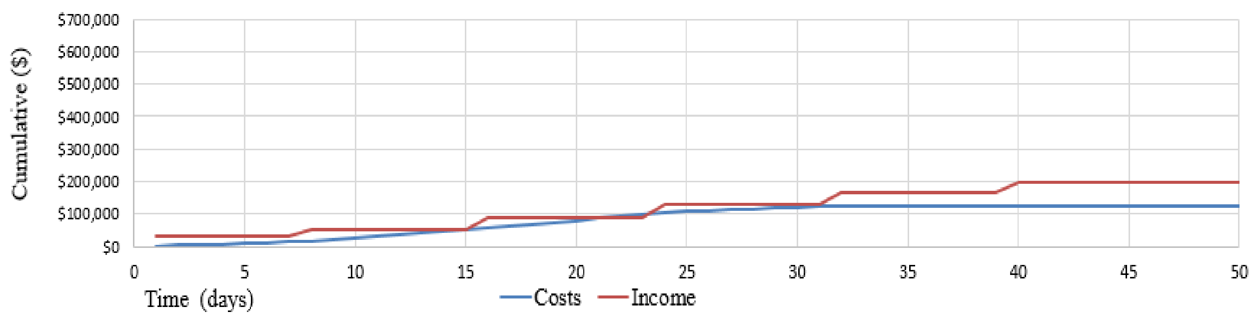

Figure 3: project cash flow

As the chart shows, the amount of income is higher than cost all the days. Therefore, it say that the use of the Genetic algorithm in this project has been quite successful, and the method used in this study has created a relatively remarkable improvement in the project cash flow.

5. Conclusions

The scheduling of the projects under uncertainty is a challenging field of research that has attracted increasing attention. The authors of this paper assumed a mathematical optimization model and solved it by using Genetic algorithm that coded in Excel using macros. Moreover, to consider the risks of the project, the scenario-based approach used by considering several executive positions for each of activities. The proposed approach helped us to optimize total profit. Furthermore, total cost and project duration reduced significantly.

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