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Optimization of Time and Cost of a Construction Project using MS-Excel

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Abstract—*Time-cost trade off analysis is one of the most important aspects of construction project planning and control. Existing methods for time cost trade off analysis uses only heuristic or mathematical approaches which have constraints of small scale CPM network. The approach adopted in this research is a meta-heuristic approach which can solve large scale CPM network. This paper presents a result of a case study of a construction project using Genetic Algorithm. The primary aim is to supply a practical support for typical construction planners in order to optimize the project price and duration.*

1. 2. INTRODUCTION

Time-Cost Optimization "TCO" is unitary of the greatest challenges in building project planning and control, since the optimization of either time or cost, would ordinarily be at the expense of the other. Since there is a hidden trade-off relationship between labor and cost, it might be hard to forecast whether the total cost would increase or fall as an effect of the schedule compression.The primary aim is to supply a practical support for typical construction planners in order to optimize the project price and duration. The diligence of these research developments in planning the typical construction projects holds a firm promise to:

1) Reduce construction duration period;

2) Minimize construction cost (direct cost plus indirect cost); and

3) Also to improve the quality of newly construction projects.

The primary inputs and end products of the proposed software are outlined. The complexity analysis of the software is discussed. In summation, the verification, and complexity of the proposed software proves and tested utilizing a tangible case study.

For large civil construction project, its planning is challenging task to execute the project in a proper way. In civil construction project management scheduling of activity and solution of activity network are supremely important which means arranging project activities in such a way that total duration of project kept minimum. Project duration is defined as the sum of the duration of individual activity situated on the critical path. Critical path is defined as the path having zero or minimum float or slack. In project activity network diagram critical path show that, there is no further possibilities, for the optimization of construction project. Due to the development of innovative and effective construction techniques, materials, equipments, project delivery methods (Pena-Mora and Park 2001), construction time performance has improved over the last few decades (Ng et al. 2000). From the client's standpoint early completion of project helps them to gain their investment sooner. Only shorting the duration is not enough for contractors or clients because the shorter duration increases the direct cost of project which would affect the margins or profit of contractor. That means contractor would get benefit from a saving in indirect costs (Li and Love 1997). Indirect costs are the overhead costs being increased with the overall project duration. Most of the project planner or project managers try to ensure that all construction activities completed within or earlier then the designated contract duration (Adeli and Karim 1997).

The critical path method or related network diagram techniques was the most popular project planning techniques used in practice (Lu and Li 2003). These techniques are based on the assumption that availability of resources is not limited. Use of extra resources to speed up the construction activity would ultimately increase the project cost. Therefore need to optimize both time and cost were noticed. Many researchers had conducted their study on time-cost trade-off (e.g. Liu et al. 1995, Feng et al. 1997, Zhang et al. 2007). Focus of the previous researchers was primarily on the identification of proper methods, materials and crew size for each activity to minimize the total project cost without exceeding the contractual project duration. In the deterministic situation time-cost trade-off (TCT) only deal with a singleobjective i.e. total project cost, this may not provide a greatest benefit to the contractor in the competitive environment.

In order to maximize the profit contracting firms try to minimize both time and cost concurrently. This requirement has led to the development of time-cost optimization (TCO) concept (Ng and Zhang, 2007). The biggest challenge of TCO problem is to find the shortest time and its corresponding cost from the all possible combination of time and cost of activities of network, for project completion (Ng et al. 2000). To solve this problem Zheng et al. (2004) had proposed genetic algorithm (GA) for solving multi-objective TCO problems.

2. TIME AND COST IN CONSTRUCTION PROJECT

Time and cost are two important concerns in a construction contract. Time and cost are basically used for planning of a project. To complete the planning task, it is necessary to estimate the cost and time of each activity through which the whole duration and total cost of the project are determined. In this chapter, the definition of planning for a construction project is given and the main steps for planning are described. The definition of time and cost is provided from the perspective of contractors, the trade off relationship between the time and cost is also described. Two types of problems i.e. time-cost trade-off problem and time-cost optimization problem is present in this chapter.

2.1 Time-Cost trade-off problem

Generally project planners choose the least costly option from available options to complete an activity, during the estimating and scheduling process. This strategy may lead to project duration that is greater than the desired duration. This is known as the Time-Cost Trade-Off analysis (TCT). The steps of TCT can be summarized as follow:

1. Estimate the direct cost and time for activities and indirect cost.
2. Calculate the cost slope for each activity.
3. Select critical activity for crashing and crash the selected activities.
4. Estimate the total project cost.
5. Recalculate the project duration and check the critical path in network.
6. Continue the above steps until it become uneconomical to continue crashing.

The main objective of TCT is to minimize the total project cost without giving a much importance to the time. Therefore, TCT analysis is a single-objective problem.

Many researchers had been used TCT analysis to select the proper construction method, equipments, materials and crew size to complete activities at minimum cost and to keep the project duration within the contractual time duration. For case study: Liu et al. (1995) applied a LP/IP approach to conduct the TCT analysis, Li and Love (1997) improved the GAs to solve the TCT problem, Chua et al. (1997) developed a TCT model considering the resource based on GAs technique, and Hegazy (1999) analyzed the construction time-cost tradeoff problem with GAs.

The disadvantage of TCT is also obvious: only one solution could be obtained in a round of computation. If this solution is impracticable for the real project, then another new round of computation would be needed. This would definitely take time especially in the situation of large scale projects.

3.2 Time-Cost Optimization Problem

In the construction field, time saving can also be transformed into some kind of opportunity such as bonus of early completion or saving in overhead. Therefore, the lowest tender price may not be the only criterion for project success and thus concurrent optimization in both time and cost is highly encouraged and desirable. Zheng et al.(2004) presented a multi-objective approach that aims to optimize the total time and total cost simultaneously. This concept is known as time-cost optimization (TCO). From the relationship between the time and cost in a project which shown in Fig. 1, two objectives – i.e. total cost and duration can be treated as conflicting objectives in a mathematical description of performance criteria, which could assist decision-makers in arriving at an optimal compromise between the time and cost.

3. GENETIC ALGORITHM

In a Genetic Algorithm, a population of candidate solutions or individuals to an optimization problem evolves toward better results. Each candidate solution has a lot of attributes which can be mutated and altered; traditionally, solutions are represented in binary as strings of 0s and 1s, but other encodings are as well possible.

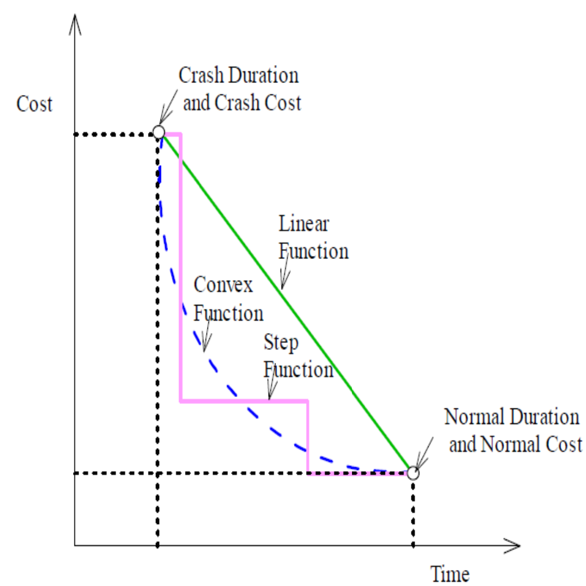

Fig. 1: Time and Cost Trade-Off

The evolution usually starts from a population of randomly generated individuals, and is an iterative process, with the population in each iteration is called a generation. In each generation,the fitness of every mortal in the population is measured; the fitness is usually the value of the objective function in the optimization problem being resolved.The fittest individuals are stochastically selected from the current population, and each individual's genome is modified to form a fresh genesis.The young generation of candidate solutions is then utilized in the next iteration of the algorithm.Normally, the algorithm terminates when either a upper limit number of generations have been produced, or a satisfactory fitness level has been accomplished for the population.

4. CASE STUDY

A project of eighteen activities is taken as a case study which was devised based on the project data taken from Chung-Wei Feng (1996). Table shows available options and corresponding time and cost for each activity. Daily indirect cost of the project is \$1000/day. Bonus for early completion is \$1000/day. Deadline of the project is 115days.

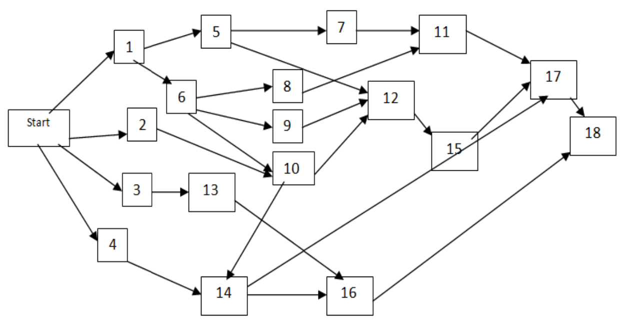

Fig. 2: Network of 18 activities project

Table 1: Details of case

ID(1)	Duration(2) (days)	Cost(3) ($)
1	14	2400
1	15	2150
1	16	1900
1	21	1500
1	24	1200
2	15	3000
2	18	2400
2	20	1800
2	23	1500
2	25	1000
3	15	4500
3	22	4000
3	33	3200
4	12	45000
4	16	35000
4	20	30000
5	22	20000
5	24	17500
5	28	15000
5	30	10000
6	12	40000
6	18	32000
6	24	18000
7	9	30000
7	15	24000
7	18	22000
8	14	220
8	15	215
8	16	200
8	21	208
8	24	120
9	15	300
9	18	240
9	20	180
9	23	150
9	25	100
10	15	450
10	22	400
10	33	320
11	12	450
11	16	350
11	20	300
12	22	2000
12	24	1750
12	28	1500
12	30	1000
13	14	4000
13	18	3200
13	24	1800
14	9	3000
14	15	2400
14	18	2200
15	16	3500
16	20	3000
16	22	2000
16	24	1750
16	28	1500
16	30	1000
17	14	4000
17	18	3200
17	24	1800
18	9	3000
18	15	2400
18	18	2200

Result: This network involves 18 activities with maximum of 5 methods. The number of maximum possible paths of this network is 11. They are as follows:

I. 1-5-7-11-17-18
II. 1-6-8-11-17-18
III. 1-5-12-15-17-18
IV. 1-6-9-12-15-17-18
V. 1-6-10-12-15-17-18
VI. 1-6-10-14-17-18
VII. 2-10-12-15-17-18
VIII. 2-10-14-17-18
IX. 3-13-16-18
X. 4-14-16-18
XI. 4-14-17-18, The critical path calculated for the network is:

Table 2: Minimum Duration for paths

Possible Path	Minimum Duration
1-5-7-11-17-18	80
1-6-8-11-17-18	77
1-5-12-15-17-18	97
1-6-9-12-15-17-18	104
1-6-10-12-15-17-18	104
1-6-10-14-17-18	75
2-10-12-15-17-18	91
2-10-14-17-18	62
3-13-16-18	58
4-14-17-18	44
4-14-16-18	50

Table 3: Maximum Duration for paths

Possible Path	Maximum Duration
1-5-7-11-17-18	134
1-6-8-11-17-18	134
1-5-12-15-17-18	142
1-6-9-12-15-17-18	161
1-6-10-12-15-17-18	169
1-6-10-14-17-18	141
2-10-12-15-17-18	146
2-10-14-17-18	118
3-13-16-18	105
4-14-17-18	86
4-14-16-18	80

Snapshot of 18 activities

The critical path of the network is1-6-10-12-15-17-18 whose minimum duration is 104 and maximum duration is 169. The optimum solution calculated by Ms-Excel using Genetic Algorithm is 112 whose cost is $194500.

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