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Redundancy resource allocation for reliable project scheduling: A game-theoretical approach

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Abstract

The redundancy allocation problem is among the most interesting and difficult problems in the system reliability design. In this paper this concept is considered to enhance reliability in projects network scheduling with stochastic activity duration. In order to determine the optimal manner of redundancy allocation, a new mathematical model is developed. Then, by simulating the problem in the form of a game-theoretical pattern, it is shown that the Nash-equilibrium points of the problem are very close to optimal solutions of original model. Therefore, an algorithmic approach is developed for the calculation of Nash equilibria. Finally, several computational experiments are executed and their results are analysed. The comparison of equilibrium outcomes with the optimal policy justifies the efficiency of Nash equilibria for increasing the projects network reliability.

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1. Introduction

The vast majority of research in the area of project scheduling presume that the factors regarding the project scheduling problem are deterministic but in reality, project activities are subject to considerable uncertainty. Main

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sources of uncertainty can be: duration of activities, resource consumption, resource availability, stochastic task insertion failures of equipment, customer's acceptance or refusal at different phases of a project etc.

In this paper we considered a reliability optimization in project scheduling with stochastic activity time. This problem involves finding a suitable allocation mode of the resource to activities network possibly under system constraints. In other word, the problem is to select redundancy-levels and activity time distribution mode to maximize project scheduling reliability, given resource constraint. The redundancy allocation problem is one of the main branches of reliability optimization problems. The maximize system reliability by redundancy resource allocation, activity time distribution selection and considering resource capacity becomes a combinatorial optimization problem. In the formulation of a maximize reliability of project scheduling problem, for each project activity multiple time distribution choices (assuming different activity duration distributions need different level of resource) are used. According to figure 1 multiple activity duration distributions are available for each activity that each distribution supports a level of reliability (probability of completion time be less than total float). Thus, accessing to higher levels of reliability is possible by injecting more redundant resource. By resource redundancy, resources able to process a given activity were multiplied, which provided a kind of flexibility and made it possible to put identical resources on standby. The objective of our probabilistic problem is to build a schedule that has the greatest probability of attaining a optimal performance. The other conditions of the model are as follows:

- The amount of a redundant resource is capacitated.
- Each activity distribution related to project activities requires a predefined level of resource.
- The durations of activities are as a Beta distribution.
- The activities are planned in as soon as possible mode.
- There is no constraint for any activity on start and finish time.
- The redundant resources such as cash are applicable for all activities.

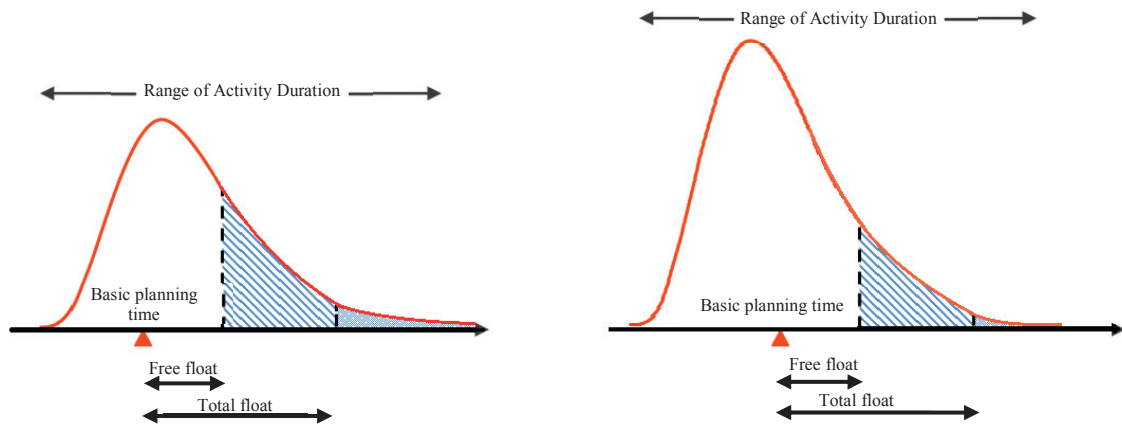


Fig. 1. Two duration distribution modes for an activity with different levels of reliability.

2. Literature Review

As mentioned previously, the scheduling problems are classified as both deterministic scheduling and scheduling with uncertainty. Deterministic scheduling has been studied extensively (i.e. [1-4]). In stochastic model of scheduling to tackle these uncertainties five approaches of scheduling are classified by Herroelen and Leus [5]: reactive approaches (i.e. Alagoz and Azizoglu [6]), stochastic approaches (i.e. Fang *et al.* [7]), fuzzy approaches (i.e. Wang [8]), proactive approaches (i.e. Lamas Vilches and Demeulemeester [9]) and approaches based on the sensitivity analysis (i.e. Penz *et al.* [10]). A comprehensive review of these approaches is provided by Herroelen and Leus [5], Brčić *et al.* [11] and Chaari *et al.* [12].

Proactive (also known as robust) scheduling approaches take uncertainty into account when designing off-line schedules. The scheduling takes future disruptions into consideration during the generation of the initial schedule.

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