A New Decision Support System for Optimal Integrated Project Scheduling and Resource Planning

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ABSTRACT

Two scheduling practices are commonly used depending on the availability of resources. When resources are not expensive, activities are scheduled and then resources are allocated until the available resources are exhausted. Then, iterative adjustments are applied to the resource allocation plan and the activities sequence to reach a feasible solution. Conversely, when expensive resources are involved, a resource allocation plan based on the economics of the resource is established and then activities are scheduled accordingly. However, Resource Constrained Scheduling Problems (RCSP) are not solved efficiently with either of these approaches. To find the optimal solution, activity scheduling and resource allocation should be formulated as an integrated optimization problem. Such models become numerically cumbersome for practical size problems and difficult to solve. In this article, a novel mathematical formulation and an efficient solution algorithm are proposed for solving RCSPs. Then, this framework is used for solving a practical problem in the context of the construction industry.

KEYWORDS


INTRODUCTION AND PROBLEM STATEMENT

The scheduling and resource allocation problem targeted in this paper is a specific type of Resource Constrained Scheduling Problem (RCSP) that is often encountered in the construction industry where portfolio of large projects is involved. Therefore, despite the general nature of the targeted RCSP, authors chose to use the context of the construction industry for demonstration purposes. The project portfolios of large construction companies encompass many activities, and each of these activities may be split into several stages. Additionally, for each stage, various resource types may be required in a specific sequence and over a specific time window. Bottlenecks can be caused by availability of heavy equipment since it is one of the most expensive resource types with the highest demand. Although such companies typically own a fleet of heavy equipment, their owned fleet capacity cannot meet the
simultaneous demands of all projects. The conventional approach for dealing with this problem is to implement empirical resource allocation strategies which typically provide suboptimal solutions. For instance, one common practice in the construction industry is to implement an empirically developed rotation plan for pieces of heavy equipment in high demand. This approach is also supplemented with the option of renting equipment locally if owned pieces of equipment are either unavailable or it is not economical to transport them. The problem can be solved using conventional approaches when it is in static setting and a small network of projects is involved. However, when a large network of projects along with highly dynamic circumstances are involved (i.e. changes in schedule and demand due to delays or weather related issues), the problem becomes extremely complex and impossible to solve using conventional approaches.

In this paper, a new integrated mathematical model supplemented with a heuristic method is introduced for efficiently optimizing the above-described problem. This model can solve practical size problems in dynamic settings. The objective of the proposed model is to maximize financial gains of the portfolio while considering a wide range of parameters, variables and practical constraints.

BACKGROUND AND LITERATURE REVIEW

The mathematical framework introduced in this study is relatively generic and modifiable for solving various Resource Constrained Project Scheduling Problems (RCPSP). In this paper, the model has been utilized to solve the specific problem of optimal integration of project activity scheduling and construction equipment planning. Because of this and due to the specific structure of each optimization problem, authors have focused the literature review on studies which specifically target the relevant RCPSPs.

Among conventional optimization approaches, Integer Programming (IP) has been commonly used to model the resource loaded scheduling problem. Lee and Gatton (1994) presented a complete IP formulation that combined construction activity scheduling with the resource utilization plan. However, because of the application of prioritization rules in the resource allocation process, their proposed solution was suboptimal. Younis and Saad (1996) proposed a model for optimal resource allocation and leveling in multi-resource type projects. In their study, a solution algorithm was proposed based on principles of explicit enumeration. The model performs Critical Path Method (CPM) calculations, finds all feasible matches between activity schedules and given resource availability plan by enumeration, and finally finds the cost optimal solution by comparing costs of all feasible solutions. Since the model is based on explicit enumeration, its efficiency drops significantly as the size of the problems grows. In the same line of research, branch and bound solution approaches by Herroelen and De Reyck (1998) and Dorndorf and Pesch (2000) are major developments.

In the heuristic line of research, Hegazy (1999) developed a Genetic Algorithm (GA) metaheuristic for finding a solution for resource allocation and leveling problems. Also, Lu and Li (2003) developed a heuristic algorithm which is capable of incorporating wide range of prioritization rules. Their algorithm utilizes different combinations of all possible cuts in a smart fashion to obtain an activity schedule that solves the resource critical issues while satisfying a given measure of performance, such as project duration. Using this heuristic resulted in a superior solution compared to approaches which use each priority rule individually. This algorithm is known as Resource Activity Critical Path Method (RACPM) in the literature.

Senouci and Adeli (2001) used nonlinear constraint programming to minimize the total cost of the project while allocating and leveling resources. Due to the nonlinear nature of this model, the efficiency drops significantly as the size of the problem grows.

Besikci et al. (2015) studied the Multi-Mode Resource Constrained Multi-Project Scheduling Problem (MRCPPSP) which is similar to the type of problem targeted in this paper. Their research introduces a mathematical model for the problem and solves it by a two-phase and a monolithic Genetic
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