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ORIGINAL ARTICLE

Smart optimization for mega construction projects using artificial intelligence

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Abstract During practicing the planning process, scheduling and controlling mega construction projects, there are varieties of procedures and methods that should be taken into consideration during project life cycle. Accordingly, it is important to consider the different modes that may be selected for an activity in the scheduling, for controlling mega construction projects. Critical Path Method "CPM" is useful for scheduling, controlling and improving mega construction projects; hence this paper presents the development of a model which incorporates the basic concepts of Critical Path Method "CPM" with a multi-objective Genetic Algorithm "GA" simultaneously. The main objective of this model is to suggest a practical support for compound horizontally and vertically mega construction planners who need to optimize resource utilization in order to minimize project duration and its cost with maximizing its quality simultaneously. Proposed software is named Smart Critical Path Method System, "**SCPMS**" which uses features of Critical Path Method "CPM" and multi-objective Genetic Algorithms "GAs". The main inputs and outputs of the proposed software are demonstrated and outlined; also the main subroutines and the inference wizards are detailed. The application of this research is focused on planning and scheduling mega construction projects that hold a good promise to: (1) Increase resource use efficiency; (2) Reduce construction total time; (3) Minimize construction total cost; and (4) Measure and improve construction total quality. In addition, the verification and validation of the proposed software are tested using a real case study.

1. Introduction

Techniques that are used for project scheduling will vary depending on project's duration, size, complexity, personnel, and owner requirements. Ashley [1] divided the construction projects into two main groups. The first one is the projects with non-repetitive activities. The second group has multiple numbers of stages. Projects with non-repetitive activities are divided into two main groups. The first one is the bar chart

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that is one of the oldest methods used in construction planning and developed by Henry L. Gantt during the World War I; the second one is network-based methods which are two widely known network based techniques, namely, the Critical Path Method "CPM" and the program evaluation and review technique "PERT". Both methods were developed simultaneously and independently during the late 1950s. Selinger [2] divided the construction projects with repetitive activities into two categories: linear and non-linear projects. Linear projects are composed of number of typical stages with identical activities of the same duration that are repeated consecutively from one unit to the next. Several techniques were developed for projects with discrete units, such as floors, houses, and offices. The names used have included the following: (1) Line Of Balance, "LOB" according to O'Brien [3]; (2) construction planning techniques according to Peer [4]; (3) Vertical Production Method, "VPM" according to O'Brien [5]; (4) time space scheduling method according to Stradal and Cacha [6]; and (5) time-location matrix model according to Carr [7]. Several techniques were proposed for projects with continuous units as highways, pipelines, tunnels, bridges, etc. The progress is measured in terms of horizontal length. The names used have included the following: (1) Velocity Diagrams, "VD" according to Harris and McCaffer [8]; and (2) Linear Scheduling Method, "LSM" according to Chrzanowski and Johnston [9]. Line-Of-Balance "LOB" is one production scheduling and control technique, which tries to surpass the CPM difficulties for the mega construction scheduling. It is developed into manufacturing environment by the US Navy, originated at the time of World War II, according to Burke [10]. Activities that repeat from unit to unit create a very important need for a construction schedule that facilitates the uninterrupted flow of resources from one unit to the next. It establishes activity-stating times and determines the overall project duration. Hence, uninterrupted resource utilization becomes an extremely important issue, according to Hafez [11]. Hafez [12] developed a tool for time and resource scheduling for mega construction projects; this has been done in three stages. This model called modified repetitive project model "MRPM" depends on the integration between the principles of "LOB" method and Critical Path Method. Hafez [13] surveyed the different issues, which related to schedule repetitive construction process. It can be used in the development of a computerized scheduling system. The time-cost tradeoff "TCTO" problem has been studied since the 1960s and is considered as a particularly difficult combinatorial problem. All methods in time-cost tradeoff branch can be classified into the following categories: linear, integer, or dynamic programing, other methods approximate, heuristic or decomposition approaches, and lately algorithms to reduce the computational effort. Ahuja et al. [14] mentioned the relationships between time and cost as shown in the following steps: (1) Linear Relationship; (2) Multi-linear Relationship; (3) Discrete Function; and (4) Curvilinear Continuous Relationship. Hafez et al. [15] proposed a mathematical model for time-cost tradeoff based on the integration between the principles of LOB and CPM. The output of this model is to determine the crashed duration for each activity which is corresponding to minimum project total cost. Genetic Algorithms "GAs" are inspired by Darwin's theory about evolution. The GA is a global search procedure that searches from one population of solutions to another, focusing on the area of the best solution. It was modeled with a set of solutions (represented by chromosomes) called initial population, computation is performed through the creation of an initial population of individuals and modifying the characteristics of a population of solutions (individuals) over a large number of generations followed by the evaluation, a satisfactory solution is found. This process is designed to produce successive populations, i.e., the solutions from one population are taken and used to form a new population. This is motivated by a hope, that the new population will be better than the old one and so on through generations. A typical implementation of genetic algorithm is shown in Fig. 1. Basic outline of genetic algorithms as follows: (1) **[Start]** generate random population of n chromosomes (suitable solutions for the problem); (2) **[Fitness]** evaluate the fitness $f(x)$ of each chromosome x in the population; (3) **[New population]** create a new population by repeating following steps until the new population is complete; (4) **[Selection]** select two parent chromosomes from a population according to their fitness (the better fitness, the bigger chance to be selected). The idea is to choose the better parents. Examples of well-known selection approaches are the following: (a) roulette wheel selection; (b) rank selection; (c) tournament selection; and (d) elitism; (5) **[Crossover]** allows promising solutions to share their success by swapping the arrangement of parents' chromosomes genes to new offspring (children) with a crossover probability. If no crossover was performed, offspring is an exact copy of parents; (6) **[Mutation]** allows random changes in the local search space of a given solution, mutate new offspring at each locus (position in chromosome) with a mutation probability; (7) **[Accepting]** place new offspring in a new population; (8) **[Replace]** use new generated population for further run of algorithm; (9) **[Test]** if the end condition is satisfied, stop, and return the best solution in current population; and (10) **[Loop]** go to step no. 2. Goldberg [16].

Crossover between parent chromosomes is a common natural process and traditionally is given a rate that ranges from 0.1 to 1.0. In crossover, the exchange of parents' information produces an offspring, as shown in Table 1. As opposed to crossover, mutation is a rare process that resembles a sudden change to an offspring. This can be done by randomly selecting

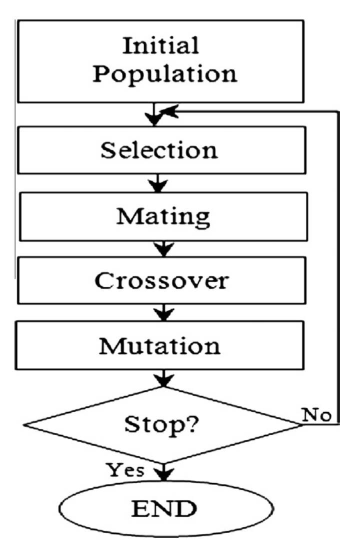

Figure 1 A typical implementation of genetic algorithm.