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Stochastic time–cost optimization using non-dominated archiving ant colony approach

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ABSTRACT

This article employs a non-dominated archiving ant colony approach to solve the stochastic time–cost trade-off optimization problem. The model searches for non-dominated solutions considering total duration and total cost of the project as two objectives. In order to expect more realistic outcomes for the time–cost trade-off problem, uncertainties in time and cost of the project should be taken into account. Fuzzy sets theory is used to answer for uncertainties in time and cost of the project. The model embeds the α-cut approach to account for accepted risk level of the project manager. Left and right dominance ranking method is used for finding non-dominated solutions. The ranking method employs decision maker's optimism using β concept. The performance of the model is tested according to performance metrics for multi-objective evolutionary algorithms proposed in the literature. The results show that the algorithm is adequately reliable. A case study is solved to show the application of the proposed model for the uncertain time–cost trade-off problem.

1. Introduction

Owing to technological improvements and diversity of machineries and methods, different implementation modes can be assigned to each activity in a construction project. In other words, an activity can be done not only with different quantities of the same resource but also with various types of resources. As a case in point, procedures to be followed in underpinning an adjacent structure, what method of scaffolding to use, how to dewater the site, all need the planner's attention [1]. One may conclude that each mode of construction will yield a particular time and duration for the activity, and project duration and cost depend directly on the choice of activity's mode of implementation. Time–cost trade-off problem (TCTP) is a combinatorial problem which involves finding implementation modes for activities such that the optimal balances between project time and cost are found [2].

Early attempts to solve TCTP were mathematical and heuristic-based approaches [3]. Despite their ability to produce optimal and near optimal results for TCTP with linear time–cost relationship [3], such solutions showed a main weakness in solving discrete TCTP. De et al. [4] assert that: *"It has recently been shown that any exact solution algorithm for discrete time–cost trade-off problem would very likely exhibit an exponential worst case complexity"*. This might be a product of the combinatorial nature of the discrete TCTP. That is, the solution space of TCTP increases exponentially with the increment in either the number of activities or the number of potential implementation modes.

Meta-heuristic approaches, on the other hand, have shown relatively higher efficiency in this domain. Although such solutions 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. Feng et al. [3], Li and Love [5] and Hegazy [6] adopted genetic algorithms (GAs) for Time–cost optimization problem. In 2008, Xiong and Kuang [7] proposed application of Ant Colony Optimization (ACO) for solving TCTP. In their technical note, they used modified adaptive weight approach (MAWA) introduced by Zheng et al. [8] to address the concurrent optimization of time and cost of the project. They also showed that the ACO results in better solutions compared to GAs. Ng and Zhang [9] also adopted ACO to solve TCTP. Similarly, a MAWA was used in order to integrate optimization of time and cost of the project into a weighted objective function, and their model showed higher efficiency over its GA counterpart. Recently, Afshar et al. [10] proposed an ant colony optimization (ACO) algorithm to solve TCTP. Their model showed efficiency in producing optimal results compared to some other well-developed algorithms [10].

A basic assumption for the TCTP was the certainty of activity-associated durations and costs although in the reality different factors make this assumption unreliable. To tackle uncertainties, different approaches are adopted so far. Feng et al. [11] proposed a probability density function in order to model uncertainties. Proposing fuzzy approach for stochastic TCTP, Eshtehardian et al. [2] argued that due

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