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Developing a Hybrid Optimization Scheduling Model in Construction Projects Using Comparative Analysis of Existing Meta-heuristic Algorithms

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ABSTRACT: Time-cost trade-off analysis is one of the most challenging tasks of construction project planners. Project planners face complicated multivariate, Time-Cost Optimization (TCO) problems, which require simultaneous minimization of total project duration and total project cost, while considering issues related to the optimal present value of profit. Also, the complexity of construction projects in recent years has risen the importance of clever management in cases of project financing and scheduling. There are choices and limits that make it difficult to project planners to develop a proper financing plan considering project time status. Therefore, the methods of financing affect the project plan. Therefore, a skilled planner should consider various effective parameters for scheduling projects. This study presents a hybrid meta-heuristic algorithm to solve a multi-objective optimization problem in construction project planning and finance. Because of the ability to get out of local optimization points, meta-algorithms can provide satisfactory results in complex problems in a short time. First, the model is compared with common meta-heuristic algorithms in a simple case study. Then it is applied to a complex case study and it shows the optimal solutions which have time, cost and the net present value of profit. It is shown that the proposed model is superior to the existing optimization algorithms to find better project planning solutions with less total project duration, less total project cost, and optimal profit in the construction project problems. The cumulative results are shown in a three-dimensional Pareto front. Also, the proposed model improves the solutions through generations and provide optimal solutions in acceptable processing time.

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1. INTRODUCTION

Increasing wide-spreading and complexity of new-fashioned construction projects needs intense management. The necessity of reducing both the cost and duration of project execution is one of the most important aspects of contractors.

The method of financing may give the contractors ensures that at any period of the project, their liability will not exceed the limits of credibility [1]. For optimizing objectives such as profit, time and cost decision-makers need to analyze and select the best executive method for each activity. Many project planners monitor project parameters during the construction period and use optimization solutions to reschedule the project to obtain maximum profit. In some real projects, these methods are applied and the results are significantly suitable, but these methods suffer a large amount of processing time to reach optimum answers. Thus, fast and advanced methods of solutions are needed to be applied to these difficult problems.

Over the past 25 years, many types of research have been done in the field of optimization. These researches include a variety of problems such as time-cost tradeoff [2], resource leveling [3], resource allocation [4], or a combination of the mentioned problems [5].

The hybrid and improved meta-heuristic algorithms are used to increase the convergence rate and quality of the solutions. Tsai et al. (2006) used 2-dimensional crossover and mutation to solve the scheduling problem [6].

The time-cost tradeoff (TCTO) problem is one of the first issues raised in the optimization problems. In addition to time and cost variables, cash flow is one of the challenging variables in the literature because of its distinctive feature. Elazouni and Gab-Allah [7] originated the finance-based scheduling to solve the cash flow problems.

Although there are significant improvements in each mentioned categories of optimization problems and its solutions, there are rarely studies which combine stated categories to actualize the problems and its solutions. This matter can be a suitable background for concurrent using of optimization objectives (time, cost, and the net present value of profit) in a complex project and with hiring an improved hybrid algorithm to reduce computing time and increase the quality of solutions.

The objective of this paper is to present an improved hybrid algorithm model for solving a compound multi-

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objective time-cost-profit construction problem. The model can calculate cash flow parameters and the net present value of the final profit of the project in a reasonable time.

2. RESEARCH METHODOLOGY

Activity Relationships of the proposed model is acquired from the Liu and Wang model [8]. It supposes that only Finish-to-Finish relation connects the activities. The total cost for a project equals the sum of direct costs, indirect costs, mobilization cost, and bond premium cost.

The cash flow model is inspired by the cash flow model of Elazouni and Metwally [9], and it contains a variety of cash outflows and inflows. It is assumed that the contract is unit price. So, the progress payments are through calculating the worth of work items based on the unit prices. These unit prices comprise the direct cost plus a proper part of the project overhead, tax, profit, and bond. Also, a markup multiplier is used to add the proper part to the periodical expenditures.

The positive outcome of all the inflows and outflows represents the profit. But it has to be considered that the inflows and outflows occur not at the same time but in different sections of the project period. The profit estimation of the project is calculated in Equation 1.

$$P = \sum_i (InFlow_i \times \frac{1}{(1+r)^{t_i}}) + \sum_j (OutFlow_j \times \frac{1}{(1+r)^{t_j}}) \quad (1)$$

3. IMPROVED HYBRID MULTI-OBJECTIVE ALGORITHM

The authors used the concept of shuffled frog leaping algorithm as a base for the hybrid algorithm because of its reasonable computing time. Also, GA was selected as the second algorithm. However, some changes need to be applied to GA operators to improve their efficiency. The process of implementation is categorized into three main phases (Initialization, Fitness Evaluation, and Generation Improvement).

4. RESULTS AND DISCUSSION

In this paper, the hybrid algorithm is applied to a common time-cost benchmark problem and its results are compared with the other five mentioned algorithms (Test 1 & Test 2). A large single-objective problem is then used to determine the performance of the hybrid model and its accuracy in solving two problems (Test 3 & Test 4). In the end, a novel complex three-objective optimization problem is utilized and the Pareto-front chart is presented (Test 5).

Test 1: An 18-activity problem which Elbeltagi et al. [10] used and presented a comparison table among five evolutionary algorithms is used to evaluate the hybrid algorithm. The five algorithms in this paper showed better performance than Elbeltagi's algorithms. Also, the improved hybrid algorithm result was better than the five algorithms.

Test 2: The objective of this Part is to plot a Pareto of optimal solutions which have both minimum duration and cost of the project. According to the results, the hybrid algorithm obtains better non-dominated solutions which show less total cost than the other algorithms. This shows the hybrid algorithm is superior in obtaining optimum solutions.

Test 3: In this Part, the hypothetical project with 63 activities is as a larger single-objective problem. The objective of this scenario is to minimize the total cost of the project. Compared to HA of Sonmez and Bettemir [11], the hybrid algorithm results were more successful.

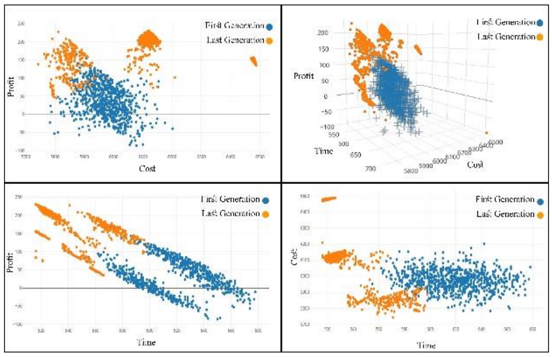

Fig. 1. Test five results

Test 4: This test is a single-objective problem to reach the maximum net present value of project profit. The model was able to reduce the search space after generations significantly. This led to reaching optimum and near-optimum solutions in a reasonable processing time. The average deviation (%) from the optimal solution for both of two activity network projects is less than 5%, which illustrates that the hybrid algorithm provides near-optimum solutions with acceptable accuracy.

Test 5: The final purpose of this paper is to present a 3D Pareto front containing three axes (time, cost, NPV of profit). Figure 1 indicates that the final generation improved significantly compared with the initial population as the duration and cost decrease over generations while the final profit of the project increases.

5. CONCLUSION

This paper presented a hybrid meta-heuristic algorithm that considers SFL as a primary algorithm and uses an improved GA as a subsidiary one. The model allows planners to make and evaluate optimal construction cash resource utilization and scheduling plans. The proposed model identifies an appropriate scheduling plan with its related cash flow to satisfy contractor financial needs. It provides project managers with an optimal plan to advance the projects as best as possible. However, more complexity of the problem such as considering negative cash flow limitation in projects and the influence of financing projects through bank credits on the final profit of the project, can be included in further studies.

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