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Genetic Algorithms Multi-Objective Model for Project Scheduling

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***Abstract*—**Time and cost are the main goals of the construction project management. The first schedule developed may not be a suitable schedule for beginning or completing the project to achieve the target completion time at a minimum total cost. In general, there are trade-offs between time and cost (TCT) to complete the activities of a project. This research presents genetic algorithms (GAs) multi-objective model for project scheduling considering different scenarios such as least cost, least time, and target time.

***Keywords*—**Genetic algorithms, Time-cost trade-off.

I. Introduction

IN implementing most of the projects, project managers face special conditions in which they have to shorten the project duration. In some cases the contractor may have to shorten activities durations to avoid contractually imposed liquidated damages. In other cases, he may want to free resources from the immediate project for future projects or he may want to take the advantage of bonuses that have been offered. The scheduler may want to take advantage of seasonal weather variations that may affect productivity. The owner, on the other hand, may wish to shorten the overall schedule to improve project economics by accelerating the cash flow derived from the project.

The above reasons require the contractor to expedite the overall completion of a project or a portion of a project. The way to reduce the duration of a project is to expedite activities. If activity duration is changed it will cause the cost of performing it to be increased or decreased. In general, there are trade-offs between time and cost to complete the activities of a project. Since there are hundreds or thousands of activities within a project, it is almost impossible to enumerate all possible combination to identify the best decisions for completing a project in the shortest time and at minimum cost [1].

This research proposes a new model which is improved from the recent TCT model. This model is based on GAs considering different scenarios and objectives such as least cost, least time, and target time. A computer program that can execute the algorithm efficiently is developed. The rest of the research is organized as follows. In Section II, the existing time-cost trade-off techniques are reviewed. In Section III, the problem and the model formulation are presented, with three modules included. GAs methodology is developed in section IV. In section V, the validation of the proposed model is tested in a case study. Finally, the conclusion is made in Section VI.

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II. Existing Techniques

The existing techniques for TCT problem can be categorized into two areas: mathematical programming *models* and heuristic methods [2].

A. Mathematical Programming Models

They convert the TCTP to mathematical models and utilize linear programming, integer programming, or dynamic programming to solve them. The main drawbacks of mathematical programming models are complexity of formulation, local minimum solutions and inability to deal with large projects [3].

B. Heuristic Methods

They rely on finding rules that help to solve complex problems, finding ways to retrieve and interpret information on each experience, and then finding the methods that lead to a computational algorithm or general solution. Although the heuristic methods are simple to understand and therefore are easier to implement, an optimal solution cannot be guaranteed.

C. Meta-Heuristic and Evolutionary Algorithms

They have shown relatively higher efficiency in received more attention, especially genetic algorithms. *GAs* are developed to mimic some of the processes observed in natural evolution. They use the concept of Darwin’s theory of evolution to search for solutions for problems in a more “natural” way [4].

Feng et al. [5], Li et al. [6] and Hegazy [7] applied GAs on TCT problem. Although they do not necessarily guarantee the global optimal solutions, their ability to search the solutions space intelligently, rather than completely, makes them capable of producing relatively good solutions to large-sized problems.

Zheng et al. [3] presented a multi-objective model to optimize total time and total cost simultaneously by utilizing genetic algorithms as opposed to others models which considered contract duration was fixed and restricted to identify the minimum total cost only.

In recent works, Ammar [8] considered TCT when discounted cash flow is taken into account and solved this integrated problem heuristically. Aghassi et al. [9] implemented a new multi attribute fitness function in order to solve TCT problem by GA and recently Ghoddousi et al. [10] considered TCT with resource leveling simultaneously in a framework and used non-domination based GA to solve it.

It can be realized that there is a need to a flexible model takes into consideration various activity relationship types, activity time constraints, reducing both project cost and time, and give alternatives for executing project to help planners to select from them such as least cost, least time, and target time.

III. Model Formulation

The time-cost trade off problem is to decide optimum duration of each activity to schedule the activities of a project, so as to minimize the project completion time at minimum project cost. Hence the problem is to find a tool that can help in taking the right decision for the duration of each activity of a project after analyzing all possible alternatives, and finally find the combination of all activities duration that lead to the optimum global solution of the problem.

The project total cost equation and the objectives of the proposed modules used in the model formulation are as follows.

$$Z = \sum_{i=1}^{n}(d_i + x_i c_i) + kT + g\sum_{i=1}^{n} d_i$$

where Z = project total cost, n = number of project activities, d_i = direct cost for activity i, x_i = rate of compression for activity i, c_i = rate of changing cost for decreasing time of activity i, k = indirect cost per time unit, T = project completion time, g = indirect cost percentage.

A. Module 1(Least Cost)

The objective function is to compress the project until reaching the optimum duration which minimizes the total project cost.

Minimize Z

B. Module 2 (Least Time)

The objective function is to minimize the total cost incurred by compressing some activities to shorten the project duration to its least possible time.

Minimize Z while T = min project duration

C. Module 3 (Target Time)

The objective function is to minimize the total cost incurred by compressing some activities to shorten the project duration to the target time.

Minimize Z while T = Target project duration

The constraints are:

- Precedence relationships of the network
- Lag
- Calendar
- Project duration at minimum level or target time
- Available options for Activity execution

IV. GAs Methodology

The first step in GA model is creating a random population of N solutions. Each individual solution is represented by a single array or string called a chromosome. A chromosome typically consists of a number of genes, which may be seen as boxes arranged in a linear fashion, as shown in Fig. 1.

Then, for each chromosome the model will adjust it by random manner to become feasible solution if it is not. As a result of this step the computational time will be reduced.

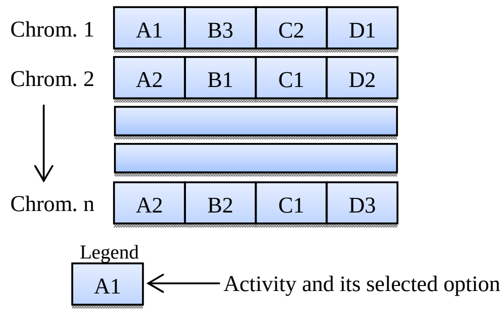

Fig. 1 Population and chromosome structure

The second step is assigning fitness for each feasible solution as follow:

1) Calculate the fitness value for each individual according to the applied module and its objective function in the population using the equation:

$$\text{Fitness} = \text{individual position}$$

2) Calculate the total fitness (F) of the population

$$F = \sum_{j=1}^{Pop.no} F_j$$

3) Calculate the probability of selection for each individual P_j

$$P_j = \frac{F_j}{F}$$

4) Calculate the cumulative probability for each individual PC_j

$$PC_j = \sum_{j=1}^{j} P_j$$

The next step is recombination (Fig. 2). According to the evolution theory, individuals with characteristics which increase their probability of survival will have more opportunities to reproduce and their offspring will also benefit from the heritable survive. So, the assumption here is to produce many offsprings and then to compare between them to choose the best ones. As a result of this step the computation time for searching for the optimum solution will be reduced.

Select a pair of chromosomes for crossover operation, if the random number generated is less than the probability of crossover. For the mutation, if the random number generated is less than the probability of mutation. The offsprings will undergo adjustments to be feasible solutions. Then the best two offsprings will be chosen to compare them with the worst two individuals in the population to replace them if they are better.

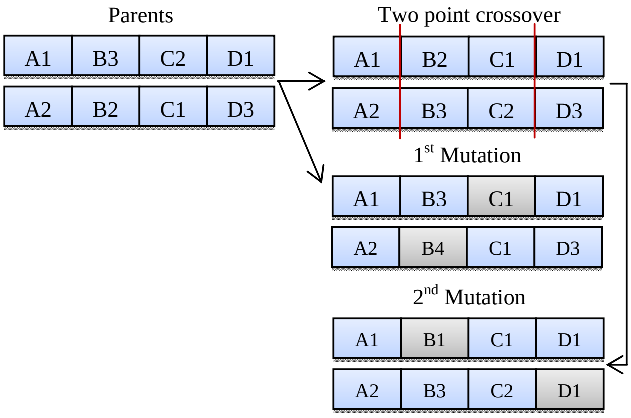

Fig. 2 Crossover and mutation

The population undergoes evaluation, selection, re-combination, and reinsertion (replacement) until the number of generations is met. Once the number of generations specified is reached, the GA determines the better solution in the current population.

Next, the model compresses critical activities of the better solution in the current population, which results in decreasing the project duration while keeping its total cost as minimum as before or compresses those which yield in decreasing the project duration and in the same time reduces project total cost.

Finally, relaxation is applied to select higher duration than the selected ones for all non-critical activities without affecting the total project time and in the same time reducing the total cost of the project. Consequently, the final solution has a valid project completion time and has the lowest project cost.

The developed GAs Model has been coded in Visual basic on a personal computer. The program has flexibility to integrate with project management software, Microsoft Project and also with Navisworks in order to export the resulted optimum schedule to its timeliner to continue developing 4D scheduling. The program interfaces are shown through the next section.

V. Case Study

For validation of the proposed model, a case study which was introduced in [5], [7] and [11] is analyzed. Both of them didn't give scenarios for executing the project such as least cost, least time. Data of the problem is given in Table I. The daily indirect cost was taken as $200.

By setting all activities' durations at their normal, the total project cost was $133540 with project duration equals to 169 days. The results of various modules are shown in Table II.

TABLE I
Input Data for Case Study

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

Table II shows the time and cost savings resulted from applied the program on the project on-hand. As shown in the table, the least total cost equals to $128050. This represents a cost saving of 4% and a time saving of 31%. The least time equals to 100 days with a corresponding total cost of $153320. This represents a time saving of 41%.

TABLE II
THE RESULTS

Module	Project Completion Time	Project Total Cost	Time Saving %	Cost Saving %
Module 1 (Least Cost)	116	128 050	31	4
Module 2 (Least Time)	100	153 320	41	-15
Module 3 (Target Time)	150	130 780	11	2
	130	128 570	23	4
	120	128 220	29	4
	105	141 150	38	-5

VI. CONCLUSION

This paper has proposed an optimization model based on the GAs with some modifications to reduce the computational time and also to guarantee achieving the optimum decision. GAs is used to search for the optimal schedules regarding project time, project cost, and activity time constraints. The model searches for the best combination of available options for activities within project to reach to either least cost, least time, or target time for executing the project. To circumvent the expected complexities in modeling, model is developed to be transparent and easily usable by practitioners.

The model is very helpful for decision makers because it gives them many alternatives to solve the TCTP. The model guarantees the reasonable optimal solution by searching each option for each activity and its effect on the project duration and its total cost. The development program is easier to understand by any user even those who are not familiar with management software.

For the future research, this model could be extended to integrate with Building Information Modeling (BIM) to use it as a base for creating the schedule.

REFERENCES

[1] Liu, L., Burns, S., and Feng, C., "Construction Time-Cost Trade-Off Analysis Using LP/IP Hybrid Method," Journal of Construction Engineering and Management, ASCE, 121(4), 446-454, 1995.

[2] Maghrebi, M., Afshar, A., and Maghrebi, M. J., "A Novel Mathematical Model for Deterministic Time-cost Trade-off Based on Path Constraint," International Journal of Construction Engineering and Management 2(5): 137-142, 2013.

[3] Zheng, D., Ng, S. T., and Kumaraswamy, M., "Applying a Genetic Algorithm-Based Multiobjective Approach for Time-Cost Optimization," Journal of Construction Engineering and Management, ASCE, 130(2), 168-176, 2004.

[4] Forrest, S., "Genetic Algorithms: Principles of Natural Selection Applied to Computation", Science 261, 1993.

[5] Feng, C., Liu, L., and Burns, S., "Using genetic algorithms to solve construction time–cost trade-off problems," ASCE Journal of Computing in Civil Engineering, 11(3), 184–189, 1997.

[6] Li, H., Cao, J.-N., and Love, P., "Using Machine Learning and GA to Solve Time-Cost Trade-Off Problems," Journal of Construction Engineering and Management, ASCE, 125(5), 347-353, 1999.

[7] Hegazy, T., "Optimization of construction time–cost trade-off analysis using genetic algorithms," Canadian Journal of Civil Engineer Vol. 26, 685–697, 1999.

[8] Ammar, M. A., "Optimization of project time-cost trade-off problem with discounted cash flows," Journal of Construction Engineering and Management, 137(1), 65-71, 2010.

[9] Aghassi, H., et al., "a multi-objective Genetic Algorithm for optimization time-cost trade-off scheduling," Knowledge Technology, Springer, 356-359, 2012.

[10] Ghoddousi, P., et al., "Multi-mode resource-constrained discrete time–cost-resource optimization in project scheduling using non-dominated sorting genetic algorithm," Automation in Construction, 216–227, 2013.

[11] Bettemir, Ö.H., "Experimental Design for Genetic Algorithm Simulated Annealing For Time Cost Trade-Off Problems," International Journal of Engineering & Applied Sciences (IJEAS) Vol.3, Issue 1, 15-26, 2011.