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A Brief Review on Integrated Planning of the Project Scheduling and Material Procurement Problem

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Abstract

According to the traditional decision makings, the project scheduling and material ordering were regarded as separate problems. However, it should be noted that integrated planning of the above mentioned issues can improve the execution costs of projects to a significant extent. This improvement has been remarkably taken into consideration within the last years. Thus, the authors aim to provide the interested readers with a concise review on the corresponding problem literature, from the advent to the present, in order to investigate the evolution course. The review aims to bring out branches for further developments by addressing the liable gaps.

Keywords: Project scheduling; Material procurement; Integrated planning

Introduction

Project scheduling has raised perceptible attention within the last decades as a widely used discipline, applicable to many different real world areas. The resource scarceness to carry out a project yielded to the resource constrained project scheduling problem advent, taken into account as an interesting research topic. Therefore, many different attempts have been dedicated to the problem, from which [1-4] can be viewed as instrumental arche-types.

Literature Review

With respect to the literature, the first paper which dealt with the integration of project scheduling and material ordering goes back to the work by Aquilano and Smith [5] to the best knowledge of the authors. They proposed an integrated model to address both the critical path method and the material requirement planning including materials, lead times and inventory level scheduling. Smith-Daniels and Aquilano [6] developed A formal set of algorithms for project scheduling with critical path method-material requirements planning [5] for large-sized projects scheduling by proposing a heuristic solution method, in terms of the least slack rule. They addressed all non-renewable and renewable resources such as materials, construction components, equipment, and labor, as well as activity durations variability.

Smith-Daniels [7] proposed a mixed-integer programming model to obtain an optimal plan for project scheduling and material ordering with fixed duration activities. They revealed that the given problem can be solved optimally when it is decomposed into a derivation of project scheduling and material ordering plan. They utilized the Wagner-Whitin algorithm to extract the optimal material ordering plan for a given schedule. Erbasi and Sepil [8] also took a heuristic procedure into consideration to find the trade-off between material ordering expenses and delay in project delivery. However, all the above mentioned studies had tackled the purchasing as a relaxed issue, in which only the orders setting had been investigated. In a broader sense, they had assumed that the associated costs could be calculated in terms of a single price without regard to the real world purchasing options.

Dodin and Elimam [9] addressed an extended version of the problem by developing variable project worth, rewards/penalty for earlier/later completion of the project than the due date, and material quantity discounts. They also considered a trade-off between the incorporated costs by accounting for variable activity durations. A mixed-integer programming model was used to formulate the problem and some analytical results were presented to enhance the efficiency of the model performance by reducing the problem size. However, the proposed solution process was delimited to networks of up to thirty activities.

A heuristic method was applied [10] to schedule recurrent construction, in which an initial schedule was generated first to dispatch the worker teams to settle down with the backlog of products. Afterwards, multiple maximal closure problems were solved to find the material release times, maximizing the net present value (NPV) of the cash flows [9,11] applying a Genetic Algorithm (GA) in order to obtain a near optimal solution for larger-sized problems. Though, it had been assumed that materials volume required to process an activity was independent of the time duration, which can be criticized for real world cases. Besides, the costs of activities' compression had been taken into consideration in terms of a linear proportion, which may not be true for all cases. Finally, they checked the average improvement percentage by applying a local search for the instances with different amount of materials.

Dixit et al. [12] investigated the uncertainty in materials lead time for the procurement scheduling model. They considered the proposed model for a real ship building case, in which the materials procurement play a crucial role in successful completion of the project. The addressed objective function included the holding and shortage costs of the project resources. Additionally, the effect of the allocated stage budget was tested on the project total costs. The main deficiency of the above paper pertained to the applied fuzzy approach which could end in some variations in the output with respect to the ranking method. In further research, Fu [13] investigated the material batch ordering problem for a multi-mode resource constrained project scheduling problem. He took the trade-off between different cost elements into account and

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proposed a hybrid algorithm, including an adapted harmony search and GA, as the solution methodology. The proposed system was allowed to incur shortage cost; though, the purchase was still done in rigid circumstances.

In a recent study, Tabrizi and Ghaderi [14] considered simultaneous planning of the project scheduling and material procurement under presence of multiple suppliers [15]. Without loss of generality, they could develop the issue to a broader boundary in which the materials supply was generalized to a more realistic condition. The proposed model took multiple suppliers into account with respect to different discount strategies. The applied objective function was aimed at finding the schedules with the best net present values. Moreover, they utilized an enhanced version of the genetic algorithm to solve the problems with large sizes. On the other hand, they tested the influence of the inflation on the objective function value by a sensitivity analysis [16-19]. In a further study, Tabrizi and Ghaderi in 2016 developed the issue by addressing a robust mixed-integer programming mathematical model. The purpose of the research was to minimize the execution costs of the project and maximize the schedule robustness, respectively. An advantage with the applied approach is associated with the possibility to control the degree of conservatism. Furthermore, two different solution methodologies were used to deal with the problem with different sizes [20-23]. Here, Table 1 incorporates a set of related research studies with respect to varied features, to provide a clear comparison.

Conclusion

The importance to manage the projects effectively and efficiently has raised the issue to optimize the associated planning and considerations. In this regard, the construction projects require a more noticeable

Authors	Project Type	Project Scheduling	Procurement Planning	Equipment Planning	Resources Type	Activities	Uncertain Parameter (S)	Uncertainty Management	Objective Function	Solution Methodology
Dodin and Elimam (2001)	General	Resource constraint	Yes	No	non-renewable	Non-preemptive	Activities duration	Robust programming	Costs minimization	Conventional branch and bound
Long, and Ohsato (2008)	General	Resource constraint	No	No	Renewable	Non-preemptive	Activities duration	Fuzzy programming	Make-span minimization	Genetic algorithm
Dodin and Elimam (2008)	General	Resource constraint	No	Yes	Renewable and non-renewable	Non-preemptive	Activities duration	Robust programming	Costs minimization	Heuristic
Drezet and Billaut (2008)	Service	Resource constraint and skilled work force	No	No	Renewable	Preemptive	-	-	Maximum tardiness minimization	Tabu and greedy search
Wuliang and Chengen (2009)	General	Resource constraint	No	No	Renewable	Non-preemptive	-	-	Costs minimization	Genetic algorithm
Lova et al. (2009)	General	Multi-mode resource constraint	No	No	Renewable and non-renewable	Non-preemptive	-	-	Completion time minimization	Hybrid genetic algorithm
Sheikh Sajadieh et al. (2009)	General	Resource constraint	Yes	No	non-renewable	Non-preemptive	Activities duration	Robust programming	Costs minimization	Genetic algorithm
Mobini et al. (2011)	General	Resource constraint	No	No	Renewable	Non-preemptive	-	-	Completion time minimization	Artificial immune algorithm
Bruni et al. (2011)	General	Multi-mode resource constraint	No	No	Renewable and non-renewable	Non-preemptive	-	-	Completion time minimization	Genetic algorithm
Kyriakidis et al. (2012)	General	Single and Multi-mode resource constraint	No	No	Renewable and non-renewable	Non-preemptive	-	-	Completion time minimization	Conventional branch and bound
Chen et al. (2012)	Construction	Resource constraint	Yes	Yes	Renewable and non-renewable	Non-preemptive	Costs and resources production rate	Stochastic programming	Costs minimization	Simulation
Dixit et al. (2014)	Construction	Resource constraint	Yes	No	Renewable and non-renewable	Non-preemptive	Lead time	Fuzzy programming	Holding and shortage costs	Conventional branch and bound
Fu (2014)	General	Multi-mode resource constraint	Yes	No	Renewable and non-renewable	Non-preemptive	-	-	Costs minimization	Memetic algorithm
Tabrizi and Ghaderi (2015)	General	Resource constraint	Yes	No	Renewable and non-renewable	Non-preemptive	-	-	Costs minimization	Memetic algorithm
Tabrizi and Ghaderi (2016)	General	Resource constraint	Yes	No	Renewable and non-renewable	Non-preemptive	Costs	Robust programming	Costs minimization and robustness maximization	Differential evolution algorithm

Table 1: Features comparison of research studies.

amount of attention, since they own a more complicate organization. For instance, it is needed to deal with the procurement issue, in addition to the activities scheduling. Moreover, it has been prove that concurrent formulation and consideration of scheduling and orders setting can improve the total costs. Hence, the issue has been seriously taken into account within the last decades. Likewise, the authors aimed to have a brief review on the extant literature, highlighting the viewpoint addressed by different research studies.

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