

Chapter 6

Simulation Based Construction Project Schedule Optimization: An Overview on the State-of-the-Art

Maximilian Bügler

Technische Universität München, Germany

André Borrmann

Technische Universität München, Germany

ABSTRACT

Construction projects require a multitude of procedures and resources for the high diversity of building concepts. Most of such projects are unique in their design and need individual schedule planning to be realized. In order to develop the required schedules, several complex decisions need to be made and several different factors need to be taken into account, including cost, make span, safety, resource sparsity, delivery schedules and geometric constraints. The problem of scheduling the involved processes in an optimal way is called the resource constrained project scheduling problem (RCPSP) and several solution algorithms are available. In addition, simulation based techniques can be used to address more complex constraints and objectives. This chapter presents an overview of traditional optimization procedures for the RCPSP and bridge the gap to simulation based techniques, which are described in detail.

1. INTRODUCTION

Large modern construction projects involve a substantial number of activities. Every activity is a process that needs to be conducted in order to complete the overall project. Each of these activities takes a certain amount of time to be carried out and requires different numbers and types of resources, such as workers, machines, and working space. Furthermore, in order to be

executed an activity may depend on one or more other activities to be started or completed, such as a pit required to be excavated for the foundation to be built. The resulting precedence constraints define a partially ordered plan of the activities to be scheduled (Weld, 1994). Scheduling the activities to satisfy all constraints is concerned with the optimal allocation of scarce resources over time. As every individual construction project is unique in nature, the job of the planner is

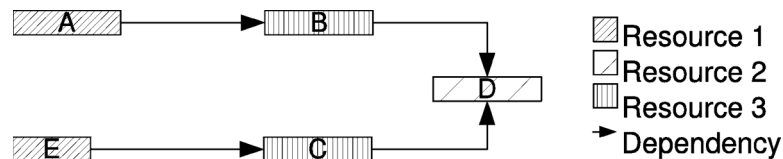
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very complex and automation is very challenging (Jaśkowski and Sobotka, 2006). The problem of scheduling all activities involved in a project in a way to optimize some objective has been subject to several research endeavors since the 1950s and different methods for modeling and solving many different types of the problem have been published since (Herroelen et al., 1998). A common way of formalizing such problems is referred to as the resource constrained project scheduling problem (RCPSP), which is the focus of this chapter. The resource constrained project scheduling problem is NP-hard (Blazewicz et al., 1983) and has been subject to extensive research. As a solution to such a problem, each activity is assigned with a specific point in time at which it is started. The resulting schedule has to comply with all precedence and resource constraints. Commonly used optimization objectives include minimizing the overall make span of the project, meeting specific milestones to minimize fines, minimizing the overall costs of the project, or maximizing the profit of construction contractors, as well as combinations of these objectives. The function to be minimized or maximized is referred to as the objective function. The chapter first introduces the notation and terminology, followed by an introduction to the usage of discrete-event simulation in construction scheduling. This is followed by an explanation of different optimization procedures, problem extensions, and case studies.

2. BACKGROUND

A project scheduling problem can either be defined as a network of activities connected by their respective precedence constraints, or by a network of milestones connected by activities. The first notation with activities as nodes will be used throughout this chapter. Generally each node is associated with a list of resource requirements and a duration value. A node's incoming arrows define its precedence constraints. To illustrate example problems throughout this chapter the scheme shown in Figure 1 is used. Each of the boxes defines one activity, which are labeled by capital letters. The width of each box is scaled according to the activity's duration. While in complex problems activities can use multiple types and numbers of resources, the illustrative problems only use a single resource per activity which is indicated by a different hatching for each resource. The arrow from A to B implies that A has to be executed prior to B. In order to illustrate solution schedules the Gantt chart scheme of Figure 2 is used. The horizontal axis defines the time line of the resulting schedule. The boxes are aligned according to their respective execution times. The right hand side extension of boxes, such as for activity E in Figure 2 illustrates the float time of the activity, which will be described in more detail in Section 4.1. Figure 3 illustrates the usage of the resources over time. Again each

Figure 1. Problem notation for resource constrained project scheduling problems. Each rectangle is an activity, arrows indicate precedence constraints, and hatching corresponds to used resources



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