Mario Vanhoucke

Project Management with Dynamic Scheduling

Baseline Scheduling, Risk Analysis and Project Control

2nd Edition

Springer

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Second Edition

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ISBN 978-3-642-40437-5 ISBN 978-3-642-40438-2 (eBook)
DOI 10.1007/978-3-642-40438-2
Springer Heidelberg New York Dordrecht London

Library of Congress Control Number: 2013956213

Printed on acid-free paper

Springer is part of Springer Science+Business Media (www.springer.com)

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 *Pro*ject *Track*ing). 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.

Acknowledgements

This book is the result of several research projects, consultancy tasks and fruitful discussions with both academics and practitioners. I am therefore indebted to many people who have helped me in writing this book.

I would like to thank my father, Robert Vanhoucke, for the fruitful discussions while writing Chap. 4 during the final stages of my PhD period. He helped me with the technical details of the project at a water production center (Vlaamse Maatschappij voor Watervoorziening) and provided me with useful information about it. I am also grateful to Dr. Stan Beernaert, chief executive at the Vlaamse Maatschappij voor Watervoorziening at the time of the project scheduling phase, for giving me the permission to use the data of the project. Last but not least, I would like to thank ir. Paul Suenens, project leader for the project, for providing me with a detailed description of the project by means of a Microsoft Project file.

I would like to thank Iris Vodderie for drawing my attention to the construction project in the Netherlands as described in Chap. 9. I am also grateful to Karel De Bel, Senior consultant Plancon and Theun Steinfort, projectmanager "Ontwerp en Voorbereiding", for giving me the permission to use the data of the project and for providing me with a detailed description of the project. I want to especially thank Koen Van Osselaer for the nice and pleasant collaboration during this project.

I am also thankful to Prof. Dr. Bert De Reyck from London Business School (UK) and University College London (UK) who allowed me to use the project description

that was used during the writing of the Chaps. 6, 11 and 14. Although the case exercises of these chapters go far beyond the original purpose of his bridge project example, the general project characteristics of this bridge example were used as the foundation to describe the three case exercises.

I also would like to thank Prof. Dr. Roel Leus from the Katholieke Universiteit Leuven (Belgium) for the co-writing of parts of Chap. 10 as a foundation article used in the Project Management course at Ghent University.

I am obviously very much indebted to Tom Van Acker, partner at OR-AS, for the co-development of our software tool ProTrack as described in Chap. 15. Obviously, without his help, this book was not what it is now. The close relation between the various chapters of the book and the features and characteristics of the software tool is the results of years of work, both at the programming side of our software tool as at the consultancy side when dealing with real project schedules and all corresponding difficulties related to that. Both the software and the book is therefore the result of joint efforts of all OR-AS customers, a team of volunteers (both researchers as people from practice) and PhD students in project scheduling who all contributed in one way or another. A special thank you goes to Stephan Vandevoorde, who always supported and motivated the OR-AS team when our activities progressed slower than expected. A special word of thank goes to Sylvain Beernaert, Vincent Van Peteghem, Broos Maenhout, Veronique Sels, Thomas De Jonghe, Jeroen Colin, Christophe Van Huele and Mathieu Wauters for their careful attention during proofreading the final manuscripts. Thank you, all.

I acknowledge the support by the Research collaboration fund of PMI Belgium received in Brussels in 2007 at the Belgian Chapter meeting, the support for a research project funding by the Flemish Government (2008), Belgium, the research support of the National Bank of Belgium (NBB) as well as the support given by the "Fonds voor Wetenschappelijk Onderzoek (FWO), Vlaanderen, Belgium" and the "Bijzonder Onderzoeksfonds (BOF)"at Ghent University. Parts of the research topics in this book have been awarded by the IPMA Research award in 2008 during the 22nd world congress in Rome (Italy) with the study "Measuring Time – An Earned Value Simulation Study". Thanks to this support and these financial sources, I was able to write parts of Chap. 12 based on data from various real-life consultancy projects.

It goes without saying that all of this took a lot of time, both during the weeks and the weekend. I am therefore especially thankful to Gaëtane for the many hours of proofreading and editing and the kids, Joyce and Thierry, for their never-ending patience when I was working on the software tool often 7 days a week.

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Contents

Chapter 1
Introduction

Abstract This chapter gives a short introduction to the central theme of the book and highlights the three components of dynamic project scheduling: the construction of a project baseline schedule, a risk analysis of this schedule and the project's performance measurement and control component. The chapter also gives a short introduction to the *project life cycle* to provide a guidance to the various chapters of the book. A simple and intuitive project mapping approach is briefly described and will be used to put all techniques discussed throughout the various chapters into perspective.

1.1 Introduction

Project management is the discipline of planning, organizing and managing resources to bring about the successful completion of specific project goals and objectives. The project management discipline can be highlighted from various angles and sub-disciplines and contains important issues such as project objective and scope management, human resource management and setting the roles and responsibilities of all participants and stakeholders of a project, planning principles and resource allocation models, etc. The current book does not aim at providing a general overview on project management, but instead has a clear focus on the planning aspect of projects. The topic of the book could be best described as *dynamic project scheduling* to illustrate that project scheduling is a dynamic process that involves a continuous stream of changes and that it is a never ending process to support decisions that need to be made along the life of the project. The focus of the book lies on three crucial dimensions of dynamic scheduling, which can be briefly summarized along the following lines:

- Scheduling: Construct a timetable to provide a start and end date for each project activity, taking activity relations, resource constraints and other project characteristics into account and aiming at reaching a certain scheduling objective.

M. Vanhoucke, *Project Management with Dynamic Scheduling*,
DOI 10.1007/978-3-642-40438-2_1, © Springer-Verlag Berlin Heidelberg 2013

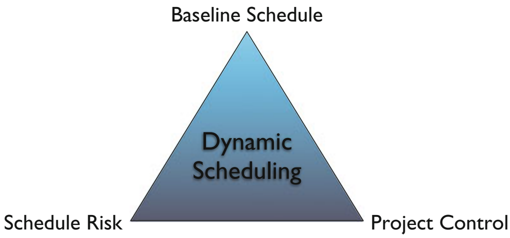

Fig. 1.1 The three components of dynamic project scheduling

- Risk Analysis: Analyze the strengths and weaknesses of the project schedule in order to obtain information about the schedule sensitivity and the impact of unexpected changes that undoubtedly occur during project progress on the project objective.
- Control: Measure the (time and cost) performance of a project during its progress and use the information obtained during the scheduling and risk analysis steps to monitor and update the project and to take corrective actions in case of problems.

The scope and purpose of the book is to bring a mixed message trying to combine theoretical principles from literature with practical examples and case exercises. To that purpose, the reader should take a step back from the buttons and looks of the project management software tools and/or the daily practice of project management to see what the dynamic scheduling principles have to offer. Rather than solely focusing on the latest state-of-the-art scheduling techniques from the academic literature, the reader will be drowned into a wide variety of scheduling and control principles and an often pragmatic project scheduling and monitoring approach, each time illustrated by means of short examples, practical case examples or fictitious integrated exercises. Figure 1.1 highlights the three basic components of dynamic scheduling.

Each of these three dimensions of dynamic scheduling plays an important role in the project life of a project. In the next section, the so-called project life cycle is briefly discussed from different angles and the link with dynamic scheduling is shown.

1.2 The Project Life Cycle (PLC)

Typically, a project goes through a number of different phases, which is often referred to as the project life cycle. In this book "Managing high-technology programs and projects", Archibald (1976) describes the project life cycle as follows:

> The project life cycle has identifiable start and end points, which can be associated with a time scale. A project passes through several distinct phases as it matures. The life cycle includes all phases from point of inception to final termination of the project. The interfaces between phases are rarely clearly separated, except in cases where proposal acceptance of formal authorization to proceed separates the two phases.

Consequently, the PLC is defined by the time window between the initial start of the project and the final termination and consists of a number of phases, separated by major milestones. The number of phases and their corresponding titles differ from industry to industry and from project to project. The next two subsections elaborate on the project life cycle with a number of examples, without having the intention to provide a full literature review.

1.2.1 Project Phases

A project consists of sequential phases. These phases are extremely useful in planning a project since they provide a framework for budgeting, manpower and resource allocation and for scheduling project milestones and project reviews. The method of dividing a project into phases may differ somewhat from industry to industry and from product to product and it can be summarized as follows:

- Concept (initiation, identification, selection).
- Definition (feasibility, development, demonstration, design prototype).
- Execution (implementation, production, design/construct/commission, install and test).
- Closeout (termination and post completion evaluation).

Archibald (1976) argues that the number of phases and the titles are so generic that they are of little value in describing the project life cycle process. Although the construction and presentation of a generic project life cycle seems to be difficult, if not impossible, each PLC shares a number of common characteristics.

- The major milestones between the phases represent high-level decision points.
- The phases may, and frequently will, overlap.

Between the various phases are decision points, at which an explicit decision is made concerning whether the next phase should be undertaken. A major review of the entire project occurs at the end of each phase, resulting in authorization to proceed with the next phase, cancellation of the project, or repetition of a previous phase.

1.2.2 The PLC in PMBOK

In the first edition of PMBOK,[1] the project life cycle concept was not mentioned at all. In the later editions, PMI realized the importance of the "divide and conquer"

[1]The Project Management Body of Knowledge, published by the Project Management Institute (PMI) – www.pmi.org.

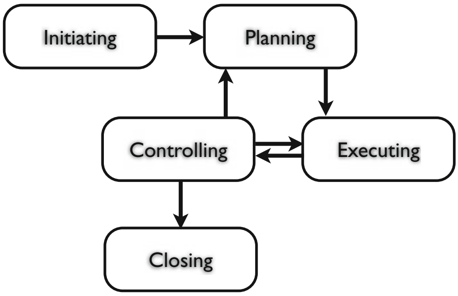

Fig. 1.2 Accomplishment of a project through the integration of five project management processes (PMBOK)

principle as the complexity and the size of the project increase and included the PLC concept in the book. More precisely, PMBOK describes the project life cycle as follows:

> Because projects are unique undertakings, they involve a degree of uncertainty. Organizations performing projects will usually divide each into several project phases to improve management control and provide for links to the ongoing operations of the performing organization. Collectively, the project phases are known as the project life cycle.

Each project is marked by the completion of one or more deliverables, such as a feasibility study or a detail design. These deliverables, and hence the phases, are part of a generally sequential logic designed to ensure proper definition of the project. The conclusion of each phase is generally marked by a review. These reviews, often called milestones, phase exits, stage gates or kill points, are necessary to:

- Determine if the project should continue to the next phase.
- Detect and correct errors cost effectively.

Although PMBOK presents a sample generic life cycle as shown in Fig. 1.2, they argue that many project life cycles have similar phase names with similar deliverables required but few are identical. The next section presents a similar generic project life cycle that will be used throughout all chapters of this book.

1.2.3 The PLC Used in This Book

Figure 1.3 shows an illustrative project life cycle that will be used throughout the remaining chapters of this book. This generic project life cycle was initially constructed and used for a consultancy study summarized in Chap. 4 and serves as an ideal tool to illustrate the dynamic scheduling approach taken in this book.

This generic project life cycle is based on a life cycle description by Klein (2000) and consists of a project conception phase, a project definition phase, a phase in which the project has to be scheduled, the execution of the project, the project control phase and the termination of the project.

At the beginning, in the so-called conceptual phase, an organization identifies the need for a project or receives a request from a customer.

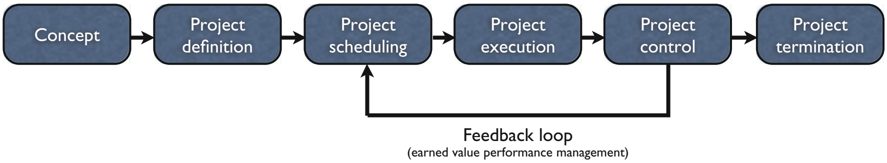

Fig. 1.3 An illustrative Project Life Cycle (PLC)

In the definition phase, the organization defines the project objectives, the project specifications and requirements and the organization of the whole project. The project objectives need to be refined and translated into a list of activities, a set of technological precedence relations and the resource availabilities and requirements. In doing so, the organization decides in detail on how it is going to achieve these objectives. The refinement of these project objectives into a final activity network containing activities and precedence relations is the subject of Chap. 2. The extension to resource availabilities and requirements is discussed from Chap. 7 onwards.

The next phase, the scheduling phase, aims at the construction of a timetable for the project activities. The construction of a precedence and/or resource feasible schedule determines a start and finish time for each activity, and hence, relies on the information obtained by the previous phase. In the following chapters of Parts I and II, a detailed overview of the scheduling principles using different techniques and aiming at reaching different targets is discussed.

During the execution and project control phases, the project has to be monitored and controlled to see whether it is performed according to the existing schedule. If deviations occur, corrective actions have to be taken. This control mechanism has been incorporated in the project life cycle by means of the feedback loop between the control phase and the scheduling phase of Fig. 1.3. This topic is the subject of Part III of this book. An update of a schedule can be done in two basic ways:

1. Reactive scheduling: This principle aims at the construction of a deterministic schedule, without taking possible risk factors or uncertainty events into account. During project execution, the project progress needs to be monitored using the information of the schedule and adaptations to the schedule need to be made when the deviations become too large. A reactive scheduling approach is the subject of Chap. 3.
2. Proactive scheduling: The uncertainty is embedded in the schedule to construct a buffered schedule. This schedule is robust and protected against possible uncertain events. In doing so, the feedback loop can be avoided within certain ranges. A proactive scheduling approach is presented in Chap. 10 of this book.

The termination phase involves the completion and a critical evaluation of the project. This information can then be used during the project life cycle of future, similar projects since the specifications of a project, the estimates of the durations, costs and resource requirements are often determined based on averages of past performance.

1.3 Dynamic Scheduling Methodology

In this section, a simple yet effective guidance is presented to classify projects along two dimensions: complexity and uncertainty. This project mapping approach will be used throughout all chapters of this book during the detailed explanation of the three dimensions of dynamic project scheduling.

1.3.1 Project Mapping

Although project scheduling is often considered to be an art more than a science, a thorough knowledge of the tools and techniques available is necessary to create a realistic project schedule. Obviously, the selection of the right tool and technique depends on the characteristics of the project and the background and knowledge of the project manager.

The approach taken along the various chapters in the book is a very pragmatic and nonscientific way of mapping projects along two dimensions as shown in Fig. 1.4: complexity and uncertainty. The advantage of this simple yet intuitive mapping approach lies in its ability to classify most project planning and scheduling techniques in one of the four quadrants. Although it is recognized that project management is more than a simple reduction to a set of scheduling tools and planning techniques, it creates awareness that techniques need to be put into perspective and need to be used only if the underlying assumptions and corresponding advantages/disadvantages are thoroughly known and understood.

The classification of scheduling techniques along the dimensions of complexity and uncertainty makes sense since dynamic scheduling is, in a way, a careful balance between dealing with complexity (mostly with the help of a commercial software tool to construct a (resource-constrained) project baseline schedule) and coping

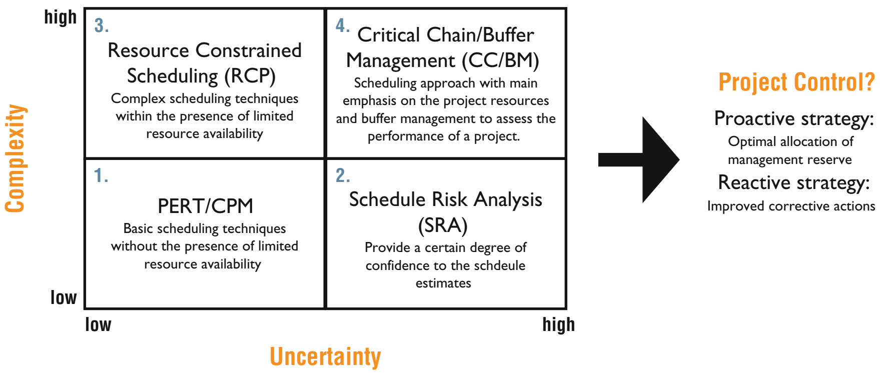

Fig. 1.4 Project mapping approach used throughout the chapters of this book

with uncertainty (realizing that a schedule obtained by a software tool will be subject to changes during the project's progress). This careful balance needs to be made by the project manager/planner and constitutes the basic starting point of this book. The ultimate goal of measuring and coping with complexity and uncertainty is to provide a basic tool to the project manager to monitor the performance of his/her project during progress. Consequently, Fig. 1.4 shows the three dimensions of dynamic scheduling: project scheduling (complexity), risk analysis (uncertainty) and project control. The complexity/uncertainty dimensions as well as their impact on the project control phase are briefly outlined in the following three subsections.

1.3.2 Complexity

The complexity dimension of Fig. 1.4 is completely related to the first dimension of dynamic scheduling: the construction of a project's baseline schedule. More precisely, it is related to the absence or presence of resources during the construction of a schedule and is used to distinguish between Parts I and II of this book.

The basic project scheduling techniques, often known under the general PERT/CPM abbreviation, assume that projects need to be done within the presence of an infinite resource capacity. Despite their simplicity, they still are considered as the basic scheduling techniques, and their principles are applicable to more advanced techniques. Due to this simplicity, their use is obviously restricted to simple and straightforward projects where resources are not assumed to be relatively highly constrained and are ignored during the scheduling process (quadrants 1 and 2 of Fig. 1.4). These resource-unconstrained project scheduling techniques are discussed in Part I of this book in Chaps. 2–6.

However, it is generally accepted that the presence of resources under limited availability is a matter of degree in practical business projects, which results in a dramatic increase in problem complexity when constructing a project baseline schedule (quadrants 3 and 4). Therefore, Part II of this book reviews the resource-constrained project scheduling techniques. The academic literature on resource-constrained project scheduling (RCP) is rich and has a main focus on the development of algorithms and procedures to solve often very complex project models. Although it is not the intention of this book to give a summary of these algorithms, it illustrates that the presence of limited resources in projects leads to an increasing complexity. The topics are discussed in Part II in Chaps. 7–10 of this book.

1.3.3 Uncertainty

When the level of uncertainty is assumed to be high, the schedule of a project becomes more and more subject to unexpected changes during project progress, and a certain knowledge of risk is therefore often indispensable. This second dimension of dynamic scheduling, project risk analysis, is shown by the uncertainty dimension of Fig. 1.4.

Schedule Risk Analysis (SRA) stems from the recognition that the construction of a project schedule is an uncertain art of estimating the set of activities, their network logic and their times and costs. Consequently, in order to provide a certain degree of confidence within each schedule estimate, SRA assigns distributions on top of the schedule to calculate a probability of meeting the scheduled end dates and cost targets (quadrant 2).

The Critical Chain/Buffer Management (CC/BM) approach can be seen as an extended view on schedule risk analysis, since it integrates the uncertainty of schedule estimates within the complexity view of resource scheduling principles (quadrant 4). This integrated view on resource complexity and schedule estimate uncertainty has led to a new scheduling framework that contains valuable principles applicable to practical project settings.

1.3.4 Control

It has been mentioned earlier that the project progress has to be monitored and controlled to measure whether the project is performed according to the original baseline schedule. Both a reactive and a proactive scheduling approach can be mapped into the quadrants of the project mapping approach, in order to allow taking timely corrective actions when the project is in trouble. This third dimension of dynamic scheduling, project control, is extensively discussed in Part III of this book.

1.4 Conclusions

This chapter gave a short and basic introduction to the principle of dynamic scheduling as the main topic of this book. This dynamic scheduling perspective consists of three connected sub-topics, i.e. the art and science of project scheduling, the analysis of risk and sensitivity of a project schedule's estimates and the project monitoring and control during the progress of the project. It has been shown that these three dynamic scheduling dimensions completely fit into the project life cycle concept presented in various sources in the literature.

A simple and straightforward project mapping framework has been presented as a general guidance for the various dynamic scheduling methods and techniques discussed in this book. This complexity/uncertainty framework will be used throughout the chapters of Parts I and II and aims at the construction of a feasible project schedule, which serves as a baseline point of reference for the project monitoring and control chapters discussed in Part III.

Part I
Scheduling Without Resources

Chapter 2
The PERT/CPM Technique

Abstract Completing a project on time and within budget is not an easy task. The project scheduling phase plays a central role in predicting both the time and cost aspects of a project. More precisely, it determines a timetable in order to be able to predict the expected time and cost of each individual activity.

In this chapter, the basic critical path calculations of a project schedule are highlighted and the fundamental concept of an activity network is presented. Throughout all chapters of Part I, it is assumed that a project is not subject to a limited amount of resources. The project is structured in a network to model the precedences between the various project activities. The basic concepts of project network analysis are outlined and the Program Evaluation and Review Technique (PERT) is discussed as an easy yet effective scheduling tool for projects with variability in the activity duration estimates.

2.1 Introduction

In this chapter, the basic concepts of the definition phase (Sect. 2.2) and the scheduling phase (Sect. 2.3) of the project life cycle are discussed. It is assumed that projects belong to the first quadrant of the project mapping matrix of Fig. 1.4 and hence are assumed to have no resource limits and a low level of uncertainty.

The chapter aims to give answers to fundamental questions, such as:

- What is the expected project finish date?
- How can precedence relations between activities be modeled in a network?
- What are the expected activity start and finish times?
- What is the effect of variability in activity time estimates on the project duration?

M. Vanhoucke, *Project Management with Dynamic Scheduling*,
DOI 10.1007/978-3-642-40438-2_2,

2.2 Project Definition Phase

In the definition phase of a project's life cycle, the organization defines the project objectives, the project specifications and requirements and the organization of the entire project. In doing so, the organization decides on how it is going to achieve all project objectives.

The Work Breakdown Structure (WBS) is a fundamental concept of the definition phase that, along with the Organizational Breakdown Structure (OBS), identifies the set of activities needed to achieve the project goal as well as the responsibilities of the project team for the various subparts of the project.

This information needs to be transformed into a network diagram that identifies a list of project activities and the technological links with the other activities. This project network is an easy and accessible tool for the critical path calculations to determine the earliest and latest activity start times of the scheduling phase.

2.2.1 WBS and OBS

The preparation of a Work Breakdown Structure (WBS) is an important step in managing and mastering the inherent complexity of the project. It involves the decomposition of major project deliverables into smaller, more manageable components until the deliverables are defined in sufficient detail to support development of project activities (PMBOK 2004). The WBS is a tool that defines the project and groups the project's discrete work elements to help organize and define the total work scope of the project. It provides the necessary framework for detailed cost estimation and control along with providing guidance for schedule development and control. Each descending level of the WBS represents an increased level of detailed definition of the project work.

The WBS is often displayed graphically as a hierarchical tree. It has multiple levels of detail, as displayed in Fig. 2.1.

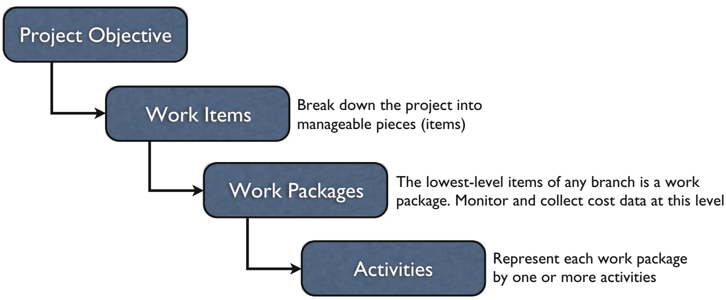

Fig. 2.1 Four levels of a Work Breakdown Structure