

Preface

Project scheduling began as a research track within the mathematical field of Operations Research in order to determine start and finish times of project activities subject to precedence and resource constraints while optimizing a certain project objective (such as lead-time minimization, cash-flow optimization, etc.). The initial research done in the late 1950s mainly focused on network based techniques such as CPM (Critical Path Method) and PERT (Program Evaluation and Review Technique), which are still widely recognized as important project management tools and techniques.

From this moment on, a substantial amount of research has been carried out covering various areas of project scheduling (e.g. time scheduling, resource scheduling, cost scheduling). Today, project scheduling research continues to grow in the variety of its theoretical models, in its magnitude and in its applications. While the focus of decennia of research was mainly on the static development of algorithms to deal with the complex scheduling problems, the recent research activities gradually started to focus on the development of dynamic scheduling tools that are able to respond to a higher uncertainty during the project's progress.

The topic of this book is known as *dynamic scheduling* and is used to refer to three dimensions of project management and scheduling: the construction of a *baseline schedule* and the analysis of a project *schedule's risk* as preparation for the *project control* phase during the progress of the project. This dynamic scheduling point of view implicitly assumes that the usability of a project's baseline schedule is rather limited and only acts as a point of reference in the project life cycle. Consequently, a project schedule should especially be considered as nothing more than a predictive model that can be used for resource efficiency calculations, time and cost risk analyses, project control and performance measurement. In all upcoming chapters, the project control phase will also be called project *tracking* or project *monitoring*.

In this book, the three dimensions of dynamic scheduling are highlighted in detail and are based on and inspired by a combination of academic research studies at Ghent University (www.ugent.be), in-company trainings at Vlerick Business School (www.vlerick.com) and consultancy projects at OR-AS (www.or-as.be).

First, the construction of a project baseline schedule is a central theme throughout the various chapters of the book. This theme is discussed from a complexity point of view with and without the presence of project resources. Second, the creation of an awareness of the weak parts in a baseline schedule is highlighted, known as schedule risk analysis techniques that can be applied on top of the baseline schedule. Third, the baseline schedule and its risk analyses can be used as guidelines during the project control step where actual deviations can be corrected within the margins of the project's time and cost reserves.

Scope

The goal of this book is not to compete with excellent handbooks on general project management principles nor to give an extensive overview of all project management aspects that might contribute to the overall success of a project. Instead, the aim is to bring a clear and strong focus on the preparatory phases, the project baseline scheduling and the schedule risk analysis phases, to support the project control phase where project performance measurement is a key issue for a project's success. The intention is to hold the middle between a research handbook and a practical guide for project schedulers or project management software users. To that purpose, the content of this book is brought in such a way that it is able to inform a wide audience about the current state-of-the-art principles in dynamic project scheduling. The target audience can consist of undergraduate or MBA students following a project management course, participants of company trainings with a focus on scheduling or software users who search for added value when using software tools.

Book Overview

Chapter 1 gives a short introduction to the central theme of the book and highlights the three components of dynamic project scheduling: project scheduling, risk analysis and project control. The chapter gives a brief overview of the project life cycle and makes a distinction between project complexity and uncertainty using a *project mapping* matrix. The *complexity* dimension is related to the absence or presence of project resources under limited availability, as discussed in Parts I (low complexity) and II (high complexity) of the book. The *uncertainty* dimension is related to the need of a project's schedule risk analysis and is discussed in individual Chaps. 5 and 10 of both parts. Example files and more information can be downloaded from www.or-as.be/books.

Part I. Scheduling Without Resources

Part I is devoted to dynamic scheduling principles for projects without resources. It is assumed that project resources are not limited in availability, which leads to simple and straightforward scheduling tools and techniques that can be considered as basic techniques for the more complex resource-constrained scheduling methods of Part II.

Chapter 2 gives an overview of the basic scheduling principles without using resources and thereby lays the foundation for all future chapters to predict the timing and cost outline of a project. The basic critical path calculations of project scheduling are highlighted and the fundamental concept of an activity network is presented. Moreover, the Program Evaluation and Review Technique (PERT) is discussed as an easy yet effective scheduling tool for projects with (low) variability in the activity duration estimates.

Chapter 3 presents an interactive game that acts as a training tool to help practitioners and project management students to gain insight in the basic project scheduling techniques. The game involves the iterative re-scheduling of a project within the presence of uncertainty. Each project activity can be executed under different duration and cost combinations, which is known as the critical path method (CPM). The game is set up to highlight the importance of a thorough knowledge of baseline scheduling techniques and to create an awareness of the need for schedule risk analyses (discussed in Chap. 5).

Chapter 4 serves as an illustrative chapter based on a case study of a capacity expansion project at a water production center in the northern part of Belgium. It shows that the clever use of basic critical path scheduling algorithms can lead to a realistic baseline schedule once the scheduling objective is clearly defined. It will be shown that scheduling the project with certain techniques will improve the financial status of the project, as measured by its net present value.

Chapter 5 highlights the importance of a schedule risk analysis (SRA) once the baseline schedule has been constructed. This second dimension of dynamic scheduling connects the risk information of project activities to the baseline schedule and provides sensitivity information of individual project activities as a way to assess the potential impact of uncertainty on the final project duration and cost. When management has a certain feeling of the relative sensitivity of the project activities on the project objective, a better management focus and a more accurate response during project control should positively contribute to the overall performance of the project.

Chapter 6 describes the first part of a series of three case exercises (Parts II and III can be found in Chaps. 11 and 14). Each case description is an integrated exercise to get acquainted with the scheduling principles discussed in the previous chapters. The case of Chap. 6 assumes the construction of a baseline schedule and knowledge of basic critical path scheduling principles and allows the extension to basic calculations of risk in order to take protective actions. The solution and the educational approach depend on the wishes and needs of the students who solve the

case and the teacher who can act as the moderator during the case teaching session. A teaching session should allow enough freedom to extend the original topic to various other dynamic scheduling related issues.

Part II. Scheduling with Resources

Part II extends the previously discussed dynamic scheduling principles to projects with resources that have a limited availability. In these complex scheduling settings, activities are executed by resources that are restricted in availability over time. This resource restriction leads to an increase in scheduling complexity, as will be shown in the various chapters of this part.

Chapter 7 gives an extensive overview of tools and techniques for resource-constrained project scheduling. It is shown that the introduction of resources in project scheduling leads to an increase in scheduling complexity. The importance of the choice of a scheduling objective is highlighted in detail by showing various resource-constrained scheduling models. The ability to assess the quality of the resource feasible schedule as well as a basic knowledge about scheduling software functionalities are discussed throughout the sections of this chapter.

Chapter 8 further elaborates on the resource-constrained project scheduling topics of the previous chapter and presents some advanced results obtained by various research projects. This chapter extends the resource models to other scheduling objectives, studies the effect of activity splitting and setup times and introduces learning effects in a resource-constrained project environment. These topics are brought together in a separate chapter such that the reader can skip these advanced topics without losing overview of the general dynamic scheduling theme.

Chapter 9 presents, similar to Chap. 4, an illustrative case study of a practical project scheduling study. The project to construct a tunnel to connect the two sides of the Westerschelde in the Netherlands is used to illustrate the importance of the scheduling objective as discussed intensively in the previous chapters. More precisely, it will be shown that the minimization of a bottleneck resource's idle time during the scheduling phase can lead to important cost savings.

Chapter 10 elaborates on the construction of a resource feasible project schedule as discussed in the previous chapter, but extends this scheduling approach to a more flexible baseline schedule protected against unexpected events. The Critical Chain/Buffer Management (CC/BM) approach incorporates a certain degree of flexibility in the activity start times in order to easily monitor schedule deviations and quickly respond by taking corrective actions to keep the whole project on schedule. The technique is initiated by E. M. Goldratt in his groundbreaking book "Critical Chain" as a practical translation of the so-called *Theory of Constraints* in a project scheduling environment.

Chapter 11 presents the second part of a fictitious case exercise introduced in Chap. 6 that aims at the construction of a resource feasible project schedule using project scheduling software tools. The goal of the student is to go further

than submitting software print-outs to the project team. Instead, the purpose is the integration of the resource-constrained scheduling principles of the previous chapters within the features of a project scheduling tool in order to provide an easy and understandable information sheet on the predicted project execution to the various members of a project team. It allows the integration of CC/BM techniques of the previous chapter to highlight the advantages and potential weaknesses.

Part III. Project Control

Part III uses the schedules constructed in the previous chapters as inputs for the project execution phase where project's progress needs to be measured and monitored in order to take corrective actions when the project runs into trouble. This third dimension of dynamic scheduling completely relies on the quality of the two other dimensions (baseline scheduling and risk analysis) discussed in the previous chapters. The construction of a baseline schedule based on a sound methodology as well as the knowledge of the sensitivity of each project activity on the project's time and cost dimensions act as inputs during the project control step to better support corrective actions in case the project is in danger.

Chapter 12 gives an overview of the Earned Value Management (EVM) method to measure a project's time and cost performance. It gives an overview of all EVM metrics and performance measures to monitor the time and cost dimension of a project's current progress to date. Moreover, it also illustrates how this performance information can be used to predict the expected remaining time and cost to finalize the project that serve as triggers to take corrective actions to bring the project back on track, when needed.

Chapter 13 is a summary chapter of a large simulation study to predict the final duration of a project in progress using EVM forecasting methods. The chapter briefly discusses results that give an idea of the accuracy of different EVM forecasting methods along the life cycle of the project. It also presents an extension to the classical use of EVM to measure the adherence of a project in progress to the original baseline schedule. The main results of this chapter have been awarded by the International Project Management Association (www.ipma.ch) with the IPMA 2008 Research Award.

Chapter 14 is a third fictitious case exercise that allows the integration of EVM reports in the project control phase in order to get acquainted with the terminology and characteristics of EVM. It assumes a dynamic multi-project setting where three projects are executed in parallel. The purpose is the clever use of EVM methods and metrics and the critical review of these methods as a dynamic time/cost performance measurement system.

Part IV. Scheduling with Software

Part IV presents the main features of a software tool that integrates the three dynamic scheduling dimensions (scheduling, risk analysis and control) discussed in the previous sections.

Chapter 15 gives a brief overview of the main features of the software tool ProTrack (acronym for *Project Tracking*). Although ProTrack is a commercial software tool and is therefore not free of charge, a student friendly version with time-limited functionalities can be freely downloaded from www.protrack.be such that the main dynamic scheduling principles discussed in this book can be easily tested in a fictitious project environment.

Part V. Conclusions

Part V contains Chap. 16 and provides overall conclusions on dynamic scheduling. It provides an overall summary of all chapters and gives directions for practical use of software tools and suggestions for further actions on research and practical applications.

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