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ScienceDirect

Procedia Engineering 153 (2016) 595 – 598

Procedia Engineering

www.elsevier.com/locate/procedia

XXV Polish – Russian – Slovak Seminar "Theoretical Foundation of Civil Engineering"

Construction projects' indicators improvement using selected metaheuristic algorithms

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Abstract

In this paper authors present methods currently used in construction for scheduling and tasks sequencing. Authors present sample construction problem. Basing on the example, authors compare selected metaheuristic algorithms (genetic algorithm and tabu search) in terms of construction projects' indicators improvement. The outcomes are analyzed and discussed. The conclusions of the paper might also be used as a guidelines for implementation of presented methods in construction companies.

Peer-review under responsibility of the organizing committee of the XXV Polish – Russian – Slovak Seminar "Theoretical Foundation of Civil Engineering".

Keywords: genetic algorithm; tabu search; construction; optimization; scheduling; sequencing, Monte Carlo simulation

1. Introduction

Construction project (just like any other project) is a unique undertaking or endeavor to be accomplished that can be divided into individual subtasks or activities each of which requires time and scarce resources for its completion. The scheduling in its basic form is a process of finding such start dates of tasks that pre-set resource and precedence constraints are satisfied and at the same time an objective function is optimized (i.e. duration minimization, NPV maximization) [14]. Although the general guidelines for scheduling are similar for different disciplines, one always

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Peer-review under responsibility of the organizing committee of the XXV Polish – Russian – Slovak Seminar "Theoretical Foundation of Civil Engineering".
doi:10.1016/j.proeng.2016.08.198

has to carefully consider specific parameters of the analyzed problem. It is especially important while dealing with construction projects, which are characterized by uniqueness of technology, location, size, availability of resources, etc. [7], [9], [15].

2. Literature study

Schedule optimization methods can be classified into three methods: *mathematical*, *heuristic* and *metaheuristic* [16], [17]. Among the mathematical methods are e.g. linear programming (LP), dynamic programming (DP) (these methods can be useful for finding the global optimum, however, suffer from some drawbacks – discrete decision variables and the exponential increase in the number of solutions as the number of decision variables increases), Branch and Bound method (effective method, however, requiring high skill of expertise and proper restrictions setup).

The heuristic methods include priority rule-based heuristics [8]. These methods are fairly easy to use, however their use might be slightly problematic when it comes to more complicated schedules. The use of heuristic methods does not guarantee finding the optimal solution of the given problem.

The tasks sequencing problem in construction is far more complicated than in other disciplines (i.e. production processes). It is caused by the uniqueness of each construction project (in terms of technology, location, size, availability of resources, etc.) [7], [9], [15]. Various authors are trying to implement different models which will resemble (to some extent) realistic constraints and complicated characteristics of the problems (different objective functions, criteria, financing models, hybrid algorithms, nondeterministic data, etc.) [2], [11], [6], [10], [12]. Practical problems in construction can be easily qualified as NP-hard (non-deterministic polynomial-time hard) problems. The time needed for solving these problems grows exponentially with the increase the problem's size [5]. That is why mathematical and heuristic methods do not allow for finding solutions of complicated construction problems in acceptable time [7]. For the same reasons metaheuristic algorithms seem to be the most appropriate measures for scheduling and task sequencing [13].

Widely analyzed metaheuristic methods include: *Particle Swarm Optimization* (PSO), *Ant Colony Optimization* (ACO), *Genetic Algorithms* (GA), *Simulated Annealing* (SA), *Tabu Search* (TS). These algorithms do not guarantee finding the optimal solution of the given problem and their results are subject to input parameters. However they are very useful when it comes to solving NP-hard problems, because they allow for finding suboptimal solutions in acceptable time.

3. Practical application

3.1. General assumptions

Authors decided to verify (with the use of commonly available software) possibility of using GA and TS algorithms by a contractor. To achieve that goal, a model of construction project was created, with both deterministic and stochastic parameters. Also, main optimization criterion was selected: reducing (minimizing) maximum monthly cash flow (CFmax). This criterion is rather rarely used in the literature due to the fact it is hard to predict, nevertheless it is a very important factor for a construction contractor. Constraints used in this example are:

- WB (work breaks)– workers teams should not be stopped for less than 1 working week (constraint important due to an option of moving workers between construction sites operated by the contractor. Shorter periods of work on one site could influence efficiency due to adaptation time of workers to a new workplace.)
- ME (maximum employment) - important constraint due to production capacity of contractor.
- System of contractual penalties related to delays of works (constraint takes under consideration requirement of schedule continuum –SC, and penalties related to due-to-time overrun of the investment – TO) [1]

Calculations were performed using Microsoft Excel software (as it is a common tool used in construction companies). Two algorithms were compared: genetic algorithm (GA) – calculated by Pikaia.f (ver. 1.2) [3] (open